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Atmospheric Pollution by Iceland Volcano Lava Dispersion - the Brussels Case

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Abstract

In April 2010 the Icelandic Eyjafjallajökull stratovolcano emitted large clouds of volcanic ashes that provoked chaotic situations for the air traffic of the Northern hemisphere. The impact of the resulting atmospheric pollution may have widespread effects on the health of the populations living in the affected regions. For this reason, the study of the airborne particles brought by the ash clouds must cover not only their concentrations expressed in μg/m^3, but also their size, shape and chemical composition. Our results revealed that during the eruption days, some periods with a higher concentration of the coarse particles (between 2.5 and 10 μm) were observed. The sphericity (R1) and roughness (R2) parameters showed specific characteristics of the particles, suggesting long distance of their origin. Furthermore, an increase up to 4 times more in the At% of the elements K, Al, Ca, Na and Si, which characterize the felsic lava, was observed during the eruption period.

Keywords: *Iceland eruption, felsic lava, long distance transport, airborne particles, granulometery, micromorphology and chemistry*

Rezumat. Poluarea atmosferică datorată dispersiei lavei vulcanului islandez – cazul orașului Bruxelles

În aprilie 2010, stratovulcanul islandez Eyjafjallajökull a aruncat nori mari de cenușă vulcanică care au generat situații haotice pentru traficul aerian din emisfera nordică. În urma acestui fenomen, impactul poluării atmosferice poate avea foarte multe efecte asupra sănătății populației care trăiește în regiunile afectate. Din acest motiv, studiul particulelor aeriene aduse de către norii de cenușă trebuie să cuprindă nu numai concentrațiile lor exprimate în μg/m^3, dar și dimensiunea, forma și compoziția lor chimică. Rezultatele au arătat că în zilele erupției au fost înregistrate unele perioade cu concentrări mai mari ale particulelor macrogranulare (între 2,5 și 10 μg). Sfericitatea (R1) și rugozitatea (R2) au indicat caracteristici specifice ale particulelor, sugerând distanța mare față de locul de origine. Mai mult, în timpul erupției s-a înregistrat o creștere de până la 4 ori a elementelor K, AL, Ca, Na și Si, caracteristice lavei riolitice.

Cuvinte-cheie: *erupția islandeză, lava riolitică, transport pe distanțe mari, particule aeropurtate, granulometrie, micromorfologie și chimie*

Introduction

Along the mid-oceanic ridges, two tectonic plates diverge from one another. New oceanic crust is formed by hot molten rock slowly cooling and solidifying. The crust is very thin along the mid-oceanic ridges due to the pull of the tectonic plates. Iceland is a region of frequent volcanic activity, due to its location astride the Mid-Atlantic Ridge, where the North American and Eurasian Plates are moving apart, and also over the Iceland hotspot, which greatly enhances the volcanic activity. It is estimated that a third of all the basaltic lava erupted throughout the world in recorded history has been produced by Icelandic eruptions. The release of pressure due to the thinning of the crust leads to adiabatic expansion, and the partial mixing of the mantle causing volcanism and creating new oceanic

crust (Kristijansson et al. 1975; Mattsson and Hoskuldsson 2003).

The Icelandic Eyjafjallajökull stratovolcano entered a new eruption phase in April 2010. The volcano has periodically emitted large clouds of volcanic ashes that provoked chaotic situations for the air traffic of the Northern hemisphere. As a consequence of the volcanic eruption in Iceland, on April 14, combined with the advection of air masses from the North, the air traffic over large areas of Western Europe was suspended, for security reasons, from the afternoon of Thursday April 15th.

Lava is molten rock expelled by a volcano during an eruption. This molten rock is formed in the interior of some planets, including Earth, and some of their satellites. When first erupted from a volcanic vent, lava is a liquid at temperatures ranging from 700°C to 1,200°C (1,300°F to 2,200°F). Up to 100,000 times as viscous as water, lava can flow great distances before cooling and solidifying, due to its thixotropic and shear thinning properties.

The densest minerals, ferro-magnesian silicates, form at the highest temperatures, whereas less dense minerals form when the magma cools down. Mineral types forming in molten rock often grow unrestricted to a very large size, and can have a fine crystal form. There are seven basic types of lava, which reflect the main types of volcanic rock which the lava is composed of: Basalt, Andesite, Dacite, Rhyolite, Carbonatite, Natrocabonatites, Komatite. Igneous rocks, which form lava flows when erupted, can be classified into three chemical types; felsic, intermediate, and mafic. Felsic (or silicic) lava Felsicor silicic. Most Silicic lava flows are extremely viscous, and typically fragment as they extrude, producing blocky autobreccias.

The study of the airborne particles brought by the ash clouds should cover not only their concentrations expressed in µg/m³, but also their size, shape and chemical composition. Apart from the damage to the jet engines, an estimation of the impact of the resulting atmospheric pollution on the health of the populations living in the regions affected by the volcanic clouds can only be based on this kind of information.

The objective of the present report is to provide data about the concentration, the micromorphology and the chemical components of the airborne particles brought by the ash clouds emitted during this exceptional volcanic phenomenon and found in the air of the Brussels urban region.

Methods and Materials

For this study we used specific methods and instrumentation that are adapted for the investigation of the proposed objectives.

The Brussels telemetric network for air pollution consists of 11 measuring sites, situated in different urban environments: traffic, residential, industrial and urban background. The PM10 mass concentration is measured in six measuring sites: Molenbeek (R001), Berchem (B011), Uccle (R012), Brussels naval port (N043), Meudon park (MREU1) and at the Brussels Environmental Institute in Woluwe (WOL1) (Fig. 1).

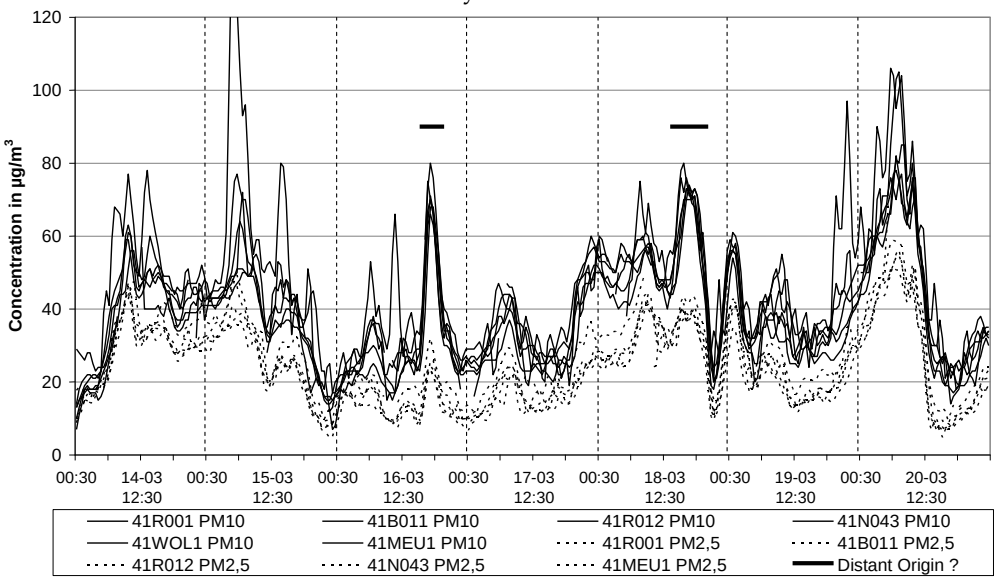

Fig. 1: Evolution "PM10-Fdms" and PM2,5-F" dms at Brussels Measuring Sites
(Period: Wednesday 14 – Tuesday 20 April 2010)

With the exception for the WOL1 site, the mass concentration for PM2.5 is measured along with PM10 in five of the six PM10 measuring sites. All PM mass concentration instruments are continuous TEOM 1400Ab analyzers (*Tapered Element Oscillating Microbalance*), equipped with FDMS 8500 system (*Filter Dynamics Measurement System*). Thus, the dynamic evolution of the mass concentration can be followed, while the mass concentration results on a 24-hour basis are relatively close to those of the gravimetric reference method. At the Brussels Institute for Environmental Management (WOL1), the particulate number concentration, expressed as the number of particulates per liter air, is also measured for 31 different classes, ranging from 0.25 μm to 32 μm, by means of a Grimm Laser light scattering spectrometer, model 365.

At two of the PM10 measuring sites (Uccle and Woluwe), and at the local university (ULB) particles were also collected on filters by use of low volume samplers, in order to investigate for their physical and chemical properties.

The analysis of the particles was performed by taking into consideration the fact that particles smaller than 2.5-3μm, constitute a health hazard by their simple presence, regardless of their mineralogical and chemical composition (Buringh and Opperhuizen 2002; Harrison et al. 2001; Ruuskanen 2001). In addition, the chemical compositions of the particles were analyzed by Scanning Electron Microscopy (SEM), X-Ray diffraction and light polarizing microscopy. Estimation of particle size distribution for a large number of particles was based on their planar projection in a JSM 5410 JEOL scanning electron microscope (Franck and Herbarth 2002).

Our estimation of the particle size distribution is a result of particle projection on a plane. The value of the particle area, A [in square micrometer], is defined as the surface of the particle enclosed within the projected border, P (the perimeter in micrometer). This must be compared to the classical size parameter that is the diameter (D) of the smallest circle enclosing the whole plane projection of the particle (Alshibli et al. 2004; Vanderstaeten et al. 2008). Using SEM, a series of parameters were measured on a large number of particles: the projected surface (A, in square micrometer), the projected perimeter (P, in micrometer) and the projected long and short axis (L_1 and L_2, in micrometer). From these values, two dimensionless ratio parameters, R1 and R2, were computed for a large number of particles (Zaady et al. 2009), characterizing the roughness and the elongation of the particles.

The first parameter, R1 [in micrometer], is defined as $R1=4\pi A/P^2$. This parameter characterizes the irregularity of the contour of the particle, i.e. the roughness of the particle surface, as compared to the smoothness of a perfectly spherical surface (Alshibli et al. 2004; Vanderstraeten et al. 2008). This quantity equals the value of 1 when the projection of the particle on the surface analyzed by the microscope is a perfect circle (Zaady et al. 2009). The second parameter R2 refers to the elongation of the particle and corresponds to the projected major axis, L_1, divided by the minor axis, L_2, of the smallest ellipse enclosing the planar projection of the particle.

The nature of the filter sampling is such that the particles that are captured must have a linear size between 1μm and 10μm. Particles larger than 10μm almost systematically rebound from the filter, whilst most of the particles smaller than 1 μm pass through it without being captured.

Statistical analysis - The statistical analysis concerns the particles collected on filter at three measuring stations Uccle, Woluwe and ULB located in the Brussels urban area, in order to characterize the difference in area and shape of atmospheric particles collected on the 16th, 17th and 18th of April 2010. One-way ANOVA, with Tukey test (Sokal and Rohlf 1995) was used to test differences in parameter means between the sites and days. Differences were considered statistically significant when $P<0.05$. Our comprehensive approach allowed us to calculate the particle size distribution, their roughness and sphericity and compare between the data regarding the changes in the chemical element compositions throughout the whole year, during normal period as expressed by non agriculture period (April) and during the eruption period (Vanderstraeten et al. 2007; Zaady et al. 2008).

Results

Following the eruption on April 14, 2010, the PM10 and PM2.5 mass concentration measured at the surface in Brussels did not exhibit any unusual concentration level (Fig. 2). The PM10 levels were normally higher than those of the PM2.5 and the differences observed between the PM10 levels, measured at different sites for most of the time,

express the typical local influences. However, on Friday, April 16th between 16:00 and 19:00 h UT and on Sunday, April 18th between 14:00 and 19:00 h UT, the PM10 mass concentrations at the different measuring sites were quite similar and the differences between the PM10 and the PM2.5 levels were much more pronounced than during the rest of the considered period.

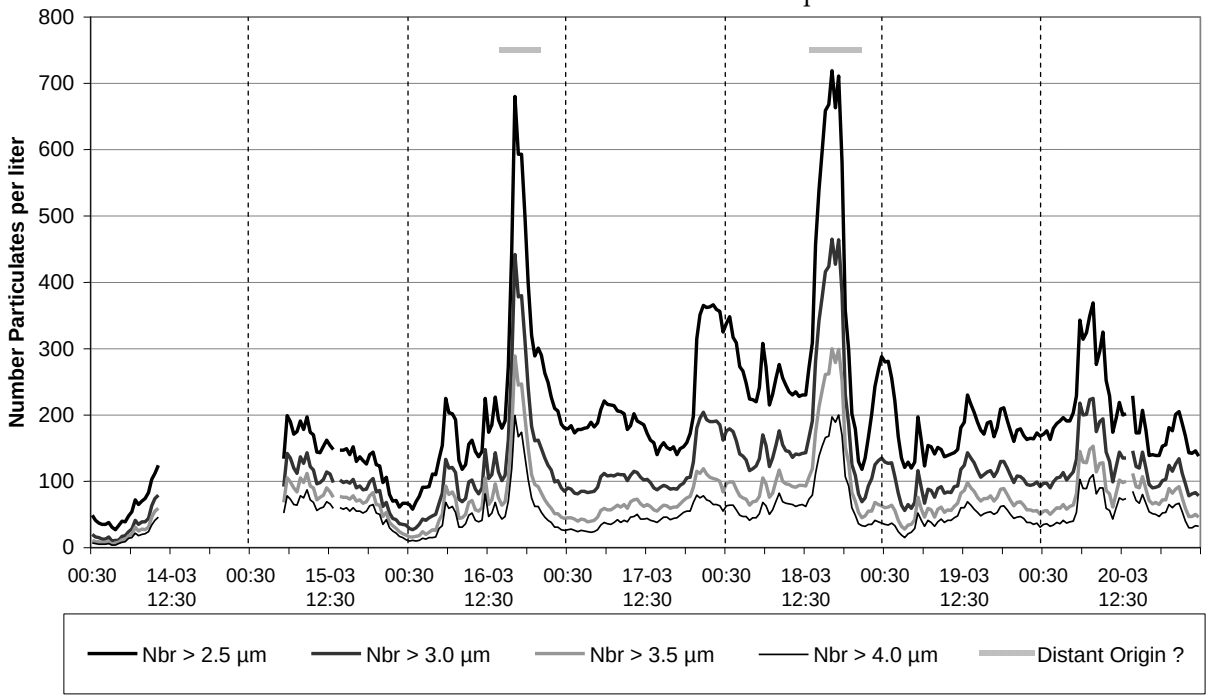

Fig. 2: Number of Particulates "> 2.5 µm" "> 3.0 µm" "> 3.5 µm" "> 4.0µm"
(Period: Wednesday 14 – Tuesday 20 April 2010)

During the two periods (between the eruption period and the regular airborne particle dynamics in Brussels Capital Region), the particulate number concentrations for the coarser fractions peak, as illustrated by Figure 3, representing the particulate number concentration for some classes: ">2.5 µm", ">3.0 µm", ">3.5 µm" and "> 4.0 µm". In both figures (2 and 3), the two periods are indicated by small horizontal lines just above the top of the peaking concentration. The peak measured on April 20th could also be partially due to the eruption, but not exclusively, since important differences in the concentration level are observed between the PM10 concentrations at different stations.

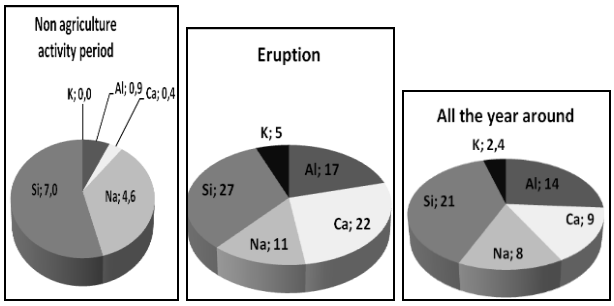

Fig. 3: Comparison between the atmospheric chemistry composition during the whole year, during non agriculture period and during the eruption period

Comparison between the atmospheric chemistry composition during the year, during non agriculture period and during the eruption period showed an increase of up to 4 fold in the At% of the elements K, Al, Ca, Na and Si (Fig. 3) for the eruption period.

The R1 (sphericity) on the three main days of the eruption period was three times higher than that found throughout the whole year and the non agriculture period, while the R2 (roughness) was lower by a factor 2 during the eruption period compared to the other two periods (Table 1).

Table 1 The micromorphological characteristics (R1 and R2) of the airborne particles during the 16, 17 and 18 April 2010 in Brussels

Period of measurement	Sphericity R1=(Long/Short)	Roughness R2=(4π A/P²)
During the whole year	0.46±0.2	1.33±0.4
Non agriculture period	0.42±0.1	1.29±0.3
Eruption	1.46±0.4	0.72±0.1

Discussion

Measurements to obtain PM10 concentrations by means of R&P TEOM 1400Ab continuous instruments were performed at six different sites in the Brussels Capital Region. Three of these sites are representative for the general activities in the city (traffic, domestic heating, business and commercial activities), a fourth one is situated in an industrial area (city naval port) with a lot of traffic and two additional sites are situated in typical city residential environments. The granulometry was measured at the Woluwe site (WOL1), while the micromorphology and the chemistry were measured only in the sites with the filter sampling system; Uccle (R012), Brussels University (ULB) and the Brussels Environmental Institute (WOL1).

The observations obtained, especially those on April 16 and 18, support the idea that a common and distant source, situated outside the Brussels urban area, is responsible for the amount of the coarser particulates (PM 2.5 to 10). Nevertheless, as for the concentration of airborne particles, very high PM10 concentrations in the past have been reported during agriculture activity periods (the harvesting and sowing of wheat, corn and barley) (Vanderstraeten et al. 2007; Zaady et al. 2008) and by advection of Sahara sand. Similar to that, during the eruption period PM10 particles were predominant to PM2.5.

Our main results concerning the airborne particle micromorphology and chemistry showed a possible temporal correlation between the eruption period and the regular airborne particle dynamics in Brussels Capital Region (Zaady et al. 2010). These results are complemented by a previous study, which compared the non agricultural work periods (April) with the whole year round (Fig. 3). At least for two short periods the principal origin of the airborne particles is likely to be found in combustion processes (volcanic eruption). The high thickness and strength of the airborne particles, of the eruption period, were the result of their chemistry, which are high in silica, aluminum, potassium, sodium, and calcium, suggesting that their origin were from the Icelandic Eyjafjallajökull felsic stratovolcano. These chemical elements form a polymerized liquid rich in feldspar and quartz, which thus has a higher viscosity than other magma types (intermediate, mafic and ultramafic).

Conclusion

- During the eruption period high concentrations of large particles of PM10 were found.
- An increase of up to 4 fold in the At% of the elements K, Al, Ca, Na and Si, which characterize the felsic lava, was observed during the eruption period.
- The R1 (sphericity) and R2 (roughness) parameters showed specific characteristics of the particles suggesting a long distance from their origin.

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Adoption of NAMEA Air Emission Accounts in Hungary

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Abstract

The current phenomena of accelerating climate change and global warming has urged scientists and policy makers to devise a comprehensive and reliable system to identify the main causes and sources of the adverse processes. NAMEA (National Accounting Matrix including Environmental Accounts") developed by EUROSTAT has gained in popularity as it highlights the impacts of societal action on the environment by linking economic indicators to environmental material flows. The paper reports on the work done in the Hungarian Central Statistical Office to adopt and further develop the NAMEA system and demonstrates the crucial changes occurred in the emission of the major pollutants between 2000 and 2009 taking into consideration economic indicators.

Keywords: air pollution, NAMEA system, pollutants, environmental economic profiles.

Rezumat. Adoptarea conturilor MCNCM pentru emisiile atmosferice in Ungaria

Fenomenele actuale de accelerare a schimbărilor climatice și încălzirii globale au obligat oamenii de știință și autoritățile să conceapă un sistem cuprinzător și fiabil pentru identificarea principalelor cauze și surse ale acestor fenomene adverse. MCNCM (Matricea Contabilității Naționale cu Conturile de Mediu) elaborată de EUROSTAT a devenit tot mai populară, întrucât pune accentul pe impactul activității societății asupra mediului, legând indicatorii economici de fluxurile de mediu. Articolul prezintă rezultatele activității desfășurate în cadrul Oficiului Central de Statistică din Ungaria pentru adoptarea și dezvoltarea continuă a sistemului MCNCM și demonstrează schimbările cruciale care s-au produs în emisiile unor poluanți majori între 2000 și 2009, având în vedere și indicatorii economici.

Cuvinte-cheie: *poluarea aerului, sistemul MCNCM, poluanți, profile economice de mediu*

Introduction

The most important task of environmental policy nowadays is to mitigate the adverse effects of climate change (Hardy, 2003). Since air pollution considerably contributes to the unfavourable process of climate change, it is crucial to be dealt with (OECD, 1995). In order to succeed in tackling air pollution, emissions need to be assigned to economic sectors, helping the elaboration and implementation of environmental policies (Rácz, 1999).

National Accounting Matrix including Environmental Accounts (NAMEA) is used to highlight the impact of the society on the environment. Developed by EUROSTAT, the NAMEA system builds on national accounts to give detailed insight into the performance of each economic sector and the harmful effects of production and service provision. NAMEA is a complex model containing data of numerous environmental domains (air, water, waste, etc.), which are compared with economic parameters.

The European Strategy for Environmental Accounting (ESEA) regards Air Emissions Accounts as a core module of Environmental Accounts. Air Emissions Accounts record and present data on air emissions in a way that they are compatible with traditional economic statistics. They record emissions in a breakdown by emitting industries and private households activities as delineated in National Accounts. Air Emissions Accounts are linked to the framework of Supply, Use and Input-Output Tables enabling numerous analytical applications. Such kind of integrated environmental-economic analyses are in high demand in the wider

policy area of sustainable development (e.g. Lisbon Strategy, EU Sustainable Development Strategy, Global Climate Change, EU policies on Sustainable Consumption and Production etc.).

Beforehand, the HCSO had data on the most common air pollutants – 3 greenhouse gases (CO_2, CH_4, N_2O) and 3 acidifying substances (SO_2, NH_3, NO_x) and non-methane volatile organic compounds (NMVOC) –, covering 5 years (2000-2004). Data were combined with economic variables based on a simplified version of industry classification.

The main aim of the project was to further study the methodology of the compilation of the new NAMEA air tables, and assess the changes occurred in the emission of the major pollutants.

The objectives of our work were as follows:

- implementation of a complex, relevant, maintainable system of the air emission part of NAMEA at the Hungarian Central Statistical Office,
- compilation of national economies' emissions in a breakdown by emitting economic activities for Hungary in time series from 2000 to the latest possible year (2009),
- analysis of the results.

Methodological background

In December 1994, the European Commission submitted a report - 'Guidelines of the European Union concerning environmental indicators and 'green' accounting: the integration of environmental and economic systems' - to the European Council and the European Parliament to describe the relationship between the economic and social system on the one hand, and the economic system and the environment on the other hand. In autumn 1996, the EUROSTAT and the national statistical offices of most Member States agreed upon projects on the production of NAMEA tables (National Accounting Matrix including Environmental Accounts).

The basic idea of NAMEA is to merge economic and environmental data in a consistent way, so it allows for direct comparison of parameters from both ranges on a sectoral level. The core of the framework is a set of tables of economic data and to form a national accounting matrix (NAM) as compiled in national accounts. The environmental accounts (EA) comprises tables containing data in physical units (mass, volume or energy units). The presentation of the data is based on the classification of economic activities, i.e. on NACE (Nomenclature générale des activités économiques dans les Communautés Européennes) Rev. 1 including private households. Thus, the economic performance (e.g. gross value added, persons employed) can be linked to the resources used for production or to the emissions generated (e.g. air pollutants, waste, waste water) in a given year.

This perspective can be used for scientific analysis and to assessment policy measures by comparing the sectoral performance either over time or across countries and the distance from emission reduction targets can also be determined. NAMEA helps to identify the sources of air pollution, too. This system allows an analysis of the performance of an industry where the emissions are normalised by the size of the economy. If a particular industry exhibits a development (e.g. measured as CO_2 emissions per million € output) that diverges from its past performance or from the average of the EU average, the reasons for the differences need to be investigated. The variations can be due to heterogeneous industry classifications, structural differences or technological changes.

The major advantage of the NAMEA Air Emission Accounts is the possibility to interlink data on air emissions with macroeconomic or even social data. That means a coherent set of environmental, social and economic indicators can be derived with a high degree of international comparability of the results and all indicators are closely linked to one another. This is a key basis for integrated economic and environmental analysis and modelling, including cost-effectiveness analyses, scenario modelling and economic and environmental forecasts. This integrated framework allows sectoral policies and indicators to be a part in a comprehensive economic, social, and environmental context.

In 2000, a set of NAMEA for air emissions standard tables was prepared by EUROSTAT and was finalised at the fourth NAMEA workshop. These tables focusing on air emissions also covered some economic data, but they were not to be reported in a matrix format. The standard tables were revised in 2002 in order to improve the comparability of data between countries as well as with other air emission statistics. Meanwhile all Member States have become involved in the compilation of air emission accounts for NAMEA. Some produce and publish NAMEA data on an annual basis, for other EU countries the compilation

is still at the stage of pilot applications. In 2005 EUROSTAT published the "NAMEA for Air Emissions - Compilation Guide" and in 2009 „The Manual for Air Emissions Accounts". The guides introduce the basic principles that apply in the NAMEA framework in general and provide an in-depth presentation of the methods on which the two main approaches used by EU countries in the compilation of air emission accounts are based.

Regarding the history of compilation of NAMEA in Hungary it is necessary to mention the 2-year bilateral co-operation established between the Dutch and Hungarian statistical offices (CBS-HCSO) in 2003 and the NAMEA grant project in 2005. The main result of the previous projects in Hungary was the compilation of the air emission part of the NAMEA tables for the years 2000 and 2004, thus completing a short time series and creating a draft version of the NAMEA Air Emission Accounts with a detailed table consisting of all required economic variables and air pollutants. We can highlight that at the present stage the Hungarian NAMEA follows a so called "light version" with respect to the combination of emissions and economic data following the NACE classification of economic sectors.

Principal structure of the calculation

For calculating emissions, the residence principle has to be taken into account. The concept of residence in National Accounts is not based on national or legal criteria. An institutional unit is said to be a residence unit of a country when it has a centre of economic interest in the economic territory of a country.

Consequently, emissions stemming from the economic activities of resident units have to be accounted for rather than those stemming from sources on the national territory. Conversely, all emissions by non-resident entities on national territory (foreign lorries and tourists) have to be excluded. In short, Air Emission Accounts record emissions arising from all resident unit's activities, regardless from where these emissions actually occur geographically.

Methods for calculation of air emissions

In general, the Air Emission Accounts belong to the block of physical supply of residuals. Air emission in EUROSTAT's Air Emission Accounts relate to those physical net flows of gaseous or particulate matters that origin in the economic system and are released into the atmosphere and remain suspended in the air for substantial time.

For compiling Air Emission Accounts, two main compilation approaches can be distinguished (Eurostat, 2009). The "inventory-first approach" starts from existing national emission inventories, which are compiled to report to international agreements on emissions of air pollutants and greenhouse gases, and re-arranges those data to a format compatible with National Accounts.

The "energy-first-approach", what our system was also based on, starts from energy statistics which are re-arranged to Energy accounts from which air emissions are calculated using certain emission factors.

Regardless of the compilation approach applied, there are two steps required when compiling Air Emissions Accounts. These two generic compilation steps are as follows:

- Adjusting the system boundaries to correspond with those of National Accounts (geographic versus economic system definition), and
- Assigning the environmental data to economic activities (industries and households) actually inducing respective energy uses and/or air emissions.

Irrespective of the starting point, allocating data to economic activities requires the use of auxiliary data to help distribute the figures from one classification system to another. Generally one attempts to find a relationship between the two categories that is as close as possible to the data to be distributed. If nothing specific can be found then employment or production output is used as a last resort.

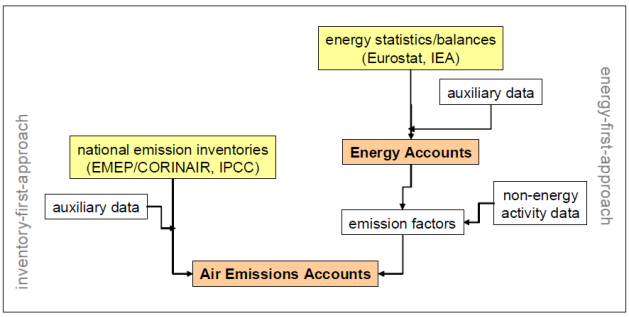

Fig. 1: Schematic overview on two generic compilation approaches for Air Emissions Accounts
Source: Eurostat 2009

The first step of the "energy-first approach" is to adjust the system boundaries from geographic to economic to meet the requirements of the residence principle. Second, the energy use needs to be assigned to industries and household based on NACE classification. Finally, emissions are calculated for each industry and households separately using industry and technology specific emission factors for each energy carrier. In order to develop comprehensive air emission inventories, accordingly, Air Emissions Accounts, it is crucial to add emissions from other sources to energy related emissions. These include industrial processes, solvent and other volatile organic product use, agriculture (number and types of animals and manure management information) and waste (treatment and incineration also).

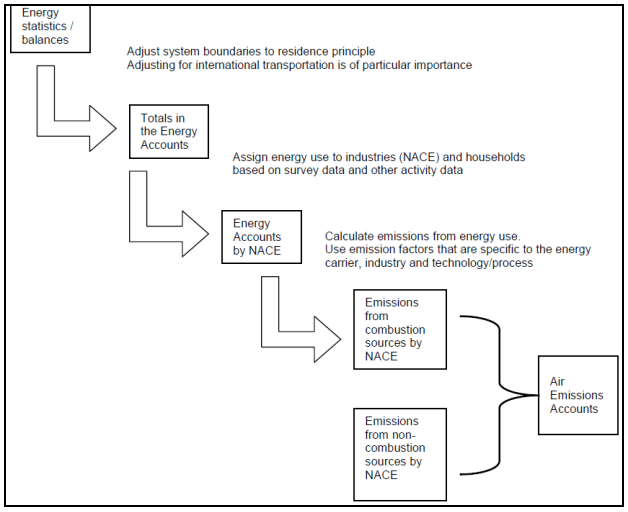

Fig. 2: Schematic flow chart on energy approach of Air Emission Accounts

Source: Eurostat 2009

Figure 2 shows the structure of calculation paying particular attention to the combustion and non-combustion sources of emissions and emission factors. Regarding methodological aspects, an important result of this project is that our system building will be based entirely on EUROSTAT's methodology taking into account local circumstances. The NAMEA was compiled according to the EUROSTAT (2009) guide. Consequently, accounts are complete and coherent with the guide.

For calculating air emissions for NAMEA the following points are to be taken into consideration:

- Measuring: the most reliable origin of data,
- Expert advice to take notice of the local specialities (factors);
- Calculation on the basis of material balances;
- Comparative calculations, analogy;
- Calculations on the basis of emission factors with the help of air emissions inventory experts;
- Entire consistency of EUROSTAT methodology on the score of Manual for Air Emissions accounts;
- Legal compliance: the best possible correspondence with proposal for a "Regulation of the European Parliament and of the Council on European environmental economic accounts (preparation of bridge tables, etc.).

When calculating emissions five essential requirements are to be met:

- Completeness: examination has to cover all available data sources;
- Consistency: calculation has to be made according to equal aspects ensuring comparability;
- Transparency: calculation process has to be understandable for everyone;
- Accuracy: results have to converge to real values as much as possible.
- Continuity: the results must be produced each year.

Summary of actions

One of the goals of the project was to identify those modules which may have the best bases for development and implementation on a regular basis. The priorities are driven by already available know-how, data as well as financial and human resources.

The main methodological development of the project is the detailed allocation of sectors to NACE categories (2 digits) and assuring consistency with economic data from the system of National Accounts (regarding especially the disaggregation of manufacturing).

Data had been collected from the different available sources between 2000 and 2008).The new version of the Hungarian NAMEA system is now in accordance with EUROSTAT requirements. Thus, the analysis covers:

- CO_2, Biomass CO_2, N_2O, CH_4,
- HFC, PFC, SF_6,
- SO_X, NO_X, NH_3 and
- NMVOC, CO, PM10.

Air emissions originated from the consumption of fossil fuels, anthropogenic activities and different technological processes (NACE 2 digit level).

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Emissions originated from so-called pyrogenic processes (combustion of fossil fuels) and from anthropogenic (but not pyrogenic) activities have been calculated separately.

Concerning calculation of emissions originated from combustion processes, aggregation has been made according to the detailed energy statistics on use of fossil fuels.

Results, sustainability

In the followings the main results will be demonstrated. A brief dataset will be presented and explanation will be given on the trends of the most important air emissions– greenhouse gases, acidifying substances and ozone precursors – of ten years (2000-2009). Data are combined with economic variables according to the industry classification of NACE from tables of chapter six.

Emission of greenhouse gases

Greenhouse gases are gases in the atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. Primary greenhouse gases in the Earth's atmosphere include carbon-dioxide, methane and nitrous oxide. The Global Warming Potential (GWP) of the individual gases varies. (In a time horizon of 100 years for CO_2=1, for CH_4=21 and N_2O=310. It means that in a 100 year's time 1 tonnes of methane cause as much warming as 21 tonnes of carbon dioxide.) Thus, it enables scientists and policy makers to compare the indicators of greenhouse gas emissions expressed in GWP.

The most polluting industry in Hungary in terms of emission of greenhouse gases is the electricity, gas, and water supply, which represents around 30-32% of the total emission, although its size and proportion is solidly decreasing (Fig. 3). The agriculture, hunting, forestry as well as manufacturing are responsible for one-fifth of the emissions, while the share of transport, storage and communication industry continued to grow from 9.7% in 2000 to 16.7% in 2009.

Figure 4 shows that carbon dioxide (CO_2) is the most important greenhouse gas in Hungary and its rate decreases less rapidly than that of nitrous oxide (N_2O) and methane (CH_4).

In Hungary, 81-82% of emissions of greenhouse gases directly stem from economic activity, the rest originates in household consumptions.

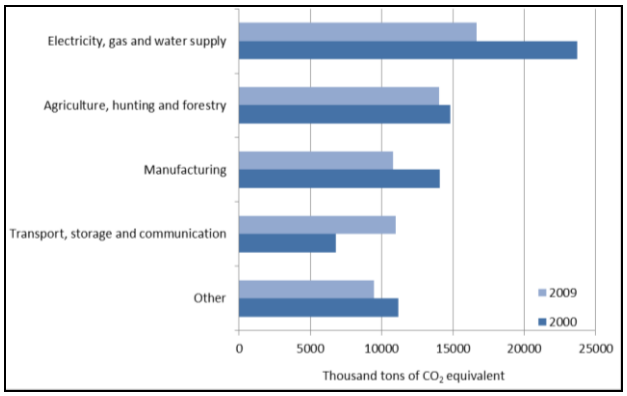

Fig. 3: The structure of emissions of aggregated greenhouse gases from the Hungarian economy by industries

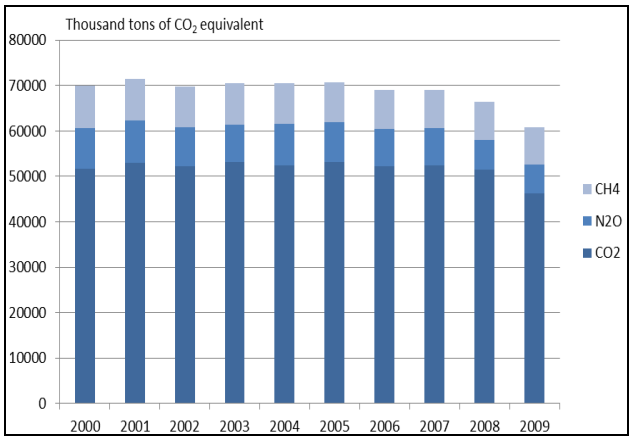

Fig. 4: The distribution of emissions of greenhouse gases from the Hungarian economy

Emission of acidifying substances

Sulphur oxides (SO_X), nitrogen oxide (NO_X) and ammonia (NH_3) are examples of acidifying substances emitted into the air. Emissions from stationary and mobile sources have adverse impacts on the air quality, especially in cities. SO_X, NO_X and NH_3 lead to acid rain and changes in the chemical composition of soil and surface water after deposition. In addition, they place great pressure on flora and fauna. Acidification has harmful effects on the biological ecosystems, forests, surface water, water supply systems, buildings and monuments.

Eutrophication of aquifers, lakes and watercourses results in excess growth of algae.

In the Hungarian economy the aggregate value of acidifying substances sank from 688 thousand tons of SO_2-equvivalent in 2000 drastically to 287 thousand tons in 2009. The reason of this decline is the sweeping technological changes in the electricity, gas, steam and water supply branch (Fig. 5).

Besides the quantity of acidifying gases, a significant rearrangement occurred also in the proportions of the ingredients (Fig. 6). The sulphur oxides emission decreased to about one-tenths of total, so the direct emissions of ammonia and nitrogen oxide have become dominant in the examined time interval.

An increasingly significant proportion of total emissions of acidifying substances is being caused by households in Hungary. This rate doubled between 2000 and 2009. In 2009 it amounted to 17% of total acidifying substances emission. The amount of emissions from households also fell during the examined years, but not as rapidly as in the case of industry. The reason for this trend is that technological changes in the households are not as substantial as in the industry.

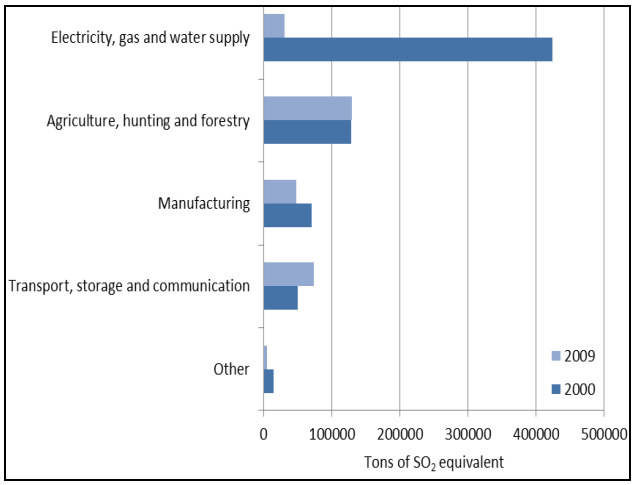

Fig. 5: The structure of emissions of aggregated acidifying substances from the Hungarian economy by industries

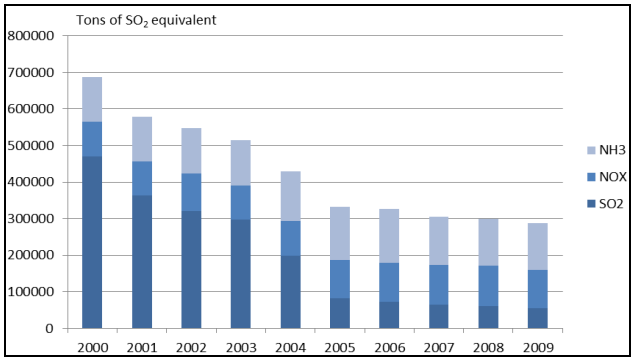

Fig. 6: The distribution of emissions of acidifying substances from the Hungarian economy

Emission of ozone precursors

Tropospheric ozone nearby the Earth surface is in connection with transboundary environmental issue. The ground-level ozone is not emitted directly into the air, but is created by chemical reactions between nitrogen oxides (NO_x), carbon-monoxide (CO) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapours, and chemical solvents are some of the major sources of NO_x and VOC. At ground level ozone is a harmful pollutant.

The emissions of ozone precursors grew slowly from 2000 (337 thousand tons of NMVOC-equivalent) until 2008 (351 thousand tons), then fell back to 321 thousand tons in 2009. While the majority of economic sectors reduced the emission of precursors, in the most polluting industry, namely the transportation, storage and telecommunication, it increased by 15-16% (Fig. 7).

Figure 8 illustrates that among ozone precursors, the non-methane organic compounds and nitrogen oxides are the most significant. In 2009, the manufacturing industry was responsible for more than two third of NMVOC emissions from Hungarian economy.

The Hungarian economy accounts for less than four-fifths of total ozone precursor emission, while households amount to more than 20%. This means that households' emission is the highest in the case of ozone precursors among the three groups of contaminants scrutinized (greenhouse gases, acidifying substances and ozone precursors).

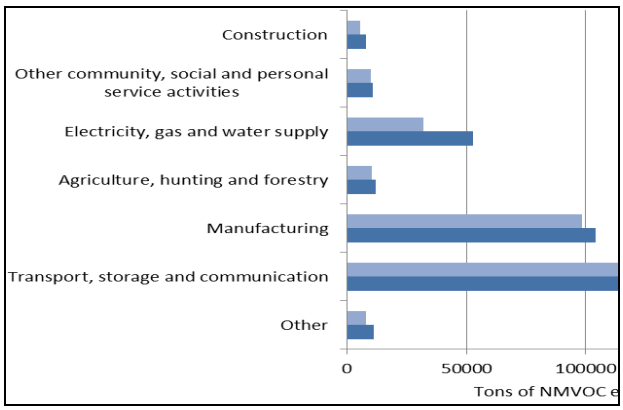

Fig. 7: The structure of emissions of aggregated ozone precursors from the Hungarian economy by industries

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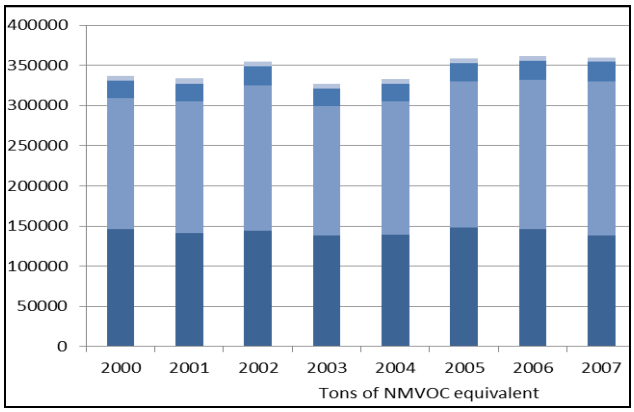

Fig. 8: The distribution of emissions of ozone precursors from the Hungarian economy

Environmental – economic profile by main industries

Air emissions accounts present air emissions by industries which are the same as shown in the National Accounts. This offers the possibility to compare several air emissions with economic parameters, hereby providing the base for conducting a deep analysis on a certain industry's emission. In so called environmental – economic profiles, both parameters can be demonstrated jointly for selected single industries. Those profiles show the share of a particular industry out of industry's total for a number of parameters such as greenhouse gas emissions, emissions of acidifying substances and ozone precursors, gross value added and the number of people employed.

In the case of direct emission of greenhouse gases, the electricity, gas, and water supply was the major emitting economic sector in Hungary (Fig. 11). However, taking into account emission per gross output, the industry with its 7.8 tons of CO_2-equivalent barely reaches 60% of mining and quarrying (12.3 tons of CO_2) in 2008. The difference is even greater if we consider the emission per employment. In the mining industry it equals to 262 tons of CO_2-equivalent of greenhouse gas emission, in the agriculture, hunting, forestry and fishing industry to 93 tons, in the transport storage and communication sector to 30 tons, while in the electricity, gas and water supply "only" 29 tons.

In the case of acidifying gases the most significant change occurred in the electricity, gas and water supply industry, where due to stricter regulations more efficient filters were installed, reducing the emission of acidifying substances considerably (Fig. 11). This change led to the increase in the share of other industries' acidifying gas emissions.

For the emission of ozone precursors, the share of different sectors did not change significantly between 2000 and 2008. Transport, storage and communication sector still have the highest share (45%, illustrated in Fig. 12), followed by the manufacturing industry (nearly 35%, shown in Fig. 10).

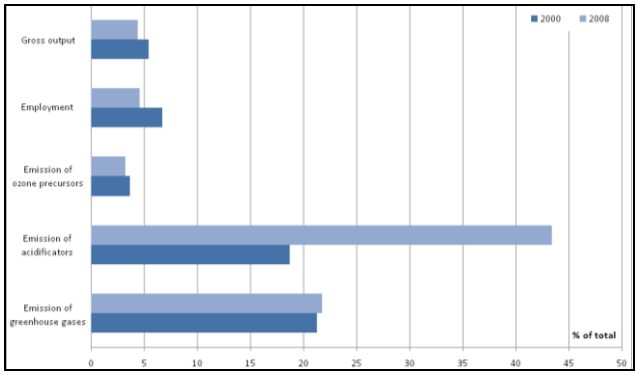

Fig. 9: The environmental – economic profile by agriculture, hunting, forestry and fishing industry

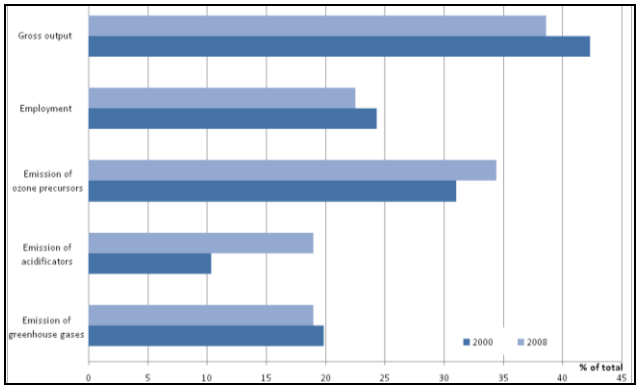

Fig. 10: The environmental – economic profile by manufacturing industry

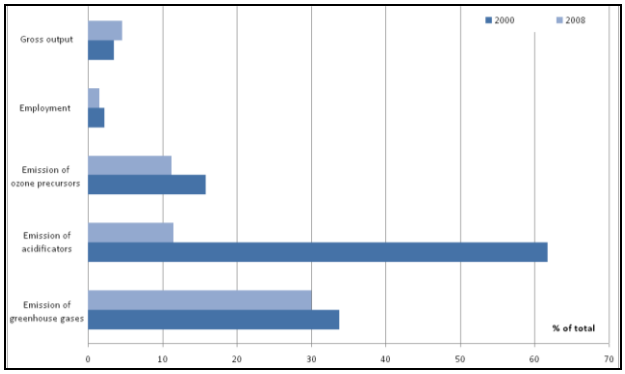

Fig. 11: The environmental – economic profile by electricity, gas and water supply industry

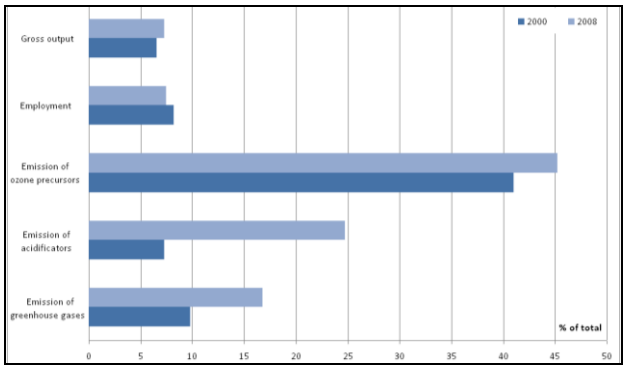

Fig. 12: The environmental – economic profile by transport, storage and communication industry

What is favourable with respect to the future and sustainability is that the emitted quantity of the examined contaminants decreased in all three groups. Greenhouse gas emission fell by 50% between 2000 and 2008. The emission of acidifying gases per gross output (calculated at current prices) also saw a drop of approximately 18kg, from 23.4 kg to 5.3kg in the same period, meaning that the production of goods and service entails less damage to the environment. For the ozone precursors, emission per gross output - expressed in NMVOC equivalent - sank from 11.5kg to 6.2kg.

Conclusion

By meeting EU requirements and successfully adopting the different, harmonised statistical method, a sustainable system that can provide long term assistance in compiling NAMEA air accounts year by year was established.

On the one hand, the project provided expertise and training to have a deeper insight into the compilation of environmental accounts. On the other hand, it helped standardize the procedures for the regular production of environmental accounts. As a long term objective of our work, the system can serve as a comprehensive analysing tool for policy making processes.

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Using GIS in the Assessment of Landscape Visual Quality: a Methodological Approach Applied to Piatra Neamt, Romania

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Abstract

This study demonstrates the feasibility of using GIS in the assessment of landscape visual quality. Based on the digital elevation model achieved by processing the 1:5000 scale topographic plans, Viewshed analysis application was performed for 5 observation points of the territory, which were selected by objective criteria. We tried to quantify the landscape values of Piatra Neamt administrative territory through an objective analysis of the reality on the ground reflected from the observation points, taking into consideration also the human perception regarding these aspects (a hardly accepted domain by the scientific community). The analysis can lead to precise values of the landscape, yet the only element more difficult to quantify remains human perception.

The application was possible starting from the mathematical interpretation of the landscape proposed by Neuray G. in 1987, but a great importance in achieving the expected results is held by the specific GIS techniques mentioned above. The main purpose is to highlight the landscape potential of the area of study, noting that this analysis can be applied to any other area.

Keywords: *GIS, landscape assessment, Piatra Neamț*

Rezumat. Utilizarea tehnicilor GIS în evaluarea calității vizuale a peisajului: o abordare metodologică aplicată la Piatra Neamț, România

Studiul de față demonstrează fezabilitatea utilizării tehnicilor SIG în evaluarea calității vizuale a peisajului. Pe baza modelului digital al terenului realizat după planurile topografice la scara 1:5000 s-a efectuat aplicația Viewshed analysis pentru 5 puncte ale teritoriului, selectate după criterii obiective. S-a încercat o cuantificare a valorilor vizuale ale peisajului din aria municipiului Piatra Neamț în urma analizei obiective a realității din teren reflectate din punctele de observație, dar și prin prisma percepției umane (domeniu mai greu acceptat de comunitatea științifică). Astfel, se poate ajunge la valori precise ale peisajului, singurul element mai greu cuantificabil fiind percepția umană.

Aplicația a fost posibilă plecând de la interpretarea matematică a peisajului propusă de Neuray G. in 1987, urmând ca un rol deosebit de important în atingerea rezultatelor dorite să-l aibă tehnicile specifice SIG amintite anterior. Scopul principal este de a vedea potențialul peisagistic obiectiv al teritoriului studiat, însă această aplicație poate fi realizată pentru orice areal.

Cuvinte-cheie: *tehnici SIG, evaluare peisaj, Piatra Neamț*

Introduction

The landscape approach is widely recognised today as a powerful method of multidisciplinary environmental research. Integrating data both on natural geoecosystems and socio-economic impacts and their relationships, it offers an ideal frame of territorial sampling for evaluating, mapping and modelling environmental status and dynamics (Lioubimtseva et Defourny, 1999).

Frequently, the plurality of position regarding the meaning of the term geosystem replaces this very complex reality of the concept of landscape. At least for pressing practical reasons, its assessment (operation that involves rigorous quantification) should be based on scientifically validated methodology. In fact, the promoters of this

assessment have not yet established whether landscape values to be measured are economic, social, functional, ecological, economic, aesthetic etc. (Ungureanu I., 2005).

The landscape is an external manifestation, an indicator image or key reflecting the processes (natural and anthropic) that take place within a territory. As a source of information, the landscape requires interpretation. (...) The absence of a clear concept of landscape, plus the difficulty in reducing the amount of information it provides to manageable quantities, have led to the recent development of methods for its analysis. The large number of features that make up the landscape have given rise to many different approaches (some of which are complementary) to its study (Pastor et al., 2007).

Landscape assessment is a much requested direction in geography today. The high priority given to landscape states on European and global scale requires a thorough study of them, and the establishment of methodologies for assessing their status (Dumitrașcu M., 2006).

Techniques for assessing landscape attractiveness are becoming increasingly important in environmental planning. They are a manifestation of the growing need to monitor landscape deterioration, to help preserve natural beauty, to learn about our cultural perceptions, and to satisfy an ever-increasing body of environmental law. (Kane, 1981)

Geographical information systems (GIS) are excellent tools for landscape modelling and three-dimensional analysis. They allow easy digitalisation of geographical information and coverage structure, as well as facilitating graphical representation. (Hernandez et al., 2004)

THE AREA UNDER STUDY

Geographically, the Piatra Neamt town location is quite original, the initial built perimeter is sheltered by heights with steep slopes carved into flysch and it expanded to the Bistrita valley and its affluents (Fig. 1), especially on terraces, but also in meadows, areas that show optimal urbigene conditions.

The great diversity of natural conditions of Piatra Neamt have led to a great complexity of anthropogenic use, which gives a distinctive note to the landscape of the area (Apostol et Chelaru, 2011).

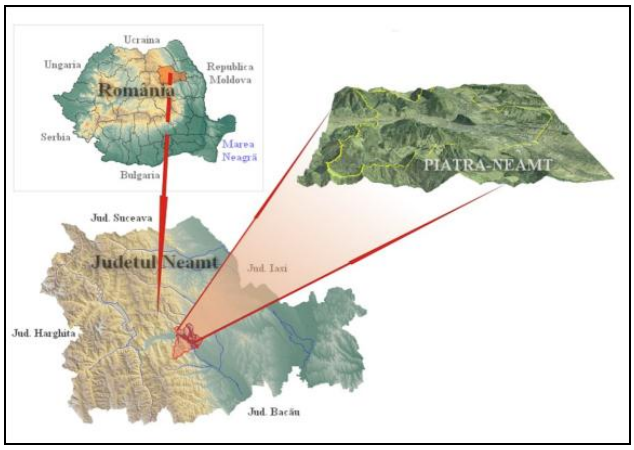

Fig. 1. Localization of area under study

Data and Methods

Based on the mathematical interpretation of the landscape proposed by Neuray G (1987) , there can be reach precise values of the landscape; the only more difficult to quantify element remains human perception. Thus, the application starts from expressing landscape value by:

V`` = L*R*S where L is the length or the visual distance calculated using the formula L= ½*10*log 10 l (l – maximum length of the distant plan visually perceived); the height of the visual area (R is an expression given by the formula R = 1 + sin $\alpha$ + sin $\beta$ + sin $\lambda$ + d/100, => V``= (L*R).; α, β, λ are the angles formed by horizontal line with elements located in the foreground and in the following existing plans in the area of predefined field of view , and d is the inclination or slope, T is the valorisation factor and represents the sum of all natural and anthropogenic components which are intercepted by the visual field coverage (180°) and this factor is introduced in the formula S= 1 + T/100.

The last step consists in calculating the total value of the landscape, which is given by the objective landscape value summed up with the value of the visual elements (in other words - the perception of each person on the landscape observed).

Each constituent element of the visual field is rated on a scale from -10 to 10. Elements that could damage the value of a landscape from anthropogenic structures that are not integrated into the landscape to polluted areas receive the lowest notes. Of course spectacular scenery will receive the maximum grade (mixed vegetation, historical monuments).

To see the perception tendency on natural and anthropogenic potential that match most of the population, there was applied a questionnaire with seven questions on a sample of 50 people.

There results that Vt = V``+ Vv , where Vt – total landscape value, Vv – subjective visual value, based on perception.

Methodologically, for achieving landscape value analysis, we used the ANALYSIS VIEWSHED application from the Microimages TNT Mips software to see the visual area from a point of observation with an 180° angle.

The next step consists in quantitative and qualitative analysis of the landscape by applying the formula of Neurray G. explained above.

Because the application depends on the relief configuration, it was necessary to achieve a more detailed Digital Elevation Model (DEM) to capture as accurately areas taken into observation. DEM was realised through the same Microimages TNT Mips professional software. Based on the analysis and processing the achieved database, DEM represents the support of the following cartographic material. The main data source for achieving the DEM are vector layers represented by contour lines and altitude rates. Vectorisation operation of the contours was a time-consuming step, because we used 1:5.000 scale topographic maps. Finally, there were assigned "z" values, resulting 3D vector layers.

By using this method of interpolation, DEM accuracy is not maximum because the contour lines already represent interpolated values of elevation data extracted from the field, and for achieving DEM it is used a second interpolation (between contour lines). Thus, the data concentration along the contour lines and their absence between isolines result in a topographical uniformity between the contour lines.

We have chosen to use detailed topographic plans at 1:5.000 scale, so that the accuracy of DEM to be higher. The final product was conducted at a resolution of 10 m, which allows us to visualize correctly the overall configuration of the landscape and the morphometric parameters taken into account.

As far as we are concerned, the utilitiy of DEM is viewing the general relief configuration, which allows, by linking with other elements, to identify certain types of landscape; cartographic determining of morphometric elements with role in landscape structure, accurate measurements on different surfaces and drawing transversal profiles on different alignments to reflect geographical phenomena and processes.

Results and Discussion

The main goal is to see the landscape potential of the studied objective. Thus, we tried to quantify the landscape values reflected in Piatra Neamt municipality, through the analysis of the visual quality obtained by specific GIS techniques, using also the subjective component of the landscape, the aesthetical part that is every person's perception.

The visual quality is not the same as the aesthetic quality of the landscape, the latter depending on the perception of images. Even if a landscape has particular aesthetic qualities, it is useless if its image is not visible from certain points (Drăguț, 2000).

The visual expression of landscapes affects people in many ways: aesthetic appreciation, health and well being (Tveit M. S., 2009).

In order to achieve this study, there have been made five Viewshed observation points (view area), from different sites of the city, for an analysis as objective as possible, after which values were compared (Fig. 2, 3, 4, 5, 6). It should be noted that this application can be made for any point in the area.

For a more realistic analysis of the phenomenon we studied, reference points were selected according to several criteria: depending on the areas most often frequented by people looking for great scenery, or by the impact of public perception on the entrance to the town (by road or rail) as follows: at the southeast entrance to the town on DN15, linking Bacau and Piatra Neamt, at the eastern entrance DN15D (Calea Romanului), very common route which allows the access to Iasi.

Cross sections are intended to better illustrate the morphology of the area and are applied to the farthest distance plan.

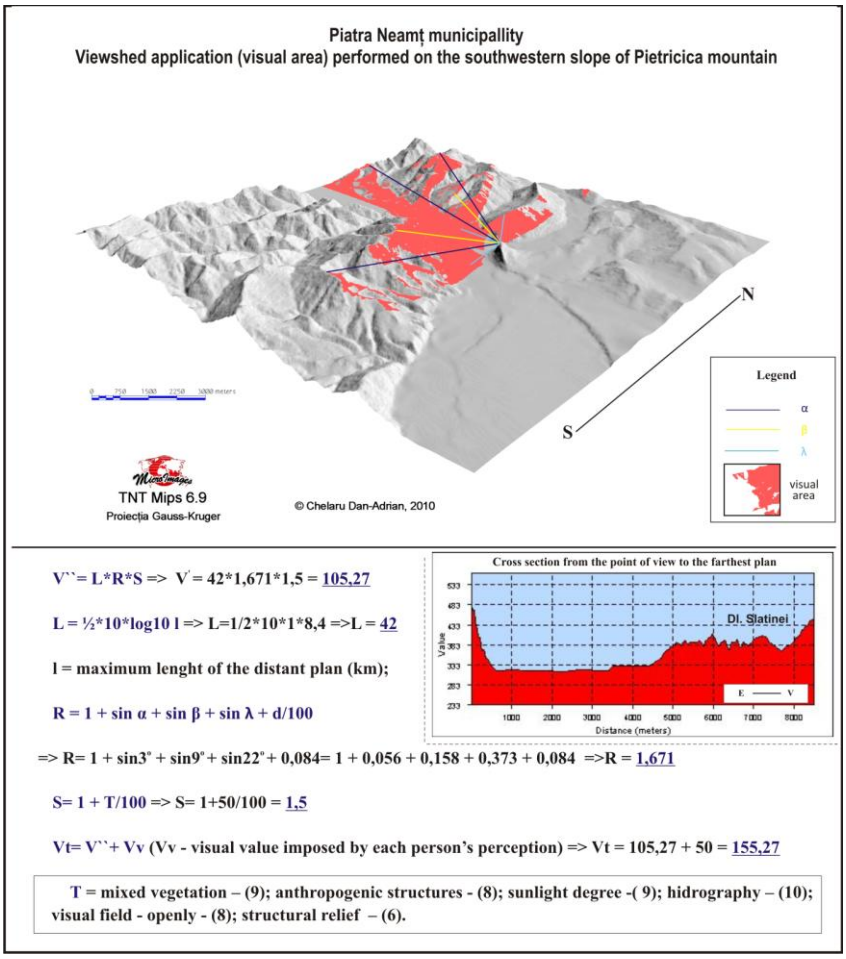

Fig. 2. Viewshed application realised on observation point 1 – SE slope of the Pietricica mountain

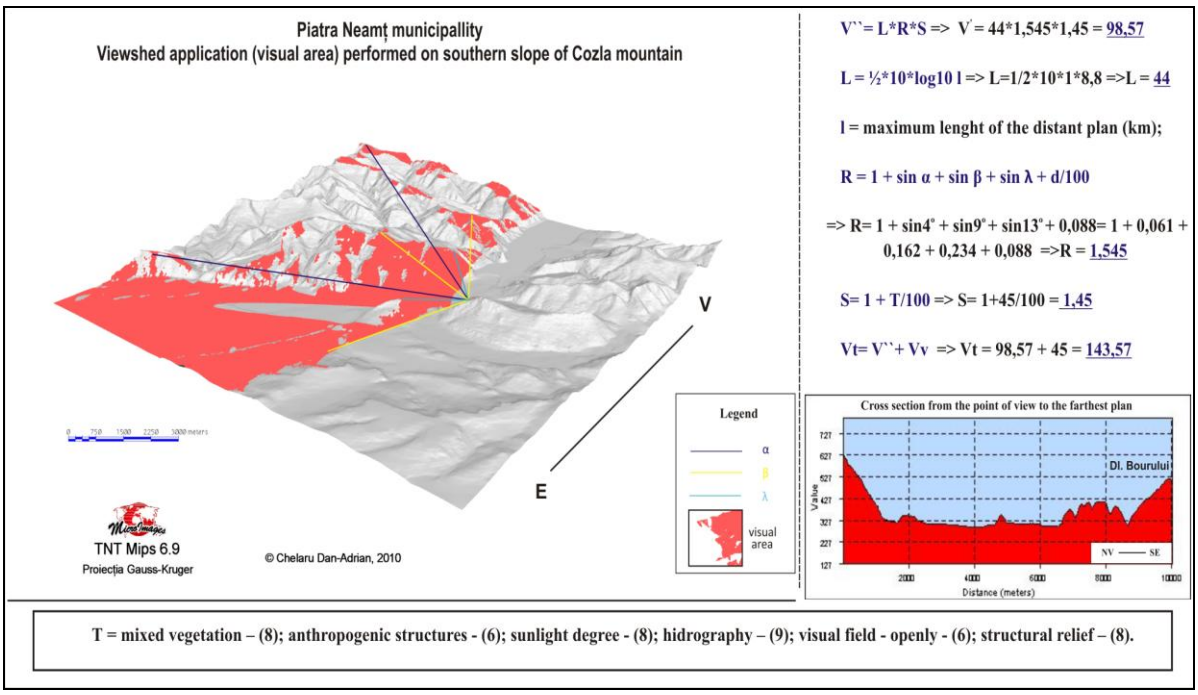

Fig. 3. Viewshed application realised on observation point 2 – southern slope of the Cozla mountain

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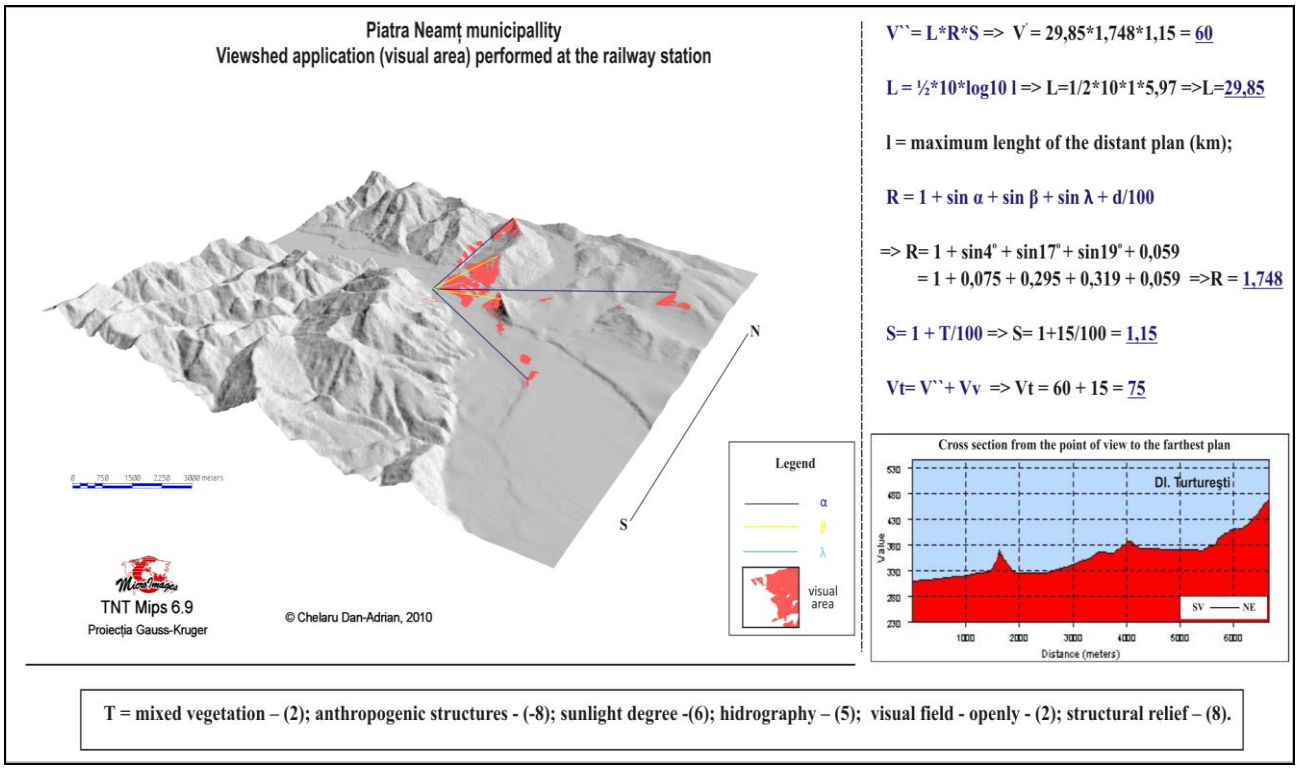

Fig. 4. Viewshed application realised on observation point 3 – The railway station

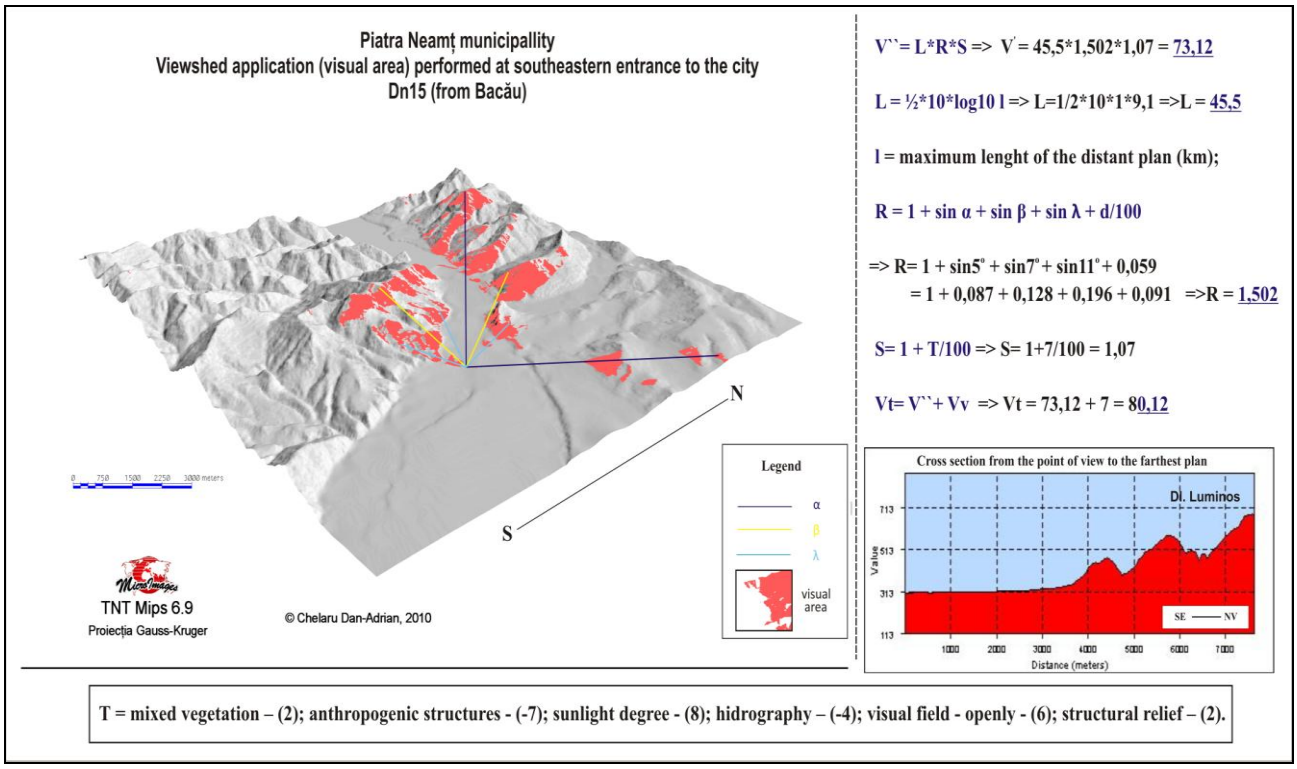

Fig. 5. Viewshed application realised on observation point 4 – DN15 road

(the southeastern town entrance from Bacau)

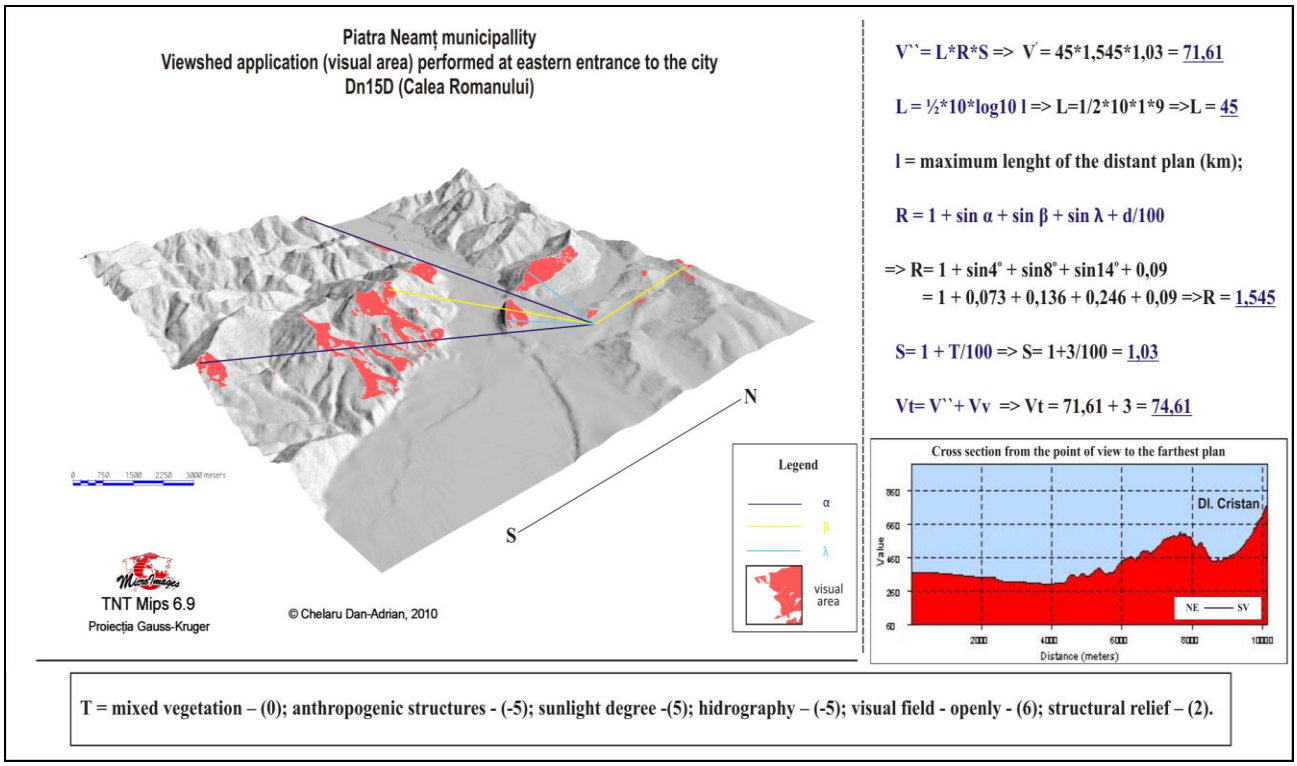

Fig. 6. Viewshed application realised on observation point 2 – DN15D road

(eastern town entrance – Calea Romanului)

The results of the Viewshed analysis of the 5 sites are shown in Fig. 7, from which we can see that the highest landscape valuesare found in the high areas of the town, such as the Cozla and the Pietricica mountains, because of the remarkable view from these points. As expected, the other three points taken into account received lower landscape values, primarily due to lower overall image and thus the less visual impact stressed on the natural and anthropogenic components intercepted by the visual field coverage.

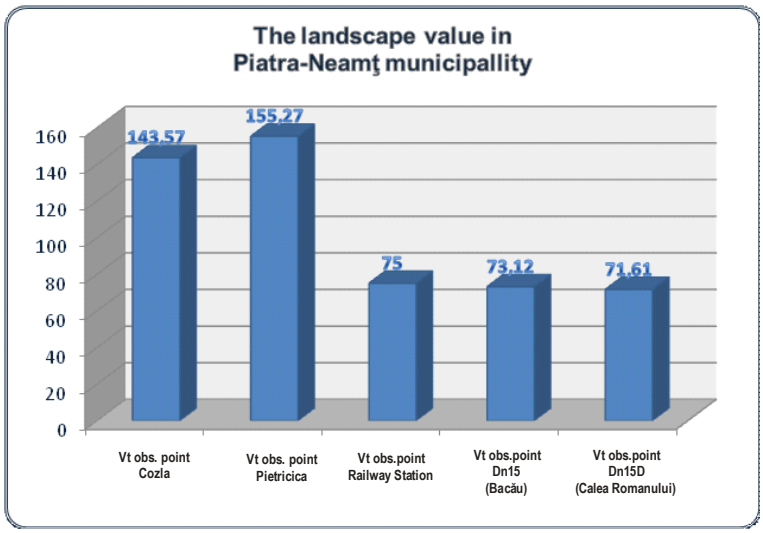

Fig. 7. The landscape values

We can highlight the observation point on Pietricica mountain (Fig. 8), its name being often asociated with the description of Piatra Neamt municipality. The landscape value in this point is maximal being situated in the town center, at a hight of 590 m, which gives it a privileged status, the

perception impact on natural (structural relief, mixed vegetation, hydrography - the Bistrita River, Bâtca Doamnei Lake etc.) and anthropogenic elements being high.

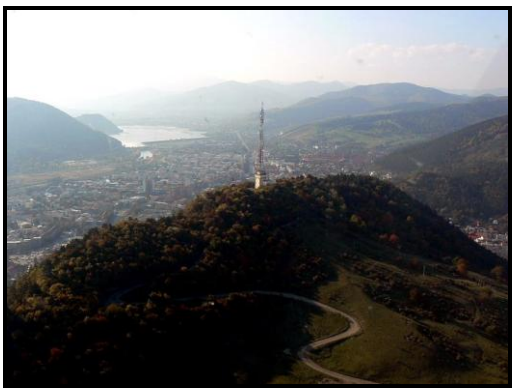

Fig. 8. Selective images of the Pietricica mountain

Conclusions

The framework aims at providing a repeatable and systematic approach in the assessment of landscape visual quality using GIS techniques, which should qualify it as a useful tool in landscape analysis and for the local authorities actions.

Acknowledgements

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Industrial Landscape Expansion and Evolution in Bucharest's District 4

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Abstract

New urban and environment policies were drafted after 1990 for Bucharest as the Romanian capital city adapts from planned to market economy and reintegrates itself into the European community. As these policies are not from the start fully effective or take time to implement, large areas inside the city, corresponding to former industrial parks, enter a long process of decay. Residential development is making a heavy presence both inside and around the city. As a consequence of these phenomena, the urban and **industrial landscape** changes dramatically. The study assesses the industrial landscape evolution over time and space in District 4 of Bucharest using available maps for 1900–2010, GIS and field observation forms. Three distinct periods were delimited: 1900–1945 with incipient industrial activity, 1946–1990 when large industrial parks were developed and 1989 – present time, with deindustrialisation and land use change. Environmental problems related to industrial areas decay need to be addressed as the residential area is expanding and neighbours or replaces former industrial sites.

Keywords: *urban landscape, industrial landscape, industrial platform, residential expansion, Bucharest, Romania*

Rezumat. Expansiunea şi evoluţia peisajului industrial în cadrul sectorului 4 al municipiului Bucureşti

Municipiul Bucureşti, sub impactul noilor politici de după 1990, înregistrează o tranziţie de la o economie de piaţă centralizată la una descentralizată, cu implicaţii numeroase la nivelul tuturor componentelor de mediu. Ca urmare a acestor transformări economice şi politice, peisajul urban, şi în special cel industrial, a înregistrat un evident recul structural şi funcţional. Analiza întreprinsă de noi are drept scop evaluarea dinamicii spaţio-temporale a ***peisajului industrial*** din cadrul sectorului 4 al municipiului Bucureşti, pornind de la hărţile istorice disponibile pentru perioada 1900-2010. Cercetările întreprinse cu ajutorul metodelor şi tehnicilor G.I.S. la care se adaugă completarea fişelor de observaţie, reflectă la nivelul anilor 1900-2010 existenţa a trei perioade distincte: 1900-1945, cu un peisaj industrial incipient, 1945-1989, cu un peisaj industrial de tip platformă (Progresu, Berceni, IMGB etc.), şi 1989 - prezent. După 1989, destructurarea unor întreprinderi şi în mod deosebit a platformelor industriale a condus la fragmentarea până la dispariţie a peisajului industrial. Remanenţa problemelor de mediu, amplificarea lor în raport cu schimbarea funcţiilor unor cartiere şi extinderea necontrolată a rezidenţialului, sunt doar câteva aspecte care ar trebui să se constituie în priorităţi ale programelor de dezvoltare urbană la nivelul sectorului 4 al municipiului Bucureşti.

Cuvinte-cheie: *peisaj urban, peisaj industrial, platformă industrială, expansiune rezidenţială, Bucureşti, România*

Introduction

Bucharest was before 1989 the single most important industrial centre in Romania, surpassing by far every other town. The industrialisation process, started around 1877 and continued with significant stages marked by the years 1912, 1936, 1952 and 1965, generated large industrial areas and a new type of landscape – ***industrial landscape***.

The concept of ***industrial landscape*** evolved over the years but kept as the underlying notion the relation with the activity that generated it. Before 1989, the industrial landscape was considered in a functionalist view as the space for industrial production (Herbst C., 1971; Herbst C. et. al., 1997 etc.). Today, the industrial landscape is seen as an important land cover and a resource in the urban environments, a target for the urban rehabilitation projects and also container of historical memory (Pătroescu M., Popescu C., 1994, Popescu C. et. al., 1997, Cândea M. et. al., 2001, 2006, Marc, A., 2005, Fontana G.L., 1997 Fontana G.L. et al, 2005, Cepoiu Al., 2008, Dincă C., 2008, Chelcea L., 2008, Nae M., Turnock D., 2011, Toledo Declaration, 2010 etc.).

The year 1989, critical for the industrial landscape, marks the beginning of an era with radical changes throughout the entire urban environment of Bucharest. Switching from a centralised to a market economy meant profound economic, social and environmental changes. During the communist era, there were created very large industrial areas, mostly by expanding former smaller ones. The size was economically justified as the market for their products was sustained by state demand. These industrial areas were in fact true "inner cities", having all the necessary endowments for the employees and their families: medical units, food serving facilities, recreational spaces, sport courts, kindergartens etc. Also, housing was provided nearby in cheap, fast to build and large capacity buildings. After 1989, the industrial areas underwent important changes (personnel layoffs and downsizing, privatization, retrocession) and in time were completely modified to serve other uses, mostly logistics and commerce.

Every important change in the political and economic background can be acknowledged in the urban landscape as these changes determine transformations of function and physiognomy in the concerned areas. The former industrial units are still present in the city through the specific architecture and elements that relate to their functions. Some of these industrial units were given a new purpose and were rehabilitated/ restored, but most of them went into an uncontrolled process of degradation. After the continuous increase of the industrial surface inside the city, we can observe nowadays a reduction of these areas and of the landscape associated with them. As this process is not perceived, studied and managed, some industrial units representative from historical, architectural, technical perspectives are in danger of being destroyed. In Bucharest's District 4 such units are Bucharest Slaughterhouse (1870), Gr. Alexandrescu Tannery (1885, in the communist era Bourul or Dâmbovița Company), Filaret Power Plant (1908), Arta Grafică (1921) or IMGB (Bucharest Heavy Machinery Enterprise, 1963).

The relict industrial areas are a consequence of the present economic conditions and of the stricter environmental standards imposed after Romania joined the E.U. in 2007, leading to the decline of the industrial activity, but this should not mean complete abandonment and destruction of the industrial artefacts, some containing important elements of local identity. The abandonment is not a durable solution and leads to further environmental problems (remnant pollution, uncontrolled waste deposits, inefficient land use), social problems (insecurity due to proximity to residential neighbourhoods, "sick buildings" phenomenon) and economic problems (unused spaces, unprofitable industrial units, poor productivity, incompliance with the environmental and sanitary regulations).

All these issues require intelligent solutions based on the principles of sustainable and comprehensive urban development in order to achieve eco-efficiency, social cohesion and improved quality of life. Adequate industrial conversion has to be the premise for sustainable urban regeneration, meeting three of Toledo Declaration's principles (Toledo Declaration, 2010). Land recycling must be implemented to prevent unnecessary transformation of natural and green areas into built environment and to conserve the existing natural capital. In this respect, the European Union has numerous successful examples.

The study aims at a spatial and temporal analysis of the industrial landscape dynamics in Bucharest's District 4, based on historical city maps, but it also makes an inventory of the industrial units in order to highlight examples and features of industrial conversion.

Study area

District 4 is situated in the south of Bucharest municipality, with District 3 as neighbour at north and east, District 5 at west and Ilfov County at south (Fig. 1). According to Decree no. 284 / July 31, 1979, District 4 is bounded by Splaiul Unirii Boulevard in the north, north-east and east, by the City's Ring

Road in the south and by Giurgiu Boulevard in the west. Bucharest's District 4 has a surface of **3400 ha** (14% of Bucharest's surface) and concentrates **15.4%** of Bucharest's population (Bucharest Statistical Yearbook, 2009).

Bucharest urban landscape underwent important aesthetic and functional transformations in his existence. Before 1840, the city displayed a well delimited central area, with complex functions (administrative, handcraft, commercial, residential) surrounded by a peripheral area, predominantly residential (Majuru, A., 2003). The first industrial areas in District 4 went into existence in the interwar period: along the Dâmbovița River, outlined in 1866-1900, and the Filaret Hill area appearing in 1867-1883, serviced by the Filaret Train Station, the first station built in Bucharest (1869) (Fig. 1).

Around 1920, Bucharest presented a more complex central area (administrative, handcraft and commercial and cultural), a predominantly residential intermediate area and a residential, industrial and agricultural peripheral area.

In the next period, after 1920, the industry became an important economic activity and the industry covered urban space increases, especially in the intermediate area and the peripheral area. The process is accompanied by the extension of residential neighbourhoods and associated services, population and inhabitant's density growth and increased demand of electricity and water. All these were further reflected into the environment quality and urban landscape physiognomy (Fig. 1).

The most profound changes took place in 1950-1989, including: large increase of industrial areas surface (with 66.22% in a period of 12 years – 1977-1989), "bedroom communities" construction, with collective dwellings (mostly 7, 10, up to 12 floors – Berceni, Giurgiu, Apărătorii Patriei, Olteniţei), environment degradation through the increasing presence of pollutant industrial sources and activity (Fig. 1).

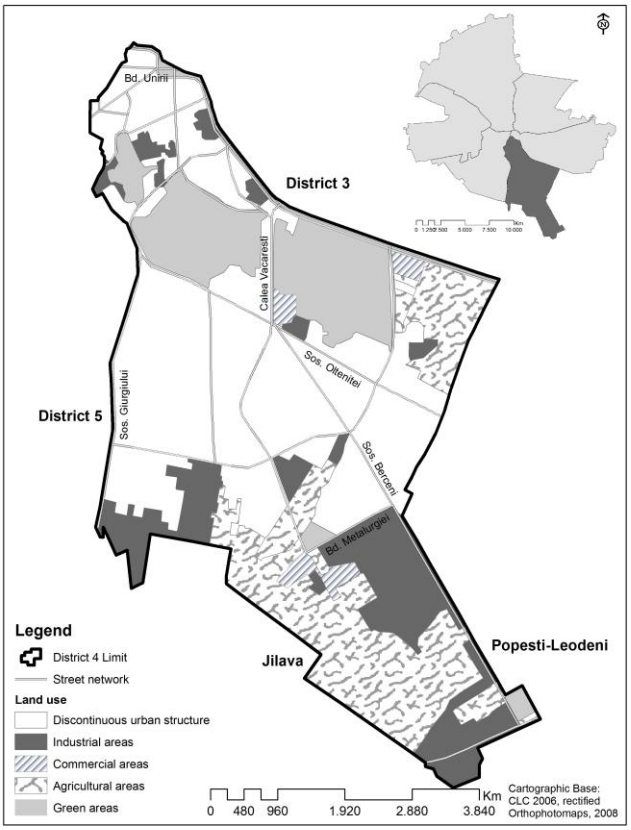

Fig. 1: Location of the study area inside Bucharest and urban landscape

The historical maps analysis for the period 1842-2010 shows that District 4 developed to the south of Bucharest's historical centre, incorporating old neighbourhoods and villages located on Cotroceni Field – Berceni (Dincă, C., 2008). Its territorial expansion was done simultaneously with the population growth and development of agricultural and commercial and crafting activities, later adding industry.

The year 1989 marked the beginning of an era of restructuring, reorganization and conversion of industrial units, and also the development of new real estate projects in the southern and south-eastern part of the District.

Given the industrialisation polices and their effects, one can distinguish four stages of evolution, corresponding to four industrial landscape types:

- ***Artisanry and manufacturing production stage or paleo – industrial stage*** (Mirea D., 2011), an "ancient industrial stage", characterized by handcraft and manufacturing workshops, located in the city centre and along the axis formed by the Dâmbovița River, having a small number of workers. The first factories appeared due to public utility improvements and policies pushing towards industrial development,

ensuring transition to the further industrialisation stage (*E. Wolff Workshop, Gr. Alexandrescu Tannery, C. Costamagna Tannery, Bags Factory etc.*).

- ***Capitalist industrialization stage*** meant the development of the existing industrial units and new units opening. From this period we must emphasize the following industrial units within District 4: *Hestper Enterprise (former E. Wolff Workshop), Dâmboviţa Enterprise (Gr. Alexandrescu Tannery), Cotton Enterprise, Adesgo Enterprise, Filaret Power Plant etc*.
- ***Modern industrialization stage (1945-1989)***, when typical industrial landscape is generated under the impact of industrialisation policies during the socialist period. Following the "city within a city" model and directly correlated to the development of new residential spaces, the industrial surface increases and Bucharest becomes an important industrial centre and a major labour polarizing point. The industrial landscape is clearly outlined and delimited in the urban tissue and several subtypes are to be distinguished depending on activity. For example, in District 4 there had been developed the following industrial platforms: *Berceni, Progresuand IMGB*.
- ***Post-industrialization stage*** (after 1989) is directly correlated with international trends (lifestyle change, economic restructuring, globalization), economic and real estate crisis, new standards of environmental, urban planning and heritage legislation (Mirea D., 2011). The typical industrial landscape before 1989 becomes a landscape in transformation afterwards, having different functions and physiognomies. Basically, we are witnessing today unprecedented changes in the urban environment, requiring detailed research and planning for medium and long term, in accordance with the principles of sustainable development and heritage elements conservation.

As a result of these industrialisation stages, District 4 had a maximum industrial area of **451.3 ha** in 1989, reduced today to **374.5 ha**. There can be outlined 7 industrial areas, heterogeneous in terms of activity – *Filaret Area* (1868 - 1920), the *Dâmboviţa River axis* (1850 - 1870), *Olteniţa Area* (1950 - 1960), *Progresul Area* (1950 - 1980), *IMGB Area* (1960), *Berceni Area* (1960) and *Apărătorii Patriei Area* (1960 - 1970)

Methodology

Landscape is defined as "*a territory portion as perceived by man and whose characteristics are resulting from the action and interaction of natural and / or human factors*" (451/2002 Law) and can be analysed and reconstructed through the retrospective mapping method.

Retrospective mapping method involves the use of maps from different periods of time, preferably at the same scale in order to observe the evolution in time of an item, a phenomenon or of the overall landscape. This is a highly useful method in the landscape analyses, but there must be taken into account the errors caused by: different scale representation and design techniques, different representation elements techniques, item generalization, interpretation errors.

For the analysis of District 4, **16** cartographic and photogrammetric representations were chosen, relevant in terms of representation and industrial landscape transformation, respectively: Borroczyn City Plan – 1852; Southern Romania Map – 1864; D. Pappasoglu City Plans – 1871-1875; Cerkez City Plan – 1890; Delattre City Plan – 1893; Bucharest City Map – 1898; Bucharest City Map – 1900; Bucharest City Map – 1911; Bucharest City Map – 1914; Bucharest City Map – 1923; Bucharest Municipality Map – 1947; Cadastral Plans – 1975-1990; Topographic Maps – 1977-1978; General Urban Plan – 2001; Orthophotomaps – 2008 and Bucharest City Map – 2010.

District 4 industrial landscape dynamics was surveyed over **158** years, respectively for the period 1852 – 2010, using these documents and GIS techniques. The industrial landscape dynamics represents an indicator of socio-economic development, economic system changing, new production techniques insertion, post-communist involution of industrial platforms and activity profile change.

Historical maps analysis was completed by conducting inventory data sheets for each industrial unit, with a total of **40** data sheets. The observation sheet includes 8 sections (location, industrial unit description, identification data, historical landmarks, industrial landscape description, conservation status, industrial landscape,

environment state) and is accompanied by graphics and maps from different historical periods.

Discussions

Analysing the historical maps available for the period 1850 - 1880, three functional areas of the District's initial landscape were observed: the centre, with mixed activities (commercial, administrative, cultural, residential, crafting) and the old neighbourhood type periphery (Majuru, 2003), predominantly residential, accompanied by large vegetables and wine plantations serving the Capital. Following the model described above, the first statistically mentioned industrial units were concentrated in the central area (Unirii Area – Bakery A. Müller - 1850, Meat and sausage factory I. Abele – 1862, Sparkling water factory C. Porumbaru – 1868, Bags factory S. Schwarz – 1883). All these are units servicing the Capital's needs (predominantly food factories) and they generated a landscape with craft and manufacturing workshops. Because of their reduced size, they were not represented on the city plans of that time. In order to cartographically represent the industrial units of that period on the present District 4 territory (Fig. 2) and show the pre-war industrial landscape ("ancient industrial stage", before 1918), the Industrial Investigation of 1901-1902 was relevant.

For the period 1901-1902, Bucharest District 4 had twenty industrial units, heterogeneous in terms of production (food industry – 2 units, alcoholic and soft drinks industry – 1 unit, textile industry – 1 unit, footwear and leather products industry – 7 units etc.).

The map analysis outlines three industrial areas (Fig. 2), respectively:

- **Unirii Area** – various industrial units (Sparkling water factory, C. Porumbaru – 1868, Church Printings (Typography) – 1882, Buttons factory M. Efraim -1895, Agricultural machinery repairing shop, S. H. Brandwein – 1898), relocated later due to the centre's functions conversion (the city centre achieved predominantly administrative and commercial functions).
- **Filaret Area** – outlined in 1868-1900; it concentrates four industrial units specialized in metal industry (three units, Ironworks E. Wolff – 1883, Cometul Factory, A. Solomon – 1887, La metallurgie roumaine - 1898) and energy industry (one unit, Filaret Gas Factory – 1868, later Filaret Power plant - 1908).

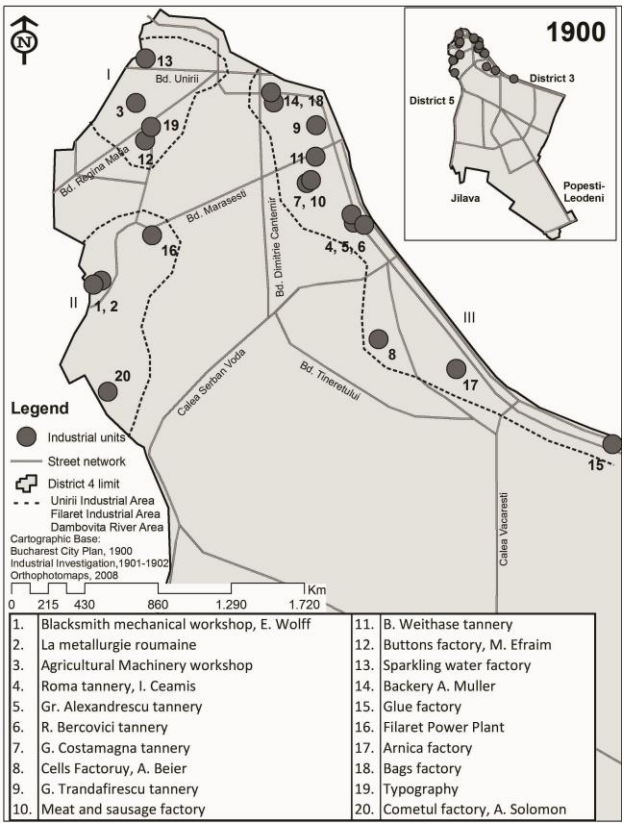

Fig. 2: Industrial landscape location and extension in District 4 - 1900

- **The Dâmboviţa River Area** – developed along the river axis, concentrated twelve industrial units, various in terms of activity. The area was characterised by tanneries presence and their specific industrial landscape, as given the concentration of a great number of units specialised in footwear and leather products industry (Roma tannery, I. Ceamis, Gr. Alexandrescu tannery, R. Bercovici tannery, G. Costamagna tannery, G. Trandafirescu tannery etc.).

In terms of mapping, most industrial units were not represented on the city plans, probably due to the reduced occupied surface and low level detail of the achieved plans. However, some industrial units, perhaps considered of public utility, are mentioned on the city plans beginning with 1871 - 1875 (Pappasoglu City Plan, 1871-1875, Cerckez City Plan, 1890, Delattre City Plan, 1893, Bucharest City Plan, 1898), as it is the case of Filaret Gas Factory and Bucharest Slaughterhouse units.

Analysing the industrial units location correlated with their specific activity and thecity administrative limit at that time, one can observe the

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peripheral location of pollutant units (Ironworks E. Wolff, Cometul Factory, A. Solomon, La metallurgie roumaine, Filaret Gas Factory and Bucharest Slaughterhouse). These units were also dependent on the railway transport (metal industry), water and land resources (food industry - Bucharest Slaughterhouse).

In terms of building appearance, there is a great concern for details and building appearance as observed for the industrial units preserved from that period: Hesper Factory, Bourul Factory (Gr. Alexandrescu tannery), Filaret Power Plant, Bucharest Slaughterhouse.

Beginning with 1911, in order to complete the "ancient industrial stage" description (Fig. 3), there were added quantitative data to qualitative data obtained through historical and cartographic materials analysis. Based on the 1911 City Plan and using GIS techniques, there resulted that the industrial surface covered 15.5 ha, representing 0.45% of the present District 4 surface. The determined surface figure is relative because of the plan's cartographic representation technique. The city plan detail level is low, as there are represented only 6 out of 20 industrial units identified during the Industrial Investigation 1901-1902 (Fig. 3).

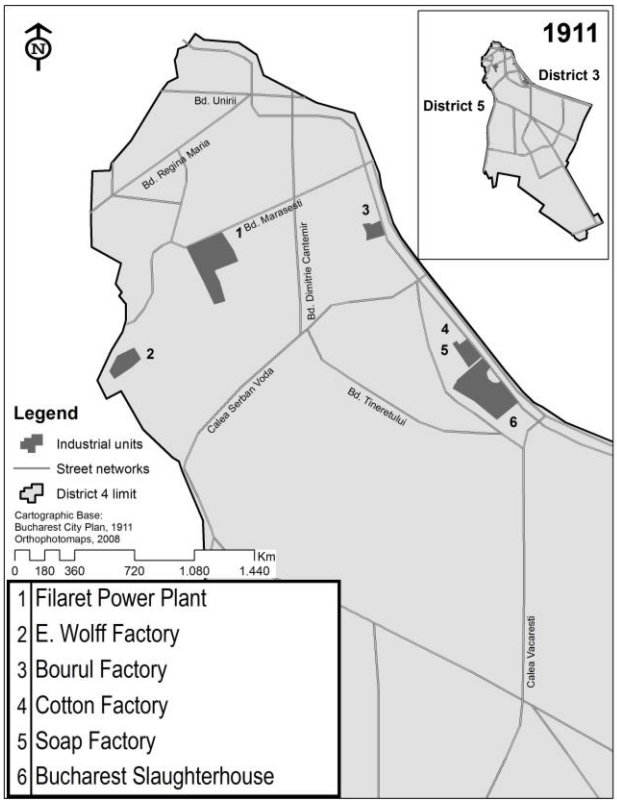

Fig. 3: Industrial landscape location and extension in District 4 - 1911

Industrial units mapped on the 1911 City Plan are representative units of that time and for the entire Bucharest industry and real urban landmarks. These are: Filaret Power Plant, Bucharest's second power plant, after Grozăveşti Power Plant, E. Wolff Factory, Bourul Leather Company, industrial unit achieved by merging three tanneries (Gr. Alexandrescu, Roma, I. Ceamis and R. Bercovici tanneries), Cotton factory, Soap factory and Bucharest Slaughterhouse. As a consequence of the policies destined to encourage the industrial activity, all industrial units were reorganized, enlarged and modernized, making them locally and regionally competitive.

The city Plan of 1923 brings out 11 industrial units (Figure 4) with a total area of 17.1 ha, with 1.6 ha more than their surface based on 1911 City Plan.

Apart from the industrial units mapped on 1911 City Plan, except the Soap Factory (no information anymore), the following units are represented (Fig. 4): Weith Leather company, later annexed to Bourul unit, T. Sapat Leather company, Wool store, Iron grinding tools factory, Buttons Factory (mapped for the first time on this plan, but mentioned since 1901-1902) and C. Gzell Acid factory, also a unit mapped for the first time on this plan, but there is poor information about it.

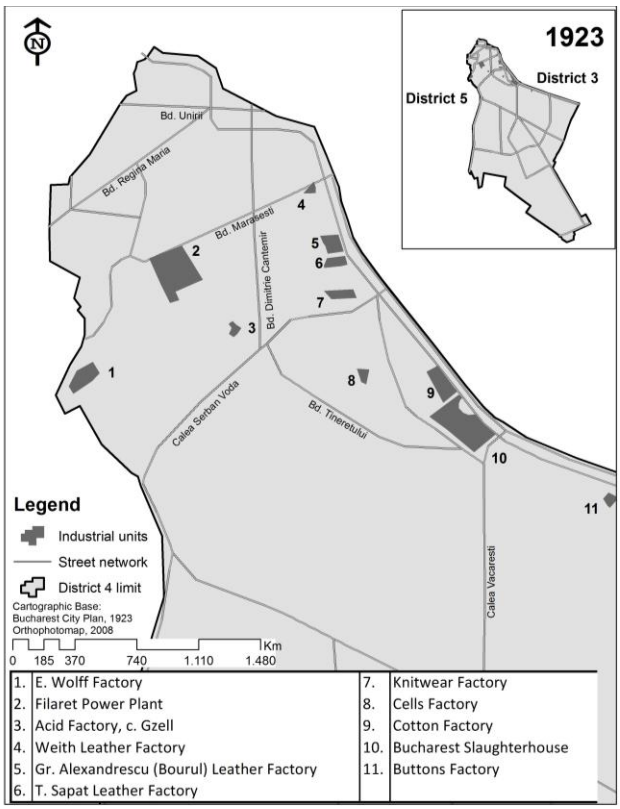

Fig. 4: Industrial landscape location and extension in District 4 - 1923

In terms of the industrial landscape, this stage represents a radical transformation of units and of the overall urban landscape. Based on Bucharest's strengthened political, administrative and economic position after 1918, the city area and inhabitants, number considerable growth and especially on industrialisation policies, old industrial units are developed by merging and reorganizing small units. The industrial landscape takes shape and can be easily outlined due to specific industrial artefacts. At the end of this inter-war industrialisation stage, Bucharest represents a labour attraction pole and an industrialized city, heterogeneous in terms of productive activities.

The next stage, the post-war stage, is one of accelerated industrialization. District 4 and the rest of the city was highly and rapidly heavily industrialized (Fig.5) under the impact of industrialization policies that sought the nationalization of existing industrial units, increasing the industry occupied area, establishment of new units, reorganization of existing ones and growth of productive capacity. The industry occupied area, identified on 1977 city plans, represented 152.4 ha, hence 4.48% of the present District surface, accounting for a 135.3 ha growth of this land use type compared to the previous period (Fig. 5).

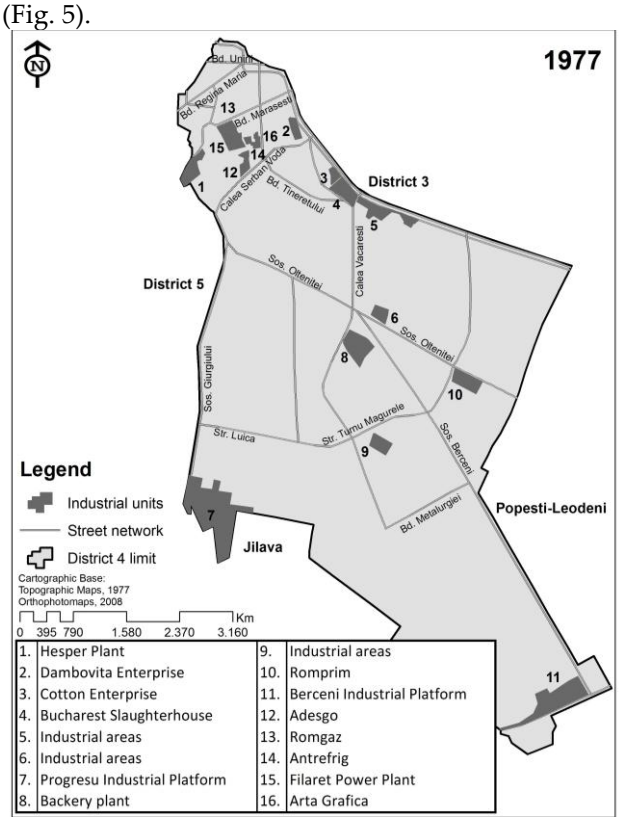

Fig. 5: Industrial landscape location and extension in District 4 - 1977

The Post-war stage represents a period of industrial landscape radical changes, small industrial units being replaced with "industrial giants" and large industrial areas. The new industrial unit was designed so that the employees could take advantage of all facilities (dispensary, dining room, kindergarten, vocational school or college to prepare personnel). Workers were also provided housing, making Bucharest a great labour attraction pole and determining great urbanization and inhabitants' growth. The decision to build Progresul, Berceni and later IMGB industrial platforms determined also the need for "bedroom neighbourhoods" type collective housing (Tineretului, Apărătorii Patriei, Olteniței, Berceni, Constantin Brâncoveanu, Progresul). Increasing residential area meant growth of population needs for food and energy, so there Berceni Bread Factory and Progresul Thermal Power Plant were founded.

As a result of the industrialisation policies, the industry occupied area is at its maximum level in 1989 (Fig. 6), just before the communist regime fall.

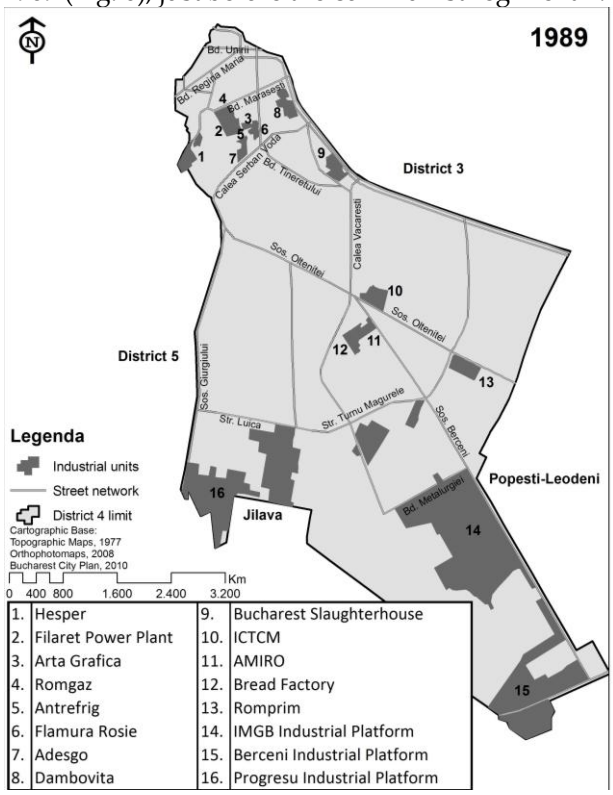

Fig. 6: Industrial landscape location and extension in District 4 - 1989

So, the industry occupies 451.3 ha, with 298.9 ha more than in 1977 and representing 13.27 % of the present District 4 surface. For this period, Graphic art industrial unit (Arta Grafică) occupied the smallest area (1 ha) and the largest one was IMGB

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Industrial Platform. The three platforms developed in District 4 had a total area 363.6 ha (IMGB - 168.6 ha, Progresul - 104.6 ha, Berceni - 90.3 ha), representing three industrial giants that concentrated a workforce that ranged from 3.000 to 5.000 people and exerted a major impact on the environment.

As said before, 1989 represents the starting point of some intense changes within the industrial and urban landscape. Analyzing the industrial landscape changes in the area of Bucharest District 4, there were established five landscape types that replaced the relict industrial landscape: abandoned / demolished industrial units, ancient industrial (< 1989), new industrial (> 1989), reconversion, specific reconversion, through space rentals (Fig. 7).

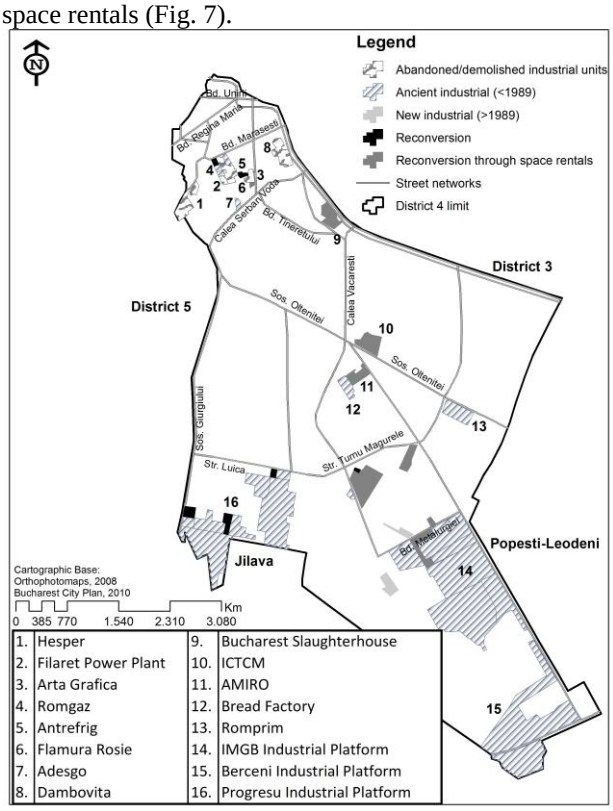

Fig. 7: Type or state of industrial landscape assessed by field research – 2011

The analysis brings out that the ancient industrial units have the highest weight – 80% (Fig. 7), being represented by former industrial sites. These are presently highly destructed, still having productive activities, but at a lower level and with few employees. For example, IMGB Platform has been destructed into nine units starting with 1991 – Strall Techniek Minex, SC UMUC SA, SC General Turbo, FECNE SA etc., and Progresul Industrial Area was shut down, its activity being replaced by five other units.

Specific reconversion took place into most Bucharest industrial units, through space rentals, this type of change accounting for 11% of the total in District 4. A relevant example in this sense is Bucharest Slaughterhouse (1870 - 1872), an industrial plant that needs heritage protection because of its historical, technical and architectural importance. Today it is used as storage and as headquarters for various retailers - this method prevented demolition of the entire unit, but on the long term it contributes to a continuous degradation of buildings.

District 4 abandoned or demolished industrial units represent only 5% of the industry occupied areas, a significantly lower percentage compared to the situation recorded in District 5, where most industrial units are either abandoned or demolished.

District 4 converted industrial units have a low share, only 2%, and are punctually located. This is the case of Arta Grafică, transformed into a services building.

A special feature of District 4 is the appearance of two new industrial units, after 1989, respectively Arta Grafică, relocated from Calea Serban Voda, no. 133 to Metallurgy Blvd., no. 73-75, and Whiteland Logistics Unit (Metallurgy Blvd., no. 132).

Map analysis, 2011, (Fig. 7) reflects that both ancient and new industrial units are concentrated towards the periphery, while abandoned or demolished industrial units and converted units are concentrated in the District central area.

Overall, within the last 158 years, District 4 industrial landscape was in expansion until 1989, with accelerated development of industry occupied area during 1977-1989 (Fig. 5, Fig. 6), and a descending trend afterwards (Fig. 7).

The industrial landscape conversion began slowly in 2005 in District 4 and all around Bucharest. Conversion was mostly industrial to services conversion and industrial to residential conversion.

Conclusion

The industrial landscape dynamics was stressed in accordance with the industrialisation stages, but there was no projection into District 4 housing and population life quality. District 4 industrialisation began in 1850, with the first mentions about industrial units located within this area. Former industrial units were originally developed near the

Dâmboviţa River axis and Filaret Train Station nucleus.

District 4 industrialisation process increased during the inter-war and especially the post-war period, causing a radical landscape transformation and accelerated urbanization. Workshops and small factories of local or regional interest were the typical industrial landscape for the period 1900 – 1944. Industrial activities were heterogeneous, being "free" or induced by a growing city needs. For this period, industrial area had a small expansion of only 5.5 ha.

Industry occupied area increased significantly in 1944-1989, by 434.2 ha. The industrial landscape is characterized by the "*city within a city*" industrial unit model. The existing industrial units are enlarged, while new ones are built, "industrial giants" as IMGB industrial platform, Progresul and Berceni.

Substantial increase of District 4 industry occupied area meant also an accelerated urbanization, causing dense residential neighbourhoods and specific infrastructure. The year 1989 was a critical point for the industrial landscape, as profound changes started and were projected into the urban landscape. Industrial units were privatized, most defectively and later being threatened with abandonment / demolition or special reconversion.

Currently, the industrial areas require application of comprehensive policies leading to intelligent reuse of urban space, as these areas are important land resources in the urban tissue (Toledo Declaration, 2010). Industrial spaces reconversion represents the ideal solution for space reuse in line with Toledo Declaration principles, but it is also important how it is done, especially because the policies pursued by authorities do not have as a priority urban artefacts conservation and industrial heritage preservation.

The present analysis outlined that reconversion is directly dependent on industrial site location and dimensions, adding the pollutant retention issues and its urban image reference character. In this sense, projects must consider all these aspects.

Despite the industrial landscape reconversion positive examples, the reconversion process will be also developed in the future based on demolition actions or former buildings poor reuse, due to lack of specialists and knowledge about the value of these sites.

District 4 industrial landscape is characterised by industrial units such as tanneries, Filaret Power Plant, Wolff Plants (Steaua Roşie or Hesper), Bucharest Slaughterhouse and IMGB Industrial Area. This specific industrial landscape is on a degrading trend and will probably collapse, leaving room to environmental conflicts, enhancing and diversifying land use and housing dysfunctions.

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Land Use Changes in the Bâsca Chiojdului River Basin and the Assessment of their Environmental Impact

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Abstract

The paper aims at analyzing the environmental quality of the Bâsca Chiojdului river basin by calculating a variety of environmental indices: human pressure index through population dynamics, human pressure index through agricultural land use, the naturality index, artificialization index and environmental change index. Choosing a 1 km grid for calculating and comparing these indices at the level of the river basin allows a more concise analysis on the environmental quality. Subsequently, the temporal dynamics of the environmental indices values is highlighted by the 40 years interval used especially in the human factor analysis, and by choosing the year 2005 as reference year. The results, embodied in the values obtained by applying formulas to calculate the environmental indices (human pressure index through agricultural land use - 44.19% agricultural land, the naturality index of the landscape - 50.82%; the artificialization index of the landscape - 2.32%; the environmental change index: Maruszczak version - 33.92; the improved version - 1.09, the completed version - 10.83) present the state of the environment. The proposed measures to stabilize and maintain a good environmental quality in the Bâsca Chiojdului river basin regard mainly the forest ecosystem, because it is the most important factor of maintaining the balance by its protective functionality on the environment.

Keywords: *state of the environment, human pressure, environmental indices, river basin, the Bâsca Chiojdului*

Rezumat. Schimbările modului de utilizare a terenurilor în bazinul hidrografic Bâsca Chiojdului şi evaluarea impactului acestora asupra mediului

Lucrarea îşi propune analizarea calităţii mediului la nivelul bazinului hidrografic Bâsca Chiojdului prin calculul unei varietăţi de indici de mediu: indicele de presiune umană prin dinamica demografică, indicele de presiune umană prin utilizarea terenurilor agricole, indicele de naturalitate, indicele de artificializare şi indicii transformării de mediu (environmentale). Alegerea unui caroiaj de 1 kmp în vederea calculării şi comparării acestor indici la nivel de bazin hidrografic, permite o analiză mult mai concisă asupra calităţii mediului. Ulterior, dinamica temporală a valorilor indicilor de mediu este evidenţiată prin intervalul de 40 de ani ales în analiza a factorului uman, şi prin sectarea anului 2005, ca an de referinţă. Rezultatele, materializate în valorile obţinute în urma aplicării formulelor de calcul ale indicilor de mediu (Indicele de presiune umană prin utilizarea terenurilor agricole - 44,19% suprafeţele agricole; Indicele de naturalitate al peisajului - 50,82%; Indicele de artificializare a peisajului - 2,32%; Indicele transformării de mediu: varianta Maruszczak - 33,92; variantei îmbunătăţită - 1,09; varianta completată - 10,83) redau starea mediului. Măsurile propuse, în vederea stabilizării şi menţinerii calităţii bune a mediului în bazinul hidrografic Bâsca Chiojdului vizează în principal ecosistemul forestier, deoarece prin funcţionalitatea sa protectoare asupra mediului este cel mai important factor de menţinere a echilibrului.

Cuvinte-cheie: *starea mediului, presiune umană, indici de mediu, bazin hidrografic, Bâsca Chiojdului*

Introduction

Human pressure on the environment takes many forms depending on the nature of human activities and the changes in the land use.

To calculate *the human pressure index through the use of agricultural land*, the percentage share that each type of agricultural land has, should be evaluated from the total area of agricultural land in the analyzed space (Dumitraşcu, 2006). *The naturality index* is the ratio of the natural forest area and total area of that space. It is expressed in percentages and its use is absolutely necessary to obtain a correct characterization of the ecological state of the examined river basin (this index actually represents the degree of afforestation).

Given that the value of the naturality index expresses the steady-state of the interrelations at the

level of the landscape, it has been studied in many papers for different geographic regions such as the Sub-Carpathian sector of the Prahova Valley (Armaş et al., 2003), Mostiştei Plain (Apostol, 2004), Oltenia Plain (Dumitraşcu, 2006), The Sub-Carpathians between Buzău and Râmnicu Sărat (Nicholas, 2011), Bălăciţei Piedmont (Ionuş et al., 2011).

Environmental change index can be calculated by various formulas depending on the characteristics of the Bâsca Chiojdului river basin.

The environmental change index was first introduced by Maruszczak in Poland in 1988 and then taken by Malgorzata Pietrzak in 1998, to assess human impact on the Sub-Carpathian landscape from Poland (Armaş et al., 2003). In Romania, it was applied for the Sub-Carpathian sector of the Prahova valley (Armaş et al., 2003), the Iron Gates Natural Park (Manea, 2003), Bărăganului Plain (Panait, 2010) and Bălăciţei Piedmont (Ionuş et al., 2011).

Study area

The Bâsca Chiojdului river basin is part (sub-basin) of the Buzău river basin. It has a total area of 340.29 km², the collector river has a total length of 42 km and an annual average flow of 1.20 m³/s at the Chiojdului hydrometric station, respectively of 2.65 m³/s where it flows into the Buzău river.

It is located within the Curvature Carpathian and Sub-Carpathians territory, and from the administrative point of view, it is equally located within the Buzău and Prahova counties (Zarea and Gheorghe, 2010). Six administrative units (Chiojdului, Cătina, Calvin and Cislău, Starchiojd and Poseşti localities) were analyzed in the study.

The total population of the basin was of 24,684 inhabitants in 1970, then increasing to 25,789 in 1975, when there was registred the maximum number of inhabitants in the whole analyzed period. After 1975, a continuous and constant decrease of population was recorded, leading to 23, 133 inhabitants in 1990; 22,226 in 2000, and 21,064 inhabitants in 2010 (Fig. 1).

The average population density of the basin was of 72.54 inhabitants/km² in 1970. It has increased in the first 5 years, reaching the maximum value of 75.79 inhabitants/km² in 1975, then began to decline, reaching 72.64 inhabitants/km² in 1980; 67.98 inhabitants/km² in 1990; 65.31 inhabitants/km² in 2000, and respectively 61.90% inhabitants/km² in 2010 (Fig. 1).

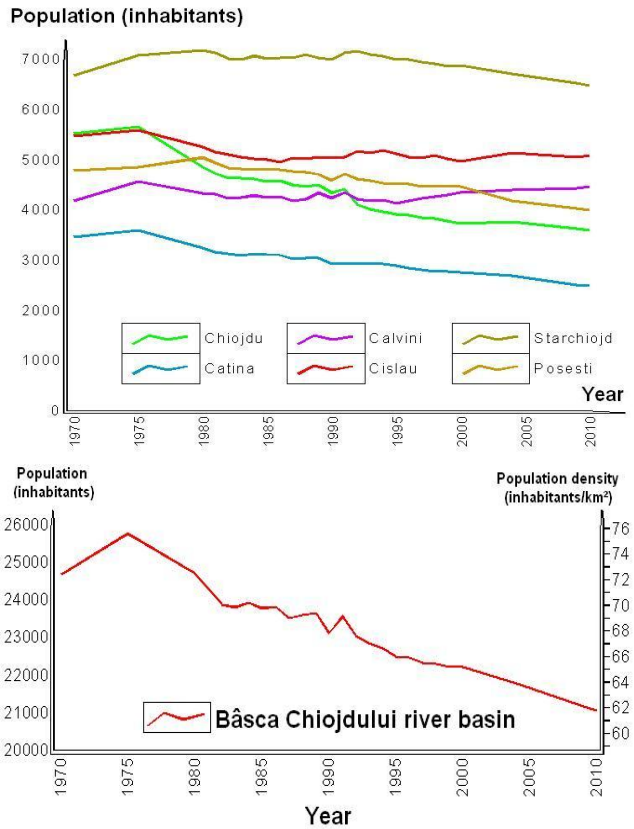

Fig. 1: The demographic dynamics within the Bâsca Chiojdului river basin in 1970-2010: number of inhabitants and the population density; number of inhabitants

In the analyzed period, 1970-2010, a general trend of population decreasing was recorded in the entire basin. The basic explanation is the migration of the population from this area to big cities (Buzău, Ploieşti and Bucharest), but also to smaller nearby towns (Pătârlagele or Vălenii de Munte). This became obvious since 1975 and continued at lower level after 1990.

A second cause of the general trend of population decline is the reduction of the birth rate, a phenomenon seen after 1990. Also after 1990 the increase of reverse migration was recorded (from towns to these villages), and that is why after 2000 and especially after 2005 we notice a reduction in the rate of inhabitants decrease, recording even a demographic increase in some localities.

The elements that define a particular type of environment differ depending on the degree of human impact on the landscapes. Thus, in the mountain area, the human impact is lower, the defining components of a particular type of environment are the relief, some climate elements or the plant communities. However in the Sub-

Carpathian area, with much higher degree of human intervention, the environmental values are expressed through the land use (Armaş et al., 2003).

The inventoried landscapes in the Bâsca Chiojdului river basin frame in four of the five defined classes using the Corine Land Cover (2006) (Fig. 2):

- artificial surface class
- agricultural areas class
- forests or semi-natural class
- aquatic organisms class

The artificial surfaces class corresponds to the most human influenced landscape types and includes three categories (the built area - urban discontinuous structure, lines of communication - transport units and industrial units). They occupy a total area of 7.91 km², which means 2.32% of the total area of the basin. The impact of these surfaces on the environment is negative, they are directly responsible for the artificial landscape.

The agricultural areas class includes several categories, such as: arable land (irrigated or non-irrigated), orchards of fruit trees and shrubs plantations of berries, vineyards, meadows, pastures and hayfields. This class includes human modified landscapes, but more environmentally friendly than the artificial surfaces (orchards especially).

The agricultural areas occupy a large percentage of the total area of the basin (44.19%), which represent 150.34 km². Under these conditions, their impact on the environment quality is significant in the basin. There are obviously differences between how different types of agricultural land affect the environment (the comparison between a pasture affected by overgrazing and a mature and dense orchard is significant).

The forests and semi-natural class consists of two broad categories (forests and areas with poor vegetation, major river beds or degraded lands). Given the very different impact on the environment, the two categories of land use will be considered separately.

Forests cover a little more than half of the total river basin (172.84 km², which means 50.79% of it). In 2005, forests were far from being uniform, the differences were significant because of tree species and tree age, size and density.

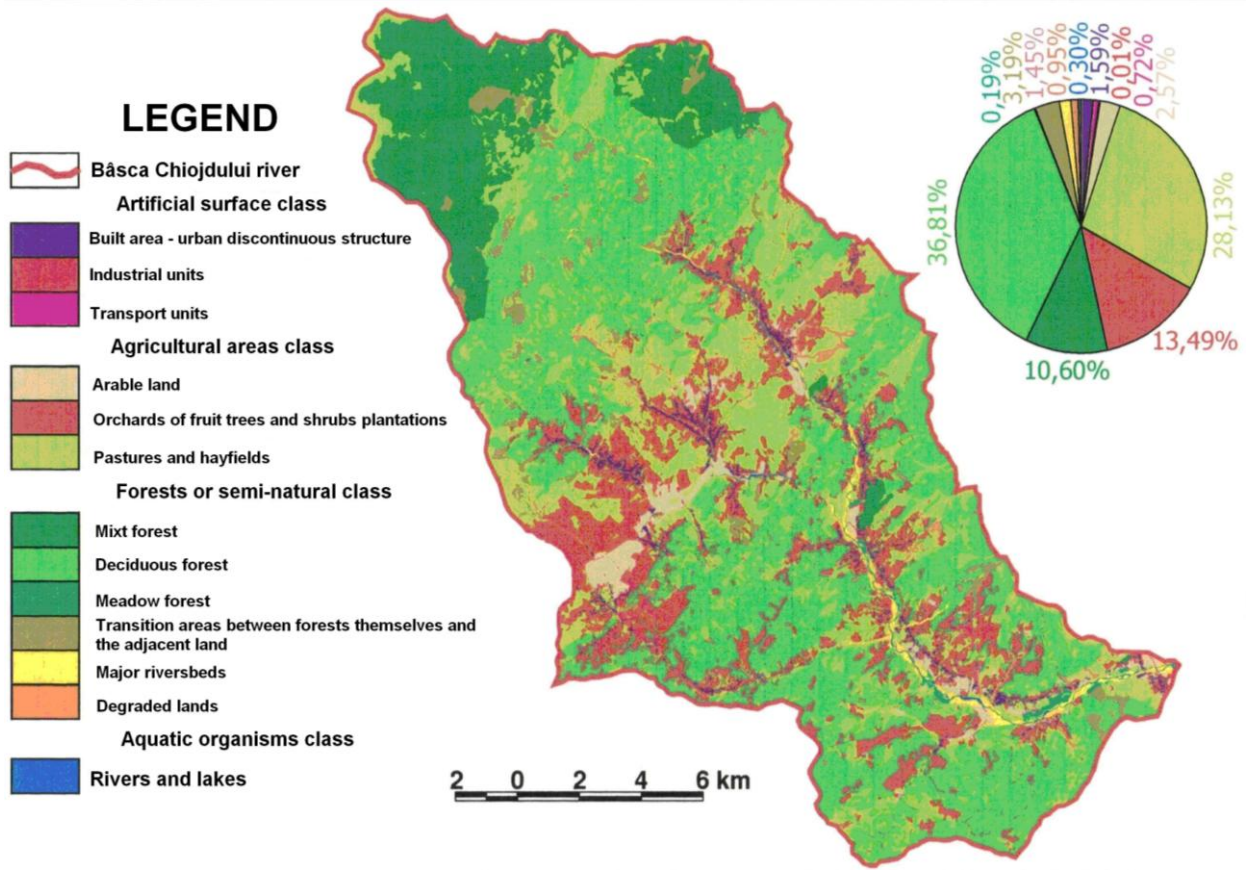

Fig. 2: Spatial dynamics of land use in the Bâsca Chiojdului river basin in 2005

Four main types of forest areas can be identified in the river basin (mixed forest, deciduous forest,

meadow forests and transition areas between forests themselves and the adjacent land - orchards, hayfields and pastures).

Areas with poor vegetation or no vegetation at all are of two types: major rivers beds and degraded lands. Although they are in a certain degree of natural origin, their impact upon environment is largely negative. For this reason, the classification of these types of surfaces within the same class as forests in literature and in Corine Land Cover classification system is forced and irrelevant when the environmental factors are characterized. Although they occupy a relatively small share in the river basin (8.15 km², that is 2.40%), their negative impact on the environment is significant.

The degraded lands largely correspond to the geomorphologic phenomena (of slope or valley). These occupy 3.22 km² (39.60% of all areas with low-vegetation coverage, which means 0.95% of the total basin). An even larger area (1.42% from the entire basin) is covered by rocks with high susceptibility to erosion (Rădoane, 2004).

The class of aquatic organisms is represented in an overwhelming percentage by streams and in a very limited extent by lakes in the Bâsca Chiojdului river basin. The aquatic organisms occupied an area of 1.04 km² in 2005, which means 0.30% of the whole basin.

Data and methods

For the calculation of environmental indices it is necessary in the first stage to use the map with the land use, using Corine Land Cover, adapted to the characteristics and the dimensions of the analyzed basin. Because of the relatively small size of the river basin, the map with the land use was done by digitizing (vectorization) on orthophotomaps made in 2005 and geo-referenced in the national projection-Stereo 70.

Although the values of the environmental indices are calculated at the level of administrative units in the literature, due to the relatively reduced size of the Bâsca Chiojduluii basin, these will be calculated for each area of 1km² of it, based on a grid made in accordance with the Stereo-70 national projection. This working methodology will allow capturing precisely the sectors with the biggest environmental problems, the paper proposing also solutions to improve its quality in the future.

Environmental change index can be calculated by various formulas depending on the characteristics of the Bâsca Chiojdului river basin.

Improved version

Armaş et al. in 2003 (for the Sub-Carpathian sector of the Prahova Valley), Manea, 2003 (for the Iron Gates Natural Park) or Panait in 2010 (for the Bărăgan Plain) have applied a new formula for calculating the environmental change index: Eci = S forest/ S (agricultural + built area). Arable lands and pastures, meadows, hayfields and orchards are included in the "agricultural area" category.

Completed version

In this case, for the Bâsca Chiojdului river basin, there is proposed also the applying of the following formula of the environmental change index (similar formulas are applied also to the natural reservations "Les Hauts of Chartreuse (French Alps)" and "Lăpuşna resonance spruce" (Central Group of Eastern Carpathians) (Băltescu, 2009) or to the Bărăganului Plain (Panait, 2010): Eci = S (forests +acquatic area)/S (built area + areas with poor vegetation).

Both the forest areas and the aquatic ones play a positive role regarding the environmental quality, while the areas with poor vegetation (degraded land or major river beds), respectively the built surfaces, the industrial ones and the lines of communication play a negative role. Being considered "neutral elements" in characterizing the ecological state, the spaces occupied by orchards, pastures and hayfields have not been taken into account in this formula.

Results and discussions

1. The human pressure index through arable land use

The human pressure indices on forest lands and on various types of agricultural lands are relevant for the Bâsca Chiojdului river basin.

Knowing both the evolution of the number of inhabitants and the evolution of forest areas in the last 3-4 decades, we can calculate the temporal dynamics of human pressure index on forest lands in the basin. In figure 3, there may be noted that at the beginning of the interval, a downward trend in the value of this index was recorded, the minimum value was recorded in 1975 (0.637 hectares of forest/capita), followed by a continuous increasing up to 0.708 hectares/capita in 1990, respectively 0.757 ha/capita in 2010.

We should not conclude (wrongly) with an improvement of the overall ecological state in the basin. The continuous increase in the value of this index between 1975-2010 is not due to the expansion

of forest areas (these being reduced with 1.23% during this period), but it is marked by the decline in the number of inhabitants. With regard to human pressure index through arable land use, in 2005 there were 0.76 hectares of agricultural land/capita, of which 0.22 hectares of orchards/capita, 0.45 hectares of pastures and hayfields/capita respectively 0.04 hectares of arable land/capita.

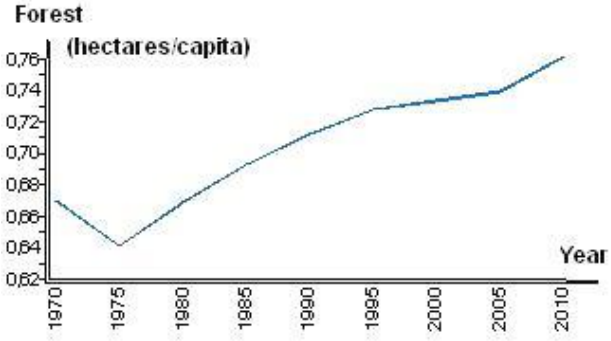

Fig. 3: The evolution of human pressure index on forest lands in the Bâsca Chiojdului river basin

2. The naturality index of the landscape

An analysis of environmental quality for the Bâsca Chiojdului river basin can not be conceived without calculating the naturality index. Speaking in percentages, it can have values between 0 and 100%. Clearly, the higher the value of this index is, the better the state of the analyzed space is from the ecological point of view.

In the Bâsca Chiojdului river basin the formula is applied as follows: Ni = [(172 840 862 m²) / (340 289 950 m²)] x 100 → Ni = 50.79

The mean value of the naturality index at the level of the whole river basin is 50.82%, almost double in comparison to the average at the national level, but insufficient if we refer to physical and geographical conditions of the analyzed area. Regarding the spatial distribution of this index, this records very large variations, ranging from 0% in the middle part of the basin (Starchiojd depression) and almost 100% (99.95%) in the north-west part of the basin, in the mountain area, where the degree of afforestation is very high.

The high values of the index between 80 and 100% are common in the northern part of the basin, in the mountain area, but local in the south part too, especially near the watersheds, where the relief is higher and more fragmented, the forest vegetation occupying large areas. Lower values, but above the basin average (between 50 and 80%), are common in the mountain areas from the northern part of the basin (at lower altitudes, near the main valley, but also at the contact with the Sub-Carpathians), but also in the Carpathian higher area from the southern part of the basin.

As far as the low values of the naturality index are concerned, (20-50%), these are found mainly in the Carpathian area in the centre and south part of the basin, on the slopes that guard the Starchiojd and Chiojdului depressions with or near the main valleys. Such values are found apart in the mountain area also, in the north-western extremity of the basin, at high altitudes, where the forest has been replaced by pastures, or in the lower sectors where deforestation has been made recently.

Very small values (critical) of the naturality index (between 0 and 20%) are found widely in the Chiojdului and Starchiojd depressions and locally in the bottom part of the basin, along the valley of the the Bâsca Chiojdului river. The worst is that in 10 analyzed sectors (1km ² each) the index is "0", the forest area is missing completely, and in other 8, the recorded values are below 1%. All these are found particularly in the Starchiojd depression and less in the Chiojdului depression.

Talking about the temporal dynamics of the naturality index, the massive deforestation carried out mainly in the last two centuries and especially in the middle part of the basin, gradually led to the decrease of this index, as time passed, it became an important indicator to characterize the environmental state of a region. The forest ecosystem, with its protective function on the environment, is the most important factor for maintaining the balance.

3. The environmental change index

The formula for environmental change index, Maruszczak version, for the Bâsca Chiojdului river basin applies as follows: Eci = (172 840 862 m² + 95 299 145 m²) / 7 907 198 m² → Eci = 33.92.

The use of this index is absolutely necessary to study human impact on the environment. While forests and grasslands (alpine and subalpine pastures, Sub- Carpathian grassland or hayfields) reflect the landscape naturalness, the built surfaces (industrial plants, buildings, lines of communication) are a factor of human change on the environment.

In the analysis of figure 4, areas with high values of this index may be identified (over 200), on relatively large areas in the mountain areas from the

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northern part of the basin, but locally also in the higher Sub-Carpathian areas from the south and east of the basin. Low values of this index (below 10 and even below 1) are found in depression areas in the middle part of the basin, along the main valleys, especially the Sub-Carpathian valley of Bâsca Chiojdului. This index has several shortcomings. These derive from the fact that the formula equals forest spaces on the one hand and the meadows (Sub-Carpathian pastures, subalpine hayfields and pastures) on the other hand, given that it is a very big difference between ecological functions of the forest and the role played by the pastures and the hayfields.

It should also be kept in mind that the pastures (both those from the sub-Carpathian sector and the subalpine ones from the north part of the basin) are mostly secondary and are used as pastures and hayfields. Although they are oxygenized surfaces, they act as agro-ecosystems (artificial entities of the landscape), their self-regulation ability is little or does not exist at all and it is subordinated to the interests of human society (Armaş et al., 2003).

Applying the formula of the improved version of the environmental change index, at the level of the Bâsca Chiojdului river basin, it results: Eci = 172 840 862 m² / (150 344 917 m² + 7 907 198 m²) → Eci = 1.09

The distribution of this index values in each square kilometre of the basin shows strong contrasts between the mountain area from the northern part (where values above 5 appear frequently and even 100 in 7 cases) and the depressions in the central part of the basin, where the value is 0 in 13 cases and that happens due to the lack of forest in these areas (Fig. 4). High values of the index are recorded locally in the south part of the basin too, even above 100 nearby Salcia Peak. Small sub- unitary values are common not only in the depression area from the median part of the basin, but also along the main valleys, especially in the Sub-Carpathian sector of the Bâsca Chiojdului valley.

Both variants of the environmental change index (both Maruszczak version and the improved version) have some shortcomings in that not all forms of land use found in the analyzed area are taken into account.

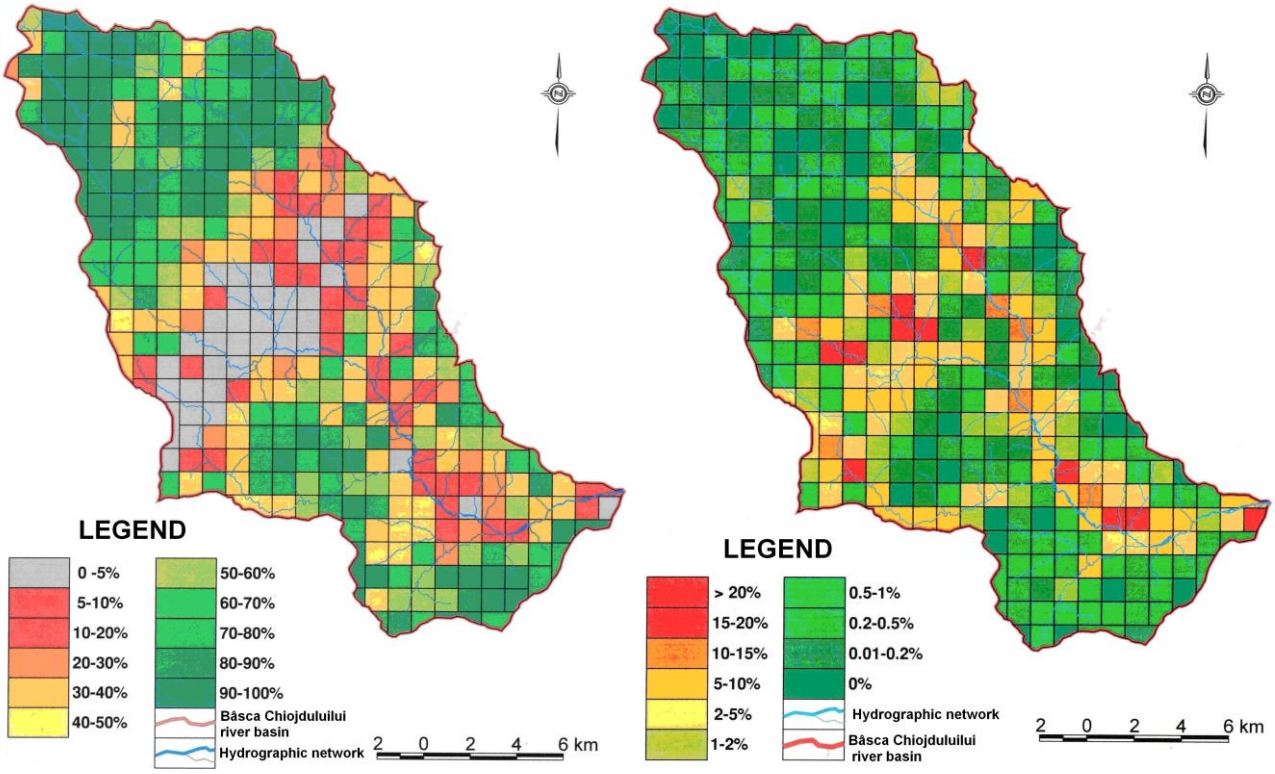

Fig. 4: Spatial dynamics for the values of environmental change index – completed version (left) respectively the arable land use (right) in the Bâsca Chiojdului river basin in 2005

They ignore two subclasses of the land use (aquatic areas, respectively the areas with poor vegetation - major river beds and degraded lands). Although such surfaces occupy small percentages within the Bâsca Chiojdului river basin (0.30% aquatic areas, 2.40% major river beds and degraded

land), they must be taken into account. Thus, aquatic areas (rivers or lakes) play a positive role in the ecosystem, being oxygenized surfaces and having a powerful role of thermal regulator. Major river beds, however, and the degraded lands too (whether of natural or anthropogenic origin) have a negative impact on the environment.

Orchards, pastures and hayfields, given that they have both a positive and a negative role, may be considered "neutral elements" in characterizing the environmental status of a region.

Applying the proposed formula for calculating the index of environmental change, the complete version for the analyzed basin is as follows: Eci = S (172 840 862 m² + 1 042 510 m²) / S (7 907 198 m² + 8 154 463 m²) → Eci = 10.83.

Thus, the average value of environmental change index calculated through the completed method is 10.83. As with the other two versions, big differences result between the minimum values recorded in the depressions in the central part of the basin (less than 0.1 in 14 sectors) and the maximum values recorded especially in the mountain area of the upper part of the basin, and also in the high areas from the lower part of the basin (above 1000 in 51 cases) (Fig. 5).

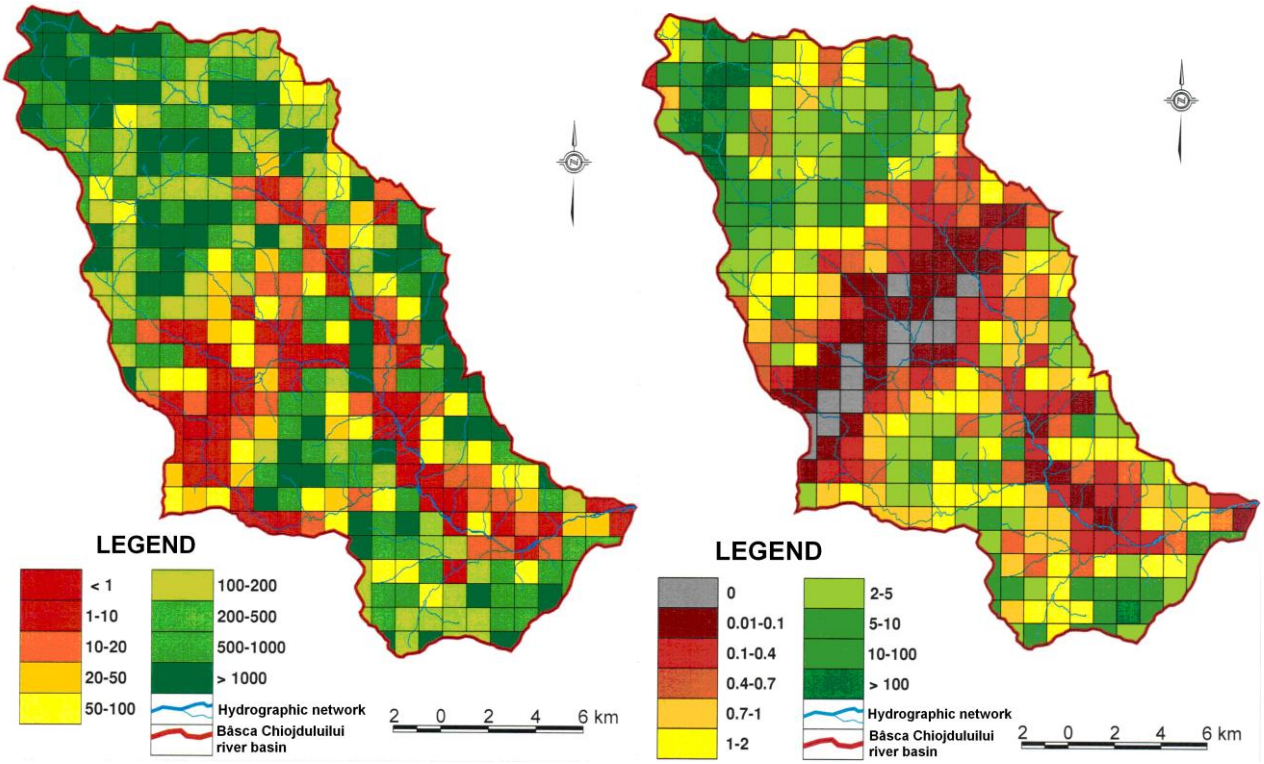

Fig. 5: Spatial dynamics for the values of environmental change index – Maruszczak version (left) and the improved version (right) in the Bâsca Chiojdului river basin in 2005

Conclusions

In terms of environmental quality, the results are similar in the Bâsca Chiojdului river basin regardless the calculated environmental index and the formula used. After analyzing the spatial and temporal dynamics of the environmental indices, the human pressure is increasing by expansion of the built areas and by interventions on the natural ecosystems.

The calculations lead to the conclusion that in the upper part of the basin, corresponding to the mountain area and locally in higher Sub-Carpathians areas, well wooded and with low anthropogenic impact, the environmental pressures are much lower than in the sub-mountain depressions from the median part of the basin (Chiojdului and especially Starchiojd) where the virtual absence of forests and the increased human pressure create a number of disruptions in the ecosystem. Strong environmental pressures also occur along the main valleys, especially on the lower course of Bâsca Chiojdului (Fig. 6). It is advisable, as necessary measures, the extension of the areas occupied by orchards, through planting fruit trees in the areas currently occupied by pastures or

hayfields. A priority should be the sloping lands, where the establishment of orchards would reduce the soil erosion. The climatic conditions should be also taken into account, being highly favourable to fruit trees. For the degraded lands with more accentuated declivity, afforestation works are necessary because orchards could not stop the geomorphologic slope processes.

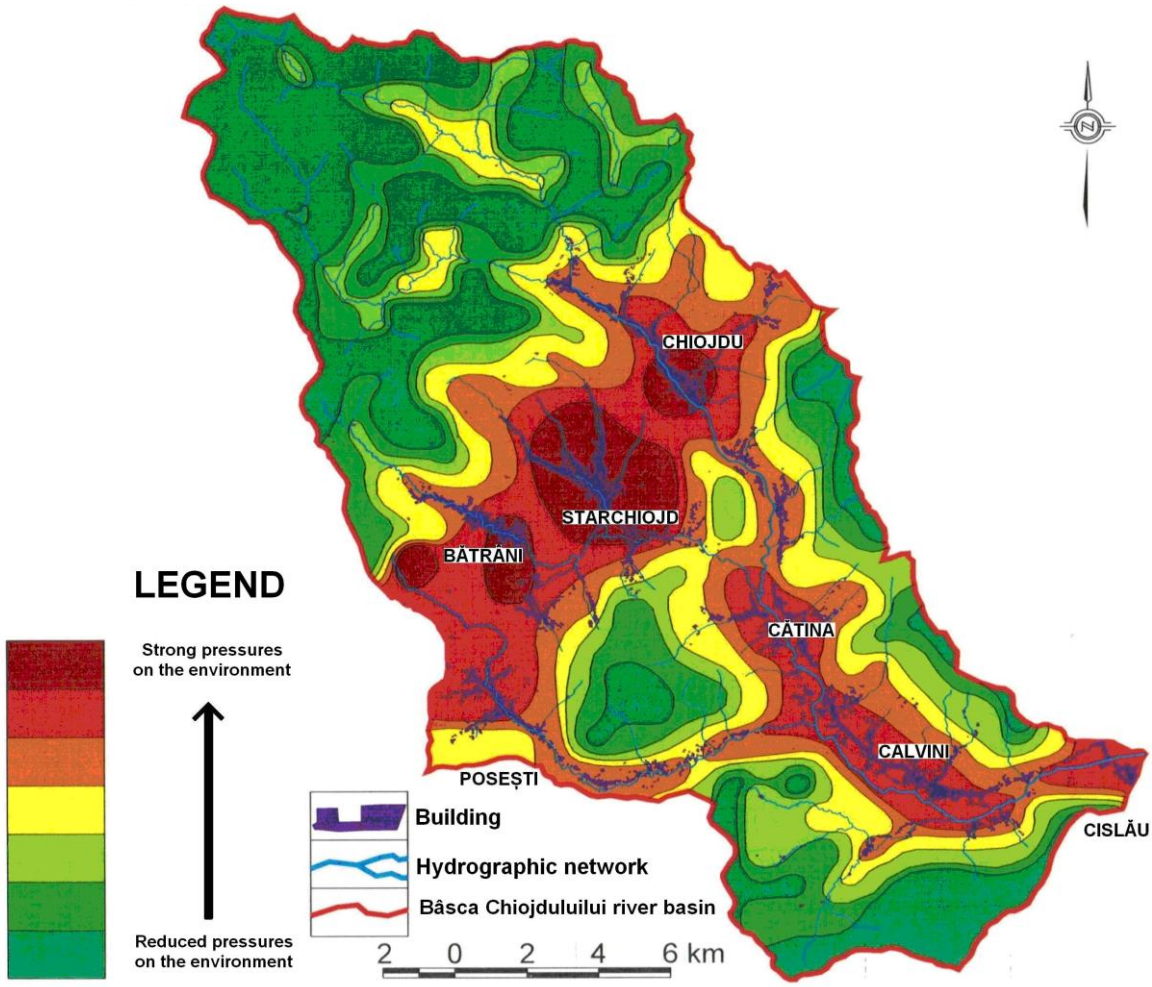

Fig. 6: Spatial dynamics of environmental quality in the Bâsca Chiojdului river basin in 2005

To control and reduce the negative environmental impact, the expansion of the growing stock is done through afforestation works. Expanding the forest areas would certainly have a positive impact on the environment due to the multiple role the forest exercises (air oxygenation, hydrological role, slopes setting etc.).

When the afforestation of the land is impossible for various reasons (ownership issues, financial difficulties, etc.), an effective solution is the establishment of orchards, knowing the fact that a mature and dense grove can achieve 70-80 % of the ecological role of a forest.

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Invasive Terrestrial Plant Species in the Romanian Protected Areas. Case Study: *Fallopia japonica* in the Maramureş Mountains Natural Park

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Abstract

Assessing invasive terrestrial plant species in protected areas is of major importance, taking into consideration the role they play as key drivers in conserving biological diversity.
The paper is aiming to argue the Invasive Terrestrial Plant Species (ITPS) in the Romanian protected areas with a special focus on the species *Fallopia japonica* in the Maramures Mountains Natural Park. *Fallopia japonica*, also known as *Polygonum cuspidatum* or *Reynoutria japonica* is an herbaceous perennial plant, largely occupying the riparian ecosystems and causing serious damages to native vegetation. The species is broadly regarded as one of the most invasive plant species in Europe, also listed by the World Conservation Union as one of the world's one hundred worst plant invaders.
The paper seeks to analyze the potential spread of Fallopia japonica in a protected area-Maramures Mountains Natural Park - V IUCN category as well as Natura 2000 site (SPA and SCI) integrating comprehensive statistical and field data with modern computing methods (GIS-based). Consequently, based on accurate mapping and field investigation of Fallopia japonica in the study-area, the authors were able to identify specie's main ecological requirements and preferences, spreading conditions etc.
The current research will have great contribution to undertaking further studies on invasive terrestrial plant species development, distribution potential and impact upon native habitats.

Keywords: *Invasive terrestrial plant species (ITPS); Fallopia japonica; Maramureş Mountains Natural Park; protected area, Romania*

Rezumat. Speciile de plante invasive terestre în ariile protejate din România. Studiu de caz: *Fallopia japonica* în Parcul Natural Munţii Maramureşului.

Evaluarea speciilor de plante invazive terestre în ariile protejate este de importanţă majoră ţinând cont de rolul acestora ca factori cheie în conservarea diversităţii biologice.
Lucrarea are drept scop analiza speciilor de plante invazive terestre (ITPS) în ariile protejate din România, cu accent pe specia *Fallopia japonica* în Parcul Natural Munţii Maramureşului. *Fallopia Japonica*, cunoscută şi sub numele de *Polygonum cuspidatum* sau *Reynoutria japonica* este o plantă erbacee perenă ce ocupă în cea mai mare mare parte ecosistemele ripariene, provocând daune grave vegetaţiei native. Specia este menţionată de către Uniunea Internaţională pentru Conservării Naturii ca una dintre cele mai periculoase o sută de plante invazive. Lucrarea urmăreşte să analizeze potenţialul de răspândire a speciei într-o arie protejată, Parcul Natural Munţii Maramureşului - categoria V IUCN, precum şi site Natura 2000 (SPA şi SCI), prin integrarea de date spaţiale şi statistice complexe cu ajutorul metodelor de calcul moderne (GIS). Prin urmare, pe baza cartărilor şi investigaţiilor de teren ale speciei *Fallopia japonica*, autorii au putut identifica principalele cerinţe ecologice, condiţiile de răspândire, etc.
Lucrarea de faţă va contribui semnificativ la elaborarea de studii referitoare la evaluarea dinamicii, a potenţialului de distribuţie şi al impactului acestei de plante invazive terestre asupra habitatelor native.

Cuvinte-cheie: *Specii de plante invazive terestre (ITPS), Fallopia japonica, Parcul Natural Munţii Maramureşului, arie protejată, România*

Introduction

Biological invasions are considered one of the key components of global change (Shea and Chesson, 2002; Arim et al., 2006) with significant impacts on populations, communities, and even ecosystems (Bailey et al., 2007) as well as one of the leading threats to biodiversity, natural habitats and their surrounding areas (Dumitraşcu et al., 2012). Therefore, the intensification of the human-induced pressures on different ecosystems enhances and broadens the biological invasions phenomena, thus becoming a major threat to European biodiversity.

Among the variety of aspects on biological invasions, some fundamental features were mostly tackled by scientists (Shea and Chesson, 2002; Bailey et al., 2007): the main characteristics that determine the invasiveness of species, the suitability of some ecosystems to being invaded (Rejmanek and Richardson 1996; Reichard and Hamilton 1997), the attributes of invaded communities and their capacity to defend against invasion (Elton 1958; Tilman 1997; Herben et al. 2004) etc. All of these are not to be considered and further assessed independently, but jointly (Shea and Chesson, 2002).

When referring to plant invasions several vital stages must be taken into account: *transport* to the new location, *establishment* and *development/growth* in the invaded area, the last two being considered as the most important in assessing the invasive potential of species. Subsequently, depending on the particularities of the invaded community/habitat, the invader increases in *abundance* (Shea and Chesson, 2002).

Determining each species' invasive potential is essential and yet difficult for establishing its future behavior (Bailey et al., 2007), growth rate and impacts. Therefore, a wide range of drivers must be considered, such as: disturbance (Hobbs and Huenneke 1992), resources, physical environment (e.g. climatic or edaphic) natural competitors etc., all of which vary in time and space. The ability of each species to respond to these factors reflects their invasive capacity (Shea and Chesson, 2002).

When assessing biological invasions, various approaches and methods were proposed and applied so far: qualitative or probabilistic trying to relate the environmental requirements of each species to its spreading potential (Dumitraşcu et al., 2010), quantitative systematic or statistical etc., but without providing thoroughly accurate predictions, because of environmental stochasticity and/or deficient data (Shea and Chesson, 2002).

Due to a constant intensification of the human-induced impacts on native ecosystems and the relief particular features, the study area is more exposed to the penetration and spreading of different invasive terrestrial plant species, among which *Fallopia japonica* ranks first. This species is particularly found in the main rivers floodplains and inside settlements, thus endangering the indigenous flora. The field surveys undertaken so far pointed to larger surfaces covered by this species and an increased spreading potential.

Study area

The current research mainly focuses on the Maramureş Mountains Natural Park. The study-area overlaps the highest mountain massif located in the central part of the Carpathian Chain (24⁰30′00″ long. E and 47⁰48′00″ lat. N), at the border of Romania with Ukraine (Fig. 1).

In 2005, the Maramureş Mountains were declared protected area, under the *Category V IUCN – Protected Landscape-Natural Park*, having as main characteristics for its designation: the specific landscape of mountains covered by forests alternating with alpine meadows, the presence of flora and fauna that is emblematic for the Carpathians within ecosystems which are still stable (forests, pastures, river bodies, lakes and marches, underground waters), the existence of natural habitats on large extension and the preservation of the traditional way of life (Năstase et al., 2010). The relief stands out as rounded summits rising up to 1800 – 1900 m, fragmented by deep valleys which had developed defile and depression sectors. The main rivers which drain this mountain unit are the Frumuşeaua, Ruscova, Vaser, Ţîsla and Vişeu out of which the latter had favoured the development of the most important settlements in the park area: Borşa and Vişeu de Sus.

The Park is administrated by National Forest Administration and has 133,354 hectares, representing the biggest park in the Romanian Carpathians. Moreover, 70 per cent of the Park area – except the inner-city of the localities within – has been up for Site of Community Importance, within the European Network – Nature 2000. Of all mammals listed in Appendix II of Directive 92/43/CEE of the European Council, in the park

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there can be identified all three species of large carnivores: wolf, bear and lynx ("Munţii Maramureşului" Natural Park – The Management Plan, 2008).

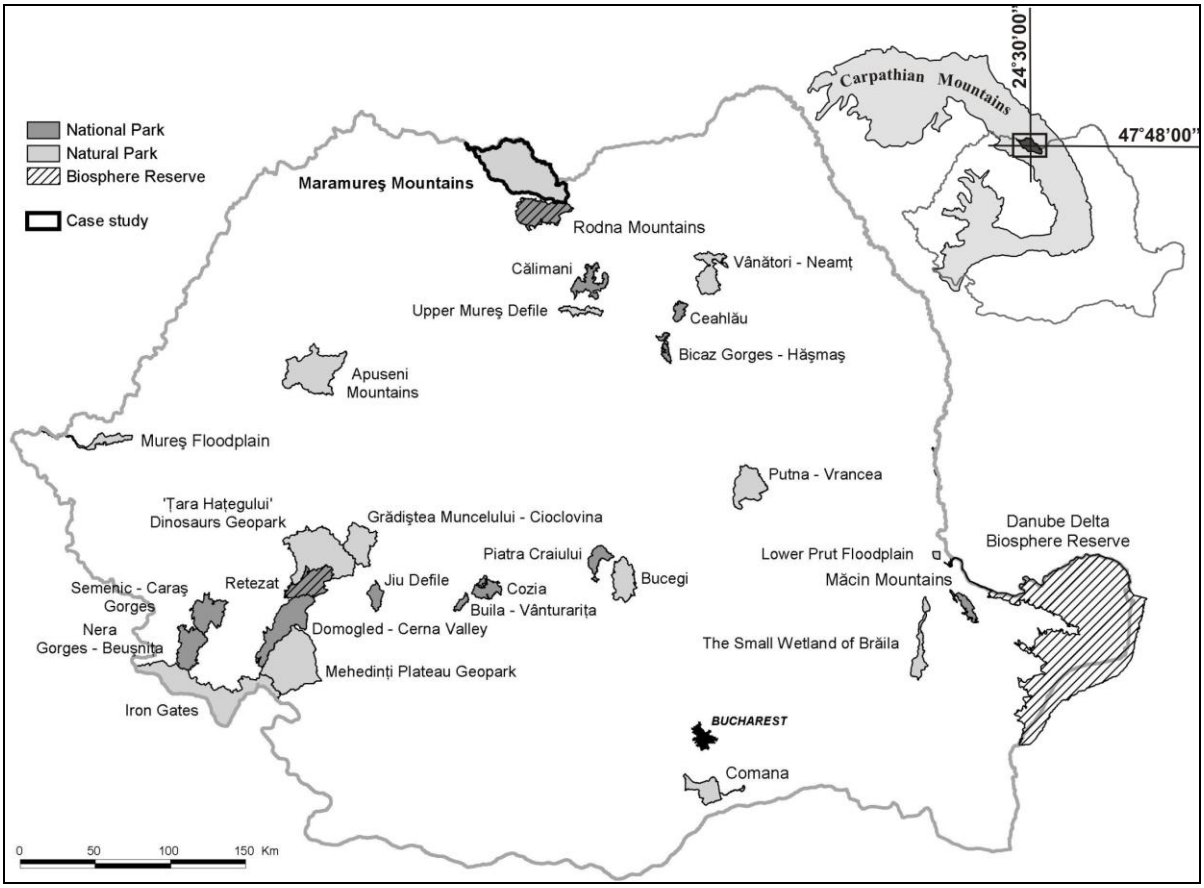

Fig. 1: Romanian protected areas network and the location of the study area

Methodology and data

The authors carried out a qualitative assessment of the occurrence and distribution of *Fallopia japonica* in the Maramureş Mountains Natural Park in relation to species habitat requirements and main environmental features.

The study consisted of cross-reference bibliographical literature (both biological and geographical), spatial data (GIS processing) and field surveys (campaigns undertaken in 2010 and 2011) aiming at identifying the species on-the-spot, mapping (on the topographic map, scale 1:25 000 and orthophotoplans scale 1:5 000) and processing the collected data. Additionally, the authors assessed the species' distribution against the main environmental features using ArcView (Geoprocessing) tools and ultimately describing its preferred habitats and estimating relevant parameters in terms of morphology, density, richness and abundance (number of stems/sq.m).

Based on the described methodology and the available data, the authors are willing to offer a general outlook of this invasive terrestrial plant species in the Maramureş Mountains Natural Park in order to identify relevant causal rationales between the spatial distribution and spread of *Fallopia japonica* and its habitat requirements.

Invasive terrestrial plant species in the Romanian protected areas

The first invasive terrestrial plant species which have been recorded in Romania date back to the beginning of 18th century. Ever since, the invasive species literature was enriched with valuable information related to systematic and floristic studies. Additionally, a great number of invasive species was identified and mentioned in different scientific works or floristic lists which were synthesized in "Flora României" (1952-1976) and more recently in "Flora Ilustrată a României" (Ciocârlan, 2000), "Lista critică a plantelor vasculare din România" (Oprea, 2005) and "Plante adventive

în flora României" (Sârbu and Oprea, 2011). Currently, the scientific literature indicates over 400 species plant species in the Romanian flora (13.87 per cent) belonging to 82 families, out of which 88.27 per cent are neophytes and 11.73 per cent are archaeophytes (Anastasiu and Negrean, 2005; Dumitraşcu et al., 2010 and 2012).

When taking into consideration natural protected areas, assessing the impact of ITPS on native flora is compulsory due to their valuable and sensitive ecosystems. Therefore, amid the most destructive ITPS in the Romanian protected areas the following ranks first: *Ailanthus altissima* (The Small Wetland of Brăila Natural Park, the Măcin Mountains National Park, the Danube Delta Biosphere Reserve etc.), *Acer negundo* (the Mureş Floodplain Natural Park), and *Amorpha fruticosa* (Mureş Floodplain Natural Park, the Danube Delta Biosphere Reserve, Comana Natural Park etc.) (Doroftei, 2009; Dumitraşcu et al., 2010), *Reinoutria japonica* (the Maramureş Mountains Natural Park) etc.

The Romanian protected areas cover 1,798,782 hectares (7.55 per cent of the national territory) which, according to *Law No. 5/2000* and the *Government Decision 2,151/2004*, stands for 958 protected areas: 13 national parks, 14 natural parks (out of which 2 geoparks and 3 biosphere reserves) (Fig. 1), 54 scientific reserves, 240 monuments of nature and 626 nature reserves.

After 2007, together with the EU accession, Romania had to reach a 17 per cent protected surface of the national territory (from 7 per cent as it had previously been) through other conservative tools, such as "Natura 2000" European Network. There resulted 273 Sites of Community Interest (3,291,854.6 ha) and 108 Special Protected Ares (2,988,713.6 ha) (Bălteanu et al., 2009). The Maramureş Mountains Natural Park is almost entirely overlapping the *Natura 2000 Network* (*SPA – Special Protection Areas* and *SCI - Site of Community Importance*) aiming to protect wildlife and its habitats (Năstase et al., 2010).

Fallopia japonica in the Maramureş Mountains Natural Park

The ***Japanese knotweed*** (*Fallopia japonica)*, also known as *Polygonum cuspidatum* or *Reynoutria japonica*) is a clonal, herbaceous, fast-growing perennial plant (Aguilera et al., 2010), largely occupying the riparian ecosystems and causing serious damages to native vegetation. The species is broadly regarded as one of the most invasive plant species in Europe, also listed by the World Conservation Union and FP6-DAISIE project as one of the top one hundred invasive species of global concern (Lowe et al., 2000 cited by Kabat et al., 2006; DAISIE, 2005-2008; Lambdon et al., 2008).

Knotweeds (the species which includes the genus *Fallopia*) are native to eastern Asia (Japan, Korea, northern China and Taiwan) (Pysek, 2006) whence they were introduced in the Unites States in the 1877s for ornamental purposes (Aguilera et al., 2010) and in Europe, starting with the Netherlands (1823) followed by Germany (1872), Poland (1882), United Kingdom (1886), Norway (1901) etc. (Alberternst and Böhmer, 2006), thus becoming the most widespread and troublesome alien species on both continents (Weber 2003 cited by Barney, 2006). Soon after, the species had become an aggressive invader to other countries such as Canada, the Czech Republic, Australia, New Zeeland, Belgium etc. (Kabat et al., 2006; Tiébré et al., 2007 and 2008; Aguilera et al., 2010; Moravcová et al., 2011; Sîrbu, 2011). Paradoxically, the Japanese knotweed become so popular as ornamental that, in 1847, it was awarded the "golden medal" by the Dutch Society of Agriculture and Horticulture as the most "interesting" species of the year (Bailey and Conolly, 2000 cited by Barney at al., 2006).

In Europe, *Fallopia* taxa includes: *Fallopia japonica var. japonica*, *F. japonica var. compacta*, *F. sachalinensis* (Bailey et al., 2007) and their hybrid (*F. xbohemica*) (Moravcová et al., 2011). They are strongly growing, herbaceous, gynodioecious, rhizomatous perennials and adventive plants which can grow up to 3 m in height (Kabat et al., 2006). *F. japonica* spreads by clonal and rhizomatous growth (stem fragments can produce buds and shoots giving rise to new plants), rapidly form a monoculture (Aguilera et al., 2010). Moreover, its invasive success may be enhanced by multiple hybridization events (Tiébré et al., 2007).

In Romania, *Fallopia japonica* was firstly introduced as an ornamental plant, in gardens and parks (especially botanical gardens). The species was quite poorly studied in the Romanian scientific literature although it was mentioned as subspontaneous species (escaped) for about seven decades, especially in Transylvania (Paucă, 1940; Ţopa, 1947 cited by Oprea, 2005; Sîrbu, 2011). Recent studies indicate its prevalence along rivers, roadsides, in ruderal places, etc. frequently in Transylvania, Maramureş, Crişana and Moldova

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and seldom in Banat, Oltenia and Wallachia (Sîrbu, Oprea, 2011).

Habitat requirements. The Japanese knotweed can usually tolerate a wide variety of environmental conditions ranging from high shade, high temperatures (even drought) to high salinity. In its native range, *Fallopia japonica* is a pioneer species on volcanic slopes and as invasive it invades disturbed habitats, tolerating a variety of soil structures and textures and pH levels, ranging from 3 to 8 (Pysek, 2006). It frequently occurs in riparian habitats (e.g. along river banks), but because of its invasive nature it also tolerates disturbed habitats, such as railroad tracks and roadsides (Forman and Kesseli, 2003; NB II, 2005). Other studies undertaken on *Fallopia japonica* also revealed its preference for: boundary walls in farmlands, urban non-industrial land, ruderal habitats, meadows, natural/semi-natural forests, roadways etc. (Tiébré et al., 2008). The species usually installs in open places, its growth and abundance being seriously affected by shading. The rhizomes are very resistant to low temperatures, thus permitting its survival in harsh climatic conditions (up to absolute minimum temperature of -30.2° C) (Barney et al., 2006).

Broad impacts. *Fallopia* taxa are now widely naturalized in many countries, thus becoming a threat to native ecosystems (Tiébré et al., 2008). It mainly occupies riparian areas, where it spreads rapidly, turning into dense monoculture structures provoking significant damages to river banks and related protected structures, paved surfaces, thus triggering significant impacts on native flora in terms of habitat and biodiversity loss (NB II, 2005; Barney at al., 2006). Consequently, through the huge amounts of rhizomes it generates, this invasive species is capable of penetrating and displacing foundations, walls, pavements, and drainage works (Beerling, 1991) causing flood hazards by increasing resistance to water flow and damaging flood prevention structures (Alberternst and Böhmer, 2006; Pysek, 2006).

The species has a significant impact on soil cover through a greater mineral content, especially in terms of K and Mn, a decrease of bulk density and increase of organic matter, water content and nutrient levels (Pysek, 2006).

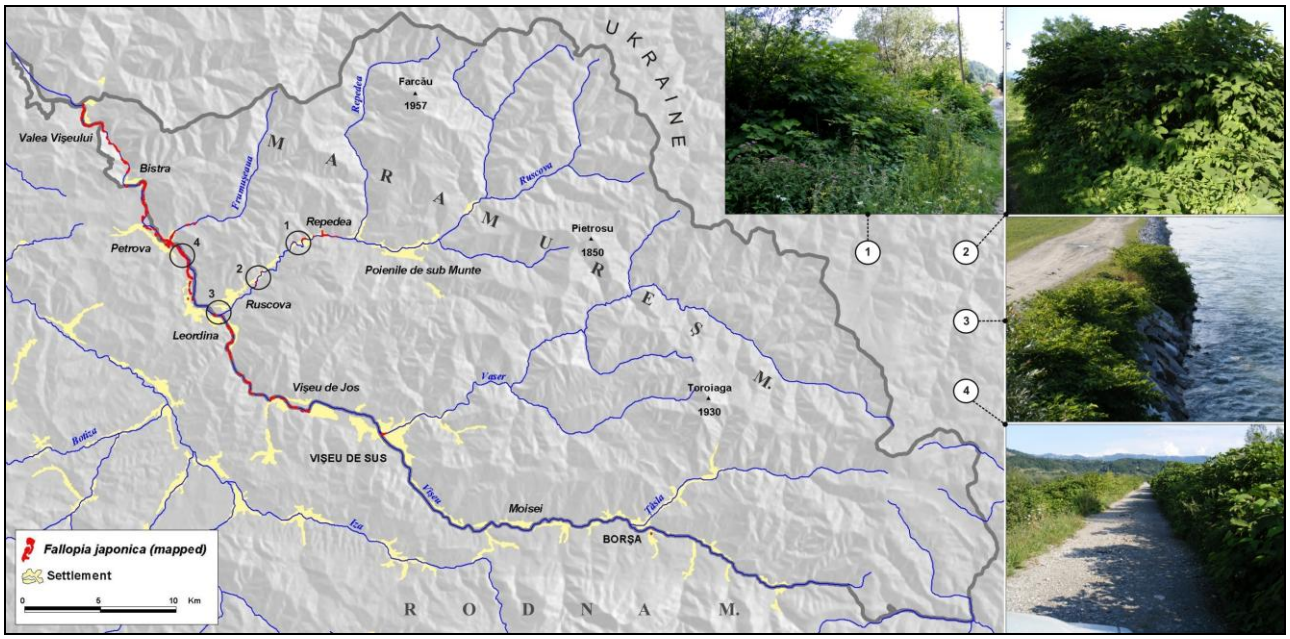

Fig. 2: ***Fallopia japonica*** **distribution in the Maramureş Mountains Natural Park (mapped areas)**

Results and discussions

Spreading and habitat description in the Maramureş Mountains Natural Park. In the Maramureş Mountains Natural Park the species was identified mainly in the western part, in the Vişeu river floodplain, but also in the central part – the Ruscova river floodplain and upstream to Repedea village (12 km from the confluence between the Ruscova and the Vişeu rivers) and on the Frumuşeaua and the Vaser rivers, near the confluence with the Vişeu. *Fallopia japonica* was also found close to the southern limit of the park area in Borşa town on Rodna Piedmont along the Pietroasa

flow. The entire mapped surface totalises approx. 88 ha and indicates areas most invaded by this invasive species mainly on the river banks. Additionally, one can find compact areas with *Fallopia japonica* along the modernized roads, the railway connecting towns of Valea Vişeului and Vişeu de Jos and the flood protection dams along the Vişeu River.

In terms of phenology, the period of maximum development for the Japanese knotweed was identified between June and August. Moreover, the species proves to be highly resistant, especially to climatic hazards (drought, frost), mechanical and chemical treatments with herbicides.

In the study-area, during our preliminary field surveys it was noticed that *Fallopia japonica* individuals were often distributed near water bodies, preferring riverbanks, mainly the floodplain area at lower altitudes (under 500 m), open areas (free of coexisting species), tending to invade grasslands, croplands and even courtyards (e.g. the Vişeu river floodplain) and thus seriously affecting native vegetation (Fig. 3).

Fig. 3: *Fallopia japonica* specific habitat: near riverbeds (A), agricultural lands (B) and the tendency to parasitism (C) (photo: Gheorghe Kucsicsa)

The species' ***distribution*** in the mapped areas revealed a preference for habitats described by lower altitudes of well under 500 m (almost 100 per cent) and declivities of 0-5º (over 70 per cent) with no specific preference for slope exposure. In terms of lithology and soils, it develops mainly on gravels and sands (88 per cent) and alluvial and alluvial protosols soil types. The broad climatic requirements of *Fallopia japonica* in the study-area are points to annual means of 8-9ºC for air temperature and 700-800 mm for precipitation amounts (Table 1).

Species morphology. In the study-area, the Japanese knotweed could reach a medium *height* of about 3-3.5 m. The *root* is very strong with a high penetrating capacity, thus producing significant damages to roads, buildings, agricultural lands etc., being able to develop well-built rhizomes; the *steam* is tubular, robust, and relatively upright build up by rhizomes (Fig. 4).

Table 1 Distribution of *Fallopia japonica* on the mapped areas in relation to the key environmental features

hypsometry (m)	ha	%	*declivity (º)*	ha	%	*slope exposure*	ha	%
300 – 400	68	77	0 – 3	58	66	shaded	48	55
400 – 500	19	22	3 – 5	5	6	semi-shaded	17	20
500 – 600	1	1	5 – 10	8	9	sunny	23	25
			> 10	17	19			

lithology	ha	%	*soil type*	ha	%
gravels, sands	77	88	alluvial and alluvial protosols	88	100
sandstones, marls, conglomerates	8	9			
epimetamorphic schists	3	3			

air temperature (º) annual mean	ha	%	*precipitation amounts (mm) annual mean*	ha	%
8 – 9	69	78	700 – 800	67	76
6 – 8	19	22	800 – 1000	21	24

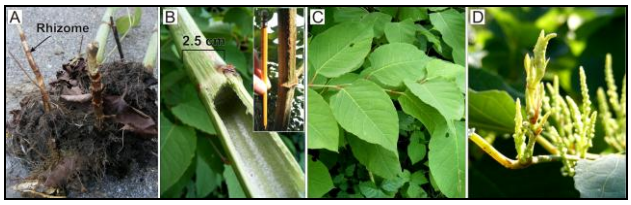

Fig. 4: *Fallopia japonica* morphology: root (with rhizomes) (A), steam (B), leafs (C) and inflorescence (D) (photo: Gheorghe Kucsicsa).

The ***abundance***, estimated based on the number of steams, points to a high density of individuals on sq.m (e.g. up to 50 steams/sq.m. in the Ruscova river floodplain) (Fig. 5). It is widely recognized that this species forms dense patches, significantly reducing the diversity of native species, shading up other plants and slowing nutrient cycling (Barney et al. 2006; Aguilera et al., 2010).

Fig. 5: *Fallopia japonica* abundance in the Maramureş Mountains Natural Park (photo: Gheorghe Kucsicsa)

The assessment of *Fallopia japonica* main parameters (distribution, abundance) and morphology in the Maramureş Mountains Natural Park reveal a high spreading and renewal potential of the species which turns it into a real threat to infrastructure, native flora and wildlife habitats, watercourses etc. Under the given circumstances, undertaking comprehensive studies on the species characteristics and distribution potential on one hand and developing eradication and control methods, on the other are highly recommended.

Conclusion

Knowing the high invasive potential of *Fallopia* taxa due to its high genotypic diversity which determines its ability to adapt and differentiate into new environments (Bailey et al., 2007; Tiébré et al., 2007) a complex assessment of this species in protected areas is highly required.

The current study on the ITPS in the Romanian protected areas with a special focus on *Fallopia japonica* in the Maramureş Mountains Natural Park – both V IUCN category and Natura 2000 site - in relation to the species' habitat requirements and key environmental features is essential in identifying and defining the most significant causal and spatial relationships. Therefore, establishing the relationship between species diversity and invasive success on one hand and the physical extrinsic factors (environmental features) on the other (Shea and Chesson, 2002) would provide valuable future predictions through GIS-based modelling techniques.

Fallopia japonica is an extremely invasive adventive species whose management and control are difficult and expensive. Due to its rapid invasive potential, high capacity for regeneration and tolerance to different environmental factors, it has an increased impact, both ecological and economic. Its spread in floodplains can cause damages to indigenous habitats and plant communities (especially the *Salix* and *Alnus* associations which have an important role in flood protection and control). Moreover, due to its presence along the access routes (mainly modernized), the species constitutes a "threat" to the pavements and railway embankments due to its strong adventive roots. It can also cause damages to river banks, aiming to protect localities against flooding, or to land cover/land use by invading arable lands or grasslands located near or along river valleys.

Therefore, in the study-area local authority's lack of knowledge on the potential danger of this species might jeopardise both natural habitats and population safety, especially in the flood-prone areas, such as the Vişeu, the Repedea and the Frumuşeaua floodplains. As a result, the outcomes of the present paper could constitute an important starting point for further assessments on *Fallopia japonica* in terms of spreading potential and dynamics aiming to develop and integrate the most appropriate eradication and control measures in the Maramureş Mountains Natural Park's Management Plan.

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The Evaluation of Geomorphosites from the Ponoare Protected Area

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Abstract

In the present paper we present a new method of evaluating the geomorphosite. The method is presented by us/ our team and it was tested in the protected area Ponoare. In the first part of the article, we will apply, for the geomorphosites inventorized here, the other methods of evaluation known worldwide, and after that we will evaluate geomorphosites by following the new method proposed by us, a method which is adapted to geomorphological reality and to the reality of touristic exploitation of the analysed area. There were taken into account the methods developed up to now in the specialized literature, namely: *the method of evaluating the touristic value of geomorphosites* for the evaluation of the touristic value conceived by J. P. Pralong in 2005, *the method developed* in 2007 by E. Reynard et al.; *the method developed at the University of Modena and Reggio Emilia* by P. Coratza and C. Giusti in 2005; *and the method proposed at the University of Cantabria* by V. M. Bruschi and A. Cendrero in 2005; *the method developed by the University from Valladolid* by E. Serrano and J. J. Gonzales Trueba in 2005; *the method proposed by the University of Minho* in 2007 by P. Pereira, *the Greek method* developed by N. Zourous in 2005 and *the Slavonian method* proposed in 2012 by B. Erhatic. The results obtained show different quantitative values compared to previous methods, but comparing the rank obtained by each geomorphosite during the evaluation, the rank stays the same. The values are situated in a different deviation compared to other methods, having in view that for additional values firstly the cultural value is reduced in the analysed area.

Keywords: *geomorphosite, carst, evaluation, method, Ponoare*

Rezumat. Evaluarea geomorfositurilor din aria protejată Ponoare

În lucrarea de faţă vă aducem în atenţie o nouă metodă de evaluare a geomorfositurilor propusă de noi şi care a fost testată în aria protejată Ponoare. În prima parte vom aplica pentru geomorfositurile inventariate aici celelalte metode de evaluare cunoscute pe plan mondial, după care vom evalua geomorfositurile urmând metoda propusă, metodă care este adaptată realităţii geomorfologice şi de exploatare turistică a spaţiului analizat. Au fost luate în considerare metodele dezvoltate până acum în literatura de specialitate şi anume: metoda de evaluare a valorii turistice a geomorfositurilor pentru evaluarea valorii turistice a geomorfositurilor concepută de J. P. Pralong în 2005, metoda dezvoltată în 2007 de E. Reynard et al.; metoda dezvoltată la Universitatea Modena și Reggio Emilia de P. Coratza și C. Giusti în 2005; metoda propusă la Universitatea Cantabria de V. M. Bruschi și A. Cendrero în 2005; metoda dezvoltată la Universitatea din Valladolid prin E. Serrano și J. J. Gonzales Trueba în 2005; metoda propusă de Universitatea din Minho în 2007 de către P. Pereira, metoda grecească dezvoltată de N. Zourous în 2005 şi metoda slovenă propusă în 2010 de B. Erhatic. Rezultatele obţinute ne arată valori cantitative diferite faţă de metodele anterioare, însă comparând rangul obţinut de fiecare geomorfosit în evaluare poziţia se menţine aceiaşi. Valorile sunt situate într-un ecart diferit faţă de celellate metode având în vedere că valorile adiţionale în primul rând valoarea culturală este redusă în spaţiul analizat.

Cuvinte-cheie: *geomorfosit, carst, evaluare, metodă, Ponoare*

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Introduction

The definition universally accepted today considers geomorphosites as forms of relief which have a special value in time, due to their perception by the human society (Panizza, Piacente, 2003). Reynard (2005) considers the values held by geomorphosites are: scientific value (central value) and additional values (ecological, cultural, aesthetic and economic). Hereinafter, we will apply the methods of evaluation known in Geography literature for the selected geomorphosites, and then we will propose a new method of evaluating them.

The following methods were applied: *the method of evaluating the touristic value of geomorphosites*, developed by IGUL (the Institute of Geography of the University of Lausanne) for evaluating the touristic value of geomorphosites conceived by J. P. Pralong în 2005, *the method developed* in 2007 by E. Reynard et al.; *the method developed at the University Modena and Reggio Emilia* by P. Coratza and C. Giusti in 2005; *the method proposed at the University of Cantabria* by V. M. Bruschi and A. Cendrero in 2005; *the method developed at the University of Valladolid* by E. Serrano and J. J. Gonzales Trueba in 2005; *the method proposed by the University of Minho* in 2005 by P. Pereira, *the Greek method* developed by N. Zourous in 2007 and *the Slavonian method* proposed in 2010 by B. Erhatic.

For each of the methods mentioned above, the qualitative (subjective) value was eliminated, being taken into consideration strictly the qualitative (objective) value. The purpose of our demarche is to establish the most efficient method of quantifying the value of geomorphosites, from which the subjectivism of the person who evaluates must be dropped out, a method which could be applied for different areas. This is the reason why we will continue to test this method in other areas with diverse geomorphosites from the genetical point of view and also by the degree of touristic exploitation.

Study area

The area taken into study is represented by the Ponoarele Natural Reserve from the Mehedinti Plateau, comprising a surface of 100 hectares with karst forms and phenomena, with a high scientific value, some of them being unique on the territory of Romania (Fig. 1).

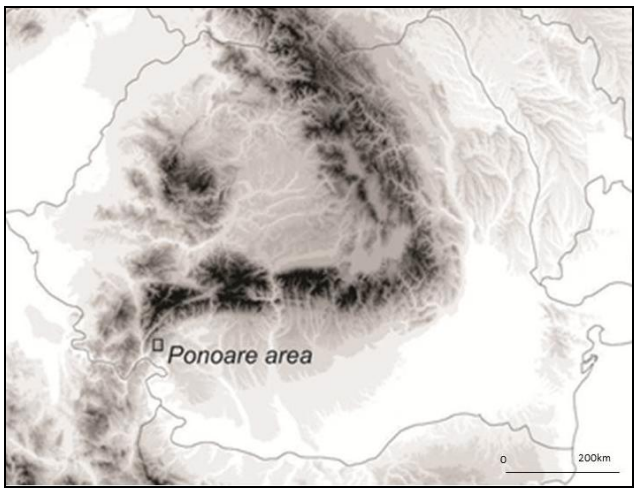

Fig. 1: The geographic location of the Ponoare protected area

From the geological point of view, the Mehedinti Plateau is formed by crystalline schists and sedimentary rocks (inclusively chalks) disposed in fasciae which are parallel (Ielenicz, 1999) (Fig. 2). On the chalks having a Mesozoic age (they occupy only 5 per cent of the surface of the plateau), specific forms developed, namely: erosion witnesses (popularly named trumpets/ horns), carst depressions which in the superior part are modelled in non-soluble sedimentary rocks or in crystalline and which present a flat bottom, having the appearance of a polje (Zătonul Mare and Zătonul Mic), the gorges sectors as the Băluţ and Cosuştea Gorges, the natural bridge from Ponoare, the sinkholes which are aligned along some valleys, forming sinkholes valleys, the fields of limestones - karrenfield (Aphrodite Field and Cleopatra Field), karst springs and caves (Topolniţa, Gramei, Isverna, Cave of Epuran, Bulba, Băluţa and Ponoare).

All these geomorphosites are part of the Mehedinti Plateau Geopark, enclosed in the list of Natura 2000 sites, which has a total surface of 105.000 hectares. Within the geopark there are 17 natural reserves, very different as typology, but with a special scientific value.

Hereinafter, all geomorphosites from the reserve area will be inventorized and evaluated, all of them having karst origin (Table 1).

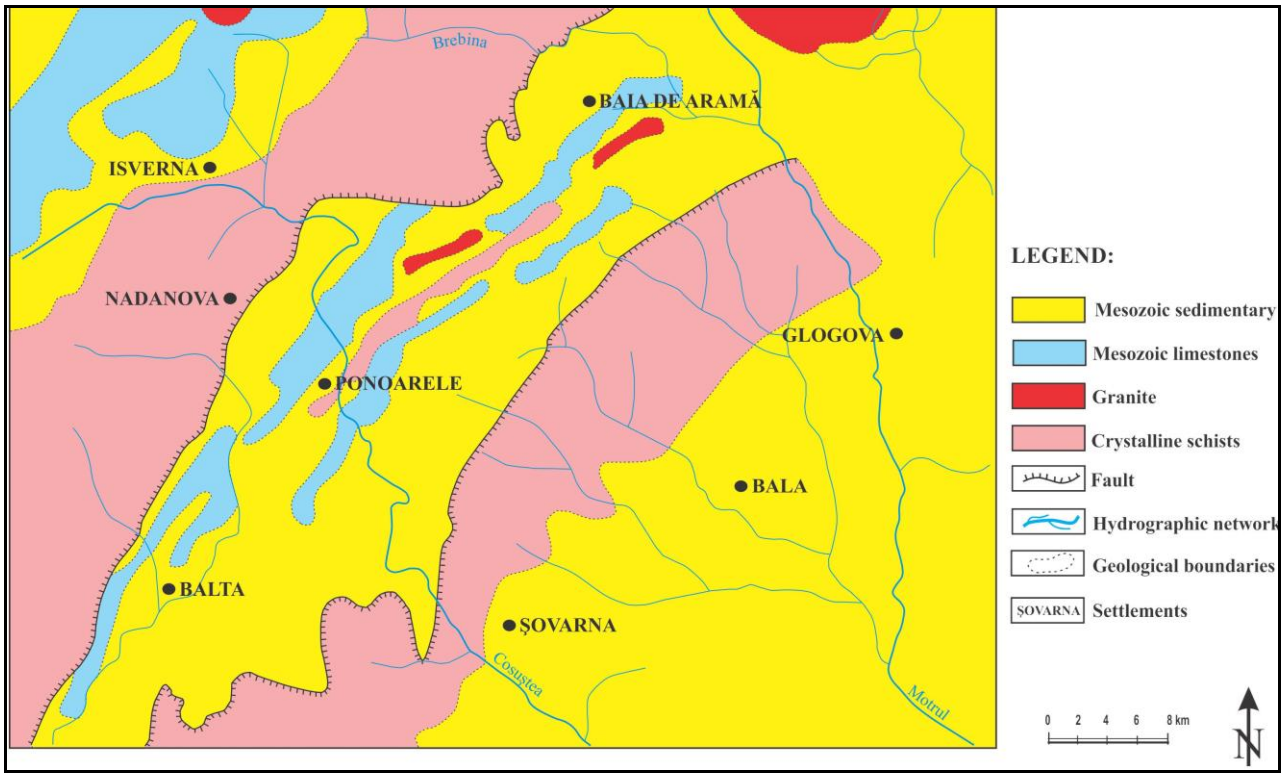

Fig. 2: The geological map of the areal Ponoare (after Geological Map- Baia de Aramă, 1977, 1: 50.000)

Table 1 Geomorphosites from the Ponoare protected area

Nr crt	Name	Origin	Type
1	Băluţa Cave	karst	punctual
2	Zătonul Mare Depression	karst	areal
3	Zătonul Mic Depression	karst	areal
4	The field of limestones-karrenfield from Ponoare	karst	areal
5	Ponoare Cave	karst	punctual
6	Băluţa Gorges	karst	linear
7	Sinkholes Field	karst	areal
8	PonoareNatural Bridge (God's Bridge)	karst	linear

Method

The methods enumerated are based on different objectives, but the following criteria are included in all of them: rareness, representativeness and integrity. Thus, some methods (Coratza and Giusti, 2005) emphasize the evaluation of the environmental impact, in other methods (Serano and Gonzales Trueba, 2005) the accomplishment of an inventory of geomorphosites is followed, the method developed by J.P. Pralong has as an objective to promote geomorphosites in the touristic activity, and in the methods developed by Pereira et al. in 2007 and Zourous N. in 2005 the accent lays on the evaluation of geomorphosites in the management of natural parks or geoparks.

The methodology proposed (Fig. 3) for evaluating geomorphosites consists in the following stages:

- studying the specialized literature, formulating observations and field mappings, able to lead to accomplishing the general morphologic map;
- identifying geomorphosites, localizing and inventorising them – the identification is done based on the aerial views and existent maps, and especially from the field. For each geomorphosite which was identified, the localization on the topographic map is done, as well as their description based on the standard inventory fiche from the specialized literature.
- accomplishing a database regarding geomorphosites – the existence of a correct and complete database, a very important operation which finally will lead to the implementation of the geomorphosites' map, a map which also forms a basis for the geotouristic map. The database must include the most important attributes of geomorphosites and it must be easily to access, the information in it must be uniform.

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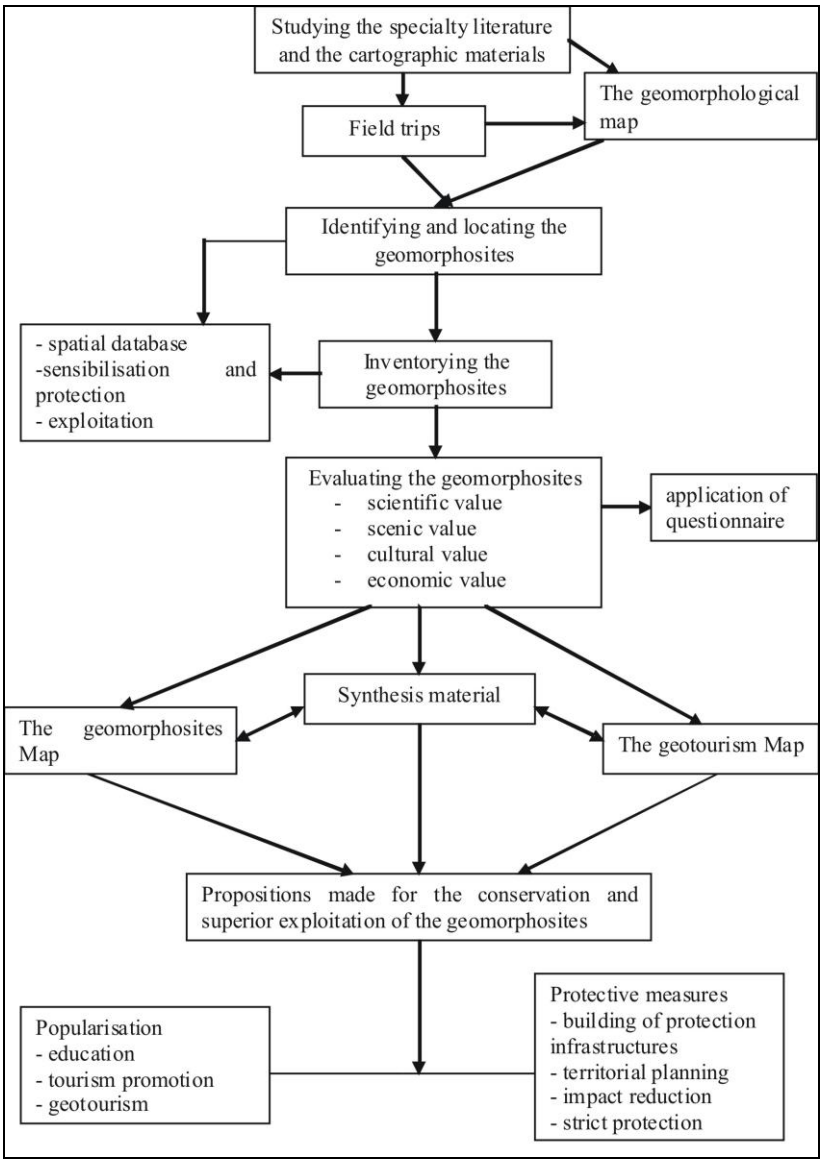

Fig. 3: The stages of studying geomorphosites (Comănescu and Nedelea, 2010)

- the evaluation of geomorphosites according to criteria proposed in table 2; the total value is calculated following the formula:

Vtot = (Vsci +Vsce +Vcult +Veco+Mg)/100. We considered necessary to calculate the division by 100 in order to do the comparison to the other methods. As it also comes out from table 2, the method proposed by us starts from the methods previously enumerated, but unlike those, it tries to globally evaluate geomorphosites. The methods known up to now in the specialized literature emphasize one or another value, depending on the purpose of evaluation.

- accomplishing the geomorphosites' map and the touristic map;
- establishing some measures for preserving geomorphosites and also for popularizing them in the touristic activity (touristic promotion, establishing some geotouristic tracks or including some of these geomorphosites in the already existent touristic tracks) or as a model in the educational promotion (their inclusion within some tracks made pupils or students).

For each of the criteria mentioned above, a score between 0 and the maximum value given to the criterion is considered, the appreciation scale being subject to modifications depending on the area and the typology of the geomorphosites taken into discussion. The sum for each criterion is calculated, and also the sum for all criteria, according to the above formula.

Table 2 The criteria and scores proposed for evaluating geomorphosites

Scientific value – 20 points	Aesthetic value - 20 points	Cultural value - 20 points	Economic value - 20 points	Management and use - 20 points
paleogeographic interest -3p	visibility – 4p	cultural characteristics -4p	accessibility -4p	preservation degree -4p
representativeness-2p	space structuring – 4p	historical characteristics -4p	infrastructure-4p	protected sites - 3p
rareness – 2p	colour contrast - 4p	religious characteristics - 4p	yearly visitors number -4p	vulnerability/ natural risks - 3p
integrity -2p	level difference-4p	iconographic/ literary representations -2p	number of types and forms of use (inclusively touristic) -4p	the intensity of use - 4p
degree of scientific knowledge -3p	landscape framing-4p	festivals/ cultural manifestations -2p	economic potential (incomes) -4p	the use of aesthetic, cultural and economic value -3p
use in educational purposes - 3p		symbolic value -4p		relationship with planning policies-3p
ecologic value-3p				
diversity-2p				

As we mentioned before, the appreciation criteria stay the same, but the scale will differ depending on the concrete situation in the field and on the purpose and objectives of the evaluation. Thus, whether the evaluation aims firstly the scientific value, its results being used for the specialist, a higher weight will be given to paleogeographic interest, the degree of knowledge/ recognition or the ecological value. If the evaluation purpose regards educational activity, then the use in this purpose will be better measured.

In accomplishing a geotouristic map, the accent will fall on the aesthetic value, which is most often perceived by the tourists, and also on the cultural value. In the studies dedicated to the impact upon environment, the most important category, whose weight must increase, is the management and economic use.

Results and discussions

For the selected geomorphosites (Table 1) there were applied (Table 3) the methods of evaluation mentioned above. For each of them, the total value was calculated and subsequently the rank held by the respective geomorphosite within the classification resulted from the respective evaluation, which allowed their comparison. The total rank results from the sum of ranks for each evaluation and it gives a generalized picture of every geomorphosite's value (Table 4). It is obvious that the subjectivism of the person who does the evaluation cannot be eliminated, and this is the reason why we consider this classification on ranks to be very important in minimizing it.

There can be noticed differences between the values obtained by different methods depending on the variables analysed, but the classification is usually the same, the variations being situated especially in the lower part of the classification (Table 4, 5).

There can be noticed that in all evaluations the Natural Bridge from Ponoare holds the first position, due to its uniqueness on the territory of Romania, to its special geomorphologic value, its status of monument of nature but also to the good accessibility and the large number of yearly visitors. This has the combined lowest rank (8). The field of limestones from Ponoare ranks second, both in the method proposed by us and as combined rank of all other methods (17). Except one geomorphosite – the

Băluţa Cave, there is a perfect correspondence between the ranks from the two evaluations.

Table 3 The evaluation of geomorphosites' value by different methods

Nr. crt	Name	Eval. of touristic value	Rank	Swiss	Rank	Modena	Rank	Cantabria	Rank
1	Băluţa Cave	0.5	4	0.40	3	0.23	4	0.45	5
2	Zătonul Mare Depression	0.5	4	0.33	4	0.44	2	0.50	4
3	Zătonul Mic Depression	0.46	5	0.25	5	0.44	2	0.66	3
4	The field of limestones-karrenfield from Ponoare	0. 75	2	0.66	2	0.44	2	0.67	2
5	Ponoare Cave	0.66	3	0.40	3	0.23	4	0.30	7
6	Băluţa Gorges	0.33	6	0.12	7	0.33	3	0.33	6
7	The sinkholes field	0.25	7	0.25	6	0.33	3	0.25	8
8	Ponoare Natural Bridge (God's Bridge)	0.84	1	0.75	1	0.5	1	0.78	1
Nr. crt	Name	Valladolid	Rank	Minho	Rank	Greek	Rank	Slavonian	Rank
1	Băluţa Cave	0.45	4	10.50	4	56	3	0.25	5
2	Zătonul Mare Depression	0.25	6	10.05	5	46	6	0.31	4
3	Zătonul Mic Depression	0.35	5	9.85	6	50	5	0.20	6
4	The field of limestones-karrenfield from Ponoare	0.50	3	11.44	2	64	2	0.55	2
5	Ponoare Cave	0.66	2	10.85	3	52	4	0.40	3
6	Băluţa Gorges	0.20	7	9.71	7	35	8	0.12	7
7	The sinkholes field	0.15	8	9.45	8	38	7	0.10	8
8	Ponoare Natural Bridge (God's Bridge)	0.75	1	12.30	1	85	1	0.66	1

Table 4 The sum of geomorphosites' ranks from Ponoarele protected area

Nr.crt	Name	Rank
1	BăluţaCave	32
2	Zătonul Mare Depression	35
3	Zătonul Mic Depression	37
4	The field of limestones-karrenfield from Ponoare	17
5	Ponoare Cave	29
6	Băluţa Gorges	53
7	The sinkholes field	55
8	Ponoare Natural Bridge (God's Bridge)	8

When evaluating the scientific value (the method from the University of Modena and Reggio Emilia) the deviation between the values is the most reduced (0.27), existing geomorphosites which have the same value due to the smaller number of criteria taken into consideration, but also due to the genetical-evolutive and morphological homogeneity of the analysed geomorphosites. Thus, the geomorphosite no. ,7 which in all evaluations has low ranks (6-8) presents rank 3 due to its special educational and research value.

The method referring to the evaluation of touristic value of geomorphosites presents the highest amplitude of the values (0, 49), amplitude which is given to the different aesthetic value of geomorphosites, but also to the absence of cultural elements.

According to the Swiss method, where management and use of geomorphosites are not taken into account, the lowest values are obtained (0.75 maximum and 0.12 minimum), a thing which is due to the high weight of additional values which do not represent the strong point of the selected geomorphosites.

The amplitude between values is pretty high (0.58), due to the introducing of the weight given to criteria.

The method from the University of Valladolid gives, as well as the Swiss method, a great importance to additional values, leading to values relatively low for geomorphosites (0.75 maximum and 0.15 minimum), but with a high weight, 70 per cent, of the values between 0.2 and 0.4.

The Slavonian method was applied only for geomorphosites of waterfall type and this is the reason why we consider it presents some lacks in order to be possible to be applied to different types of geomorphosites, determining relatively low amplitudes and an equalization of values.

Table 5 The evaluation of geomorphosites' value from Ponoarele protected area by the proposed method

Nr. crt	Name	Scientific value	Aesthetic value	Cultural value	Economic value	Management and use	Total points	Total evaluation	*Rank*
1	Băluţa Cave	12	8	2	6	8	**36**	**0.36**	*6*
2	Zătonul Mare Depression	12	10	2	6	9	**39**	**0.39**	*4*
3	Zătonul Mic Depression	12	10	2	6	9	**39**	**0.39**	*4*
4	The field of limestones-karrenfield from Ponoare	18	14	4	8	10	**54**	**0,54**	*2*
5	Ponoare Cave	12	8	2	8	10	**40**	**0.40**	*3*
6	Băluţa Gorges	10	10	2	7	8	**37**	**0.37**	*5*
7	The sinkholes field	11	9	2	7	6	**35**	**0.35**	*7*
8	Ponoare Natural Bridge Ponoare (God's Bridge)	19	16	8	14	18	**75**	**0.75**	*1*

We considered very purposefully the evaluation by the method from the University of Minho and we applied in this demarche the method of ranks. The values thus obtained also differ from the others, and they keep the classification established by the other methods.

The method applied by Zouros resembles the method proposed by us, both having a maximum score of 100 and being applied in case of some protected areas, at different scales. The maximum value is higher (85) in case of the Greek method compared to the value obtained by applying the proposed method (75), but the minimum value is the same (35), due to the higher weight in the evaluation of scientific, ecological values or of geodiversity.

The method we propose gives an equal importance to all the values of geomorphosites (scientific – where we also enclosed ecological, aesthetic, cultural and economic value), but also to the management and use of geomorphosites. The results obtained are presented in fig. 4 and except geomorphosite no. 8 it shows that it is not compulsory that geomorphosites with the highest scientific value must also have high values for additional criteria. The amplitude between the values obtained is 0.39, the majority of geomorphosites being enclosed between the values 0.3 – 0.4 (80 per cent).

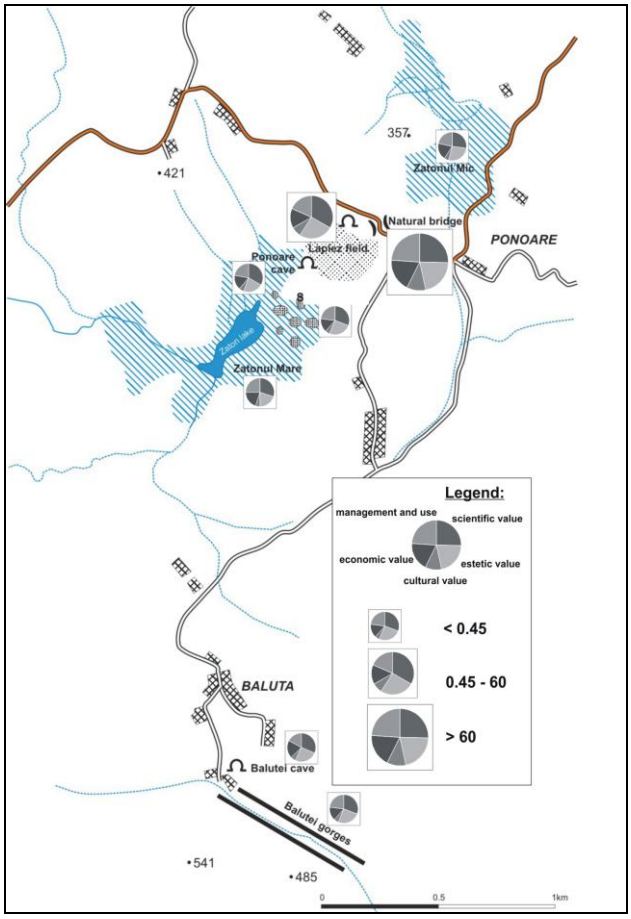

Fig. 4: Geomorphosites from Ponoare protected area - the evaluation of their value according to the proposed method

Conclusions

The method proposed was applied within Ponoare natural protected area, with the aim of increasing the role of geomorphology in the territorial management, in order to find the most adequate ways and modalities of introduction in the policies of local development. Only those geomorphosites which also present a touristic importance were evaluated. The results are useful for inventorying and classifying the geomorphosites from the analysed space.

Acknowledgements

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Morphometric Features of the River Network from the Bârlad Catchment

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Abstract

After a brief presentation of the Bârlad catchment, the hydrographic network is analyzed using the Horton-Strahler classification system. From the amount of morphometric parameters, the drainage and the slope patterns are taken into consideration for the entire Bârlad catchment and for the 13 hydrometric stations in the catchment that have data on water flows and suspended sediments. From those there were chosen the Vaslui hydrometric station as representative for the geomorphologic units of the Bârlad catchment and the Feldioara hydrometric station for the Berheci catchment. Based on the analyzed patterns there were determined a series of morphometric parameters specific to the river network for all the 13 analyzed stations and from their comparison one can see obvious differences between the obtained values for the basins in the Central Moldavian Plateau and the ones in the Tutovei Hills.

Keywords: *morphometric patterns, hydrographic network, geometric progressions*

Rezumat. Caracteristici morfometrice ale reţelei hidrografice din bazinul Bârladului

După o scurtă prezentare a bazinului hidrografic Bârlad, reţeaua hidrografică este analizată folosind sistemul de clasificare Horton-Strahler. Dintre parametrii morfometrici, s-au analizat doar scurgerea şi pantele pentru întreg bazinul hidrografic al Bârladului şi pentru cele 13 staţii hidrometrice din bazin pentru care există date despre debitul lichid şi al sedimentelor în suspensie. Dintre aceste staţii, am ales staţia hidrometrică Vaslui ca fiind reprezentativă pentru unităţile geomorfologice din bazinul Bârladului şi staţia hidrometrică Feldioara pentru bazinul Berheci. În urma analizării modelelor au fost stabilite o serie de parametrii morfometrici specifici reţelei hidrografice pentru toate cele 13 staţii analizate; a analiză comparativă relevă diferenţe semnificative între valorile obţinute pentru bazinele din Podişul Central Moldovenesc şi cele din Colinele Tutovei.

Cuvinte-cheie: *model morfometric, reţea hidrografică, progresii geometrice*

Introduction

The progress of contemporary society in the context of sustainable development requires, among others, detailed knowledge of the physical environment as support for human social activities. In this context there are included the efforts of the scientific research to find and quantify a number of morphometric parameters of detail, and on their basis to compare the river catchments as basic units in all the actions of water resources management. To verify the methodology of morphometric characterization of the river network, the Bârlad catchment was used, being large enough and located on lithological formations with small differences in the resistance to erosion. The final aim of such tests is to find the relation between the agent, in this case the water, and the landforms generated during the evolution in time, thus to decode the information stored in the landforms.

The detailed studies carried out by the geographical school of Iaşi and Suceava (following the studies at the Stejaru Research Station- Piatra Neamţ) have clarified many issues concerning the knowledge of the entire complex of physico-geographical factors in the Bârlad catchment. The processes of torrential erosion and gullying have been investigated, the latter included in the comprehensive studies of dynamic geomorphology (Rădoane Maria, et. all., 1988; Ioniţă, 2000a; Hurjui et. all., 2008; Vasiliniciuc and Ursu, 2007 etc.).

The studies of the authors mentioned above are related to the spread and dynamics of gullies and landslides carried out by Rădoane Maria et. al., (1990, 1994, 2001), Ioniţă, (1997, 1999, 2000b), Hurjui, (2000, 2008), Niacşu, Ursu, (2007) etc. and conclude that the areas most susceptible to gullying dominate

large surfaces in the Tutovei Hills and Fălciului Hills with a density reaching 2-3 km/km^2.

The morphometry of the hydrographic network as the main collector of surplus water from the slopes, however, is less often mentioned. The material and energy flow in the smallest to the largest catchments, contribute to measure a morphology represented by the network of river beds with morphometric features which can be determined and measured or calculated. Knowing these characteristics, an important step is made in the knowledge of the features of the physical environment as support for human social activities, currently conducted there.

A series of morphometric parameters were used to date, but only sporadically and disregarding their catchment controls. This paper aims at meeting this requirement using the morphometric analysis of the network from the entire Bârlad catchment and for sub-basins, seeking the achievement of some parameters that can be used successfully in their differentiation and individualization.

Methodology

To determine the morphometric features of the hydrographical network in the Bârlad catchment, the information was used from the topographic maps at the scale of 1:25000, which we consider satisfactory for the degree of details it provides. The morphometric elements for the entire catchment of the Bârlad river and of sub-basins with hydrometric stations were obtained as follows:

- after digitizing the entire hydrographical network, (the vector of line type which contains in the database information such as: hydronym, order in Horton- Strahler system, length), it was verified topologically so that the vector do not have errors such as: intersections, overlaps, free segments etc.;
- gradually the start and end points of each river segment - Feature Vertices To Points – were generated in ArcGIS;
- altitudinal values were assigned to the two themes of point type mentioned above, taken from the numerical model of the land- Extract Values to Points – in ArcGIS;
- in the next step, using the Join function there was joined the information from the themes of point type, themes representing the hydrographic network- at this time, adding in the attribute table two more columns: H_{max}- with the altitude of the starting point of the stream segment and H_{min}- with the altitude of the final point of the stream segment;
- after operating in the database, from the subtraction of the 2 columns H_{max}-H_{min} resulted the differences of level of successively higher orders river segments (ΔH).

Once the digitizing was done, a ranking of the network of 2nd to 8th order river segments was done. There was started from the 1st order considered the river segment which morphologically has the ability to guide and organize the surface drainage. It is individualized by a springhead and on all the way it does not receive any tributary stream. From the junction of 2 segments of 1st order it results a segment of 2nd order and so on until reaches the river course of the highest order. In this classification there has been established a set of rules that are necessary to be applied in the ranking process. Thus, a course of a certain order can receive tributaries of lower orders without changing its order, which happens only if it junctions with another river segment of the same order.

The analysis of the hydrographic network from the Bârlad catchment can be done by taking into consideration the evolution in time of the drainage which eventually reached the current plan configuration which can be measured and studied to identify the most relevant issues. The entire catchment and the main course are of 8th order in the Horton-Strahler classification system (Fig. 1). Given the fact that the evolution of the hydrographic network follows a series of laws of probability and the morphometric elements of the river segments of each order can be analyzed, whereas their average sums and values form geometric progressions which can be checked very well. In this situation a lack of a term, of 1st order for example, can be obtained by calculation, reducing by half the working and classification time if one starts from 2nd order up.

The procedure is recommended because for the 2nd order segments there can be easily determined the starting point at the junction of 2 segments of 1st order while for the segments of 1st order setting the starting point raise problems due to the high degree of operator subjectivity, not being clearly emphasized morphologically.

By applying the mentioned methodology, during the digitization the entire network of river segments of the Bârlad catchment was classified, there was calculated their length and the differences of level of the each segment` s start and end points. In this way

there were obtained a series of data which allowed the setting out of laws which define the drainage and slopes pattern.

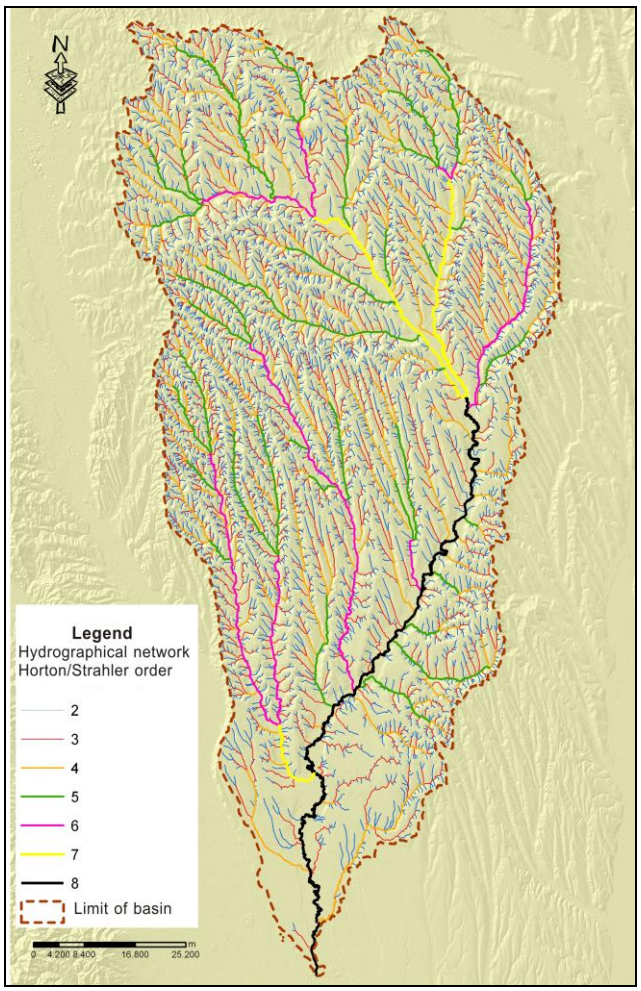

Fig. 1: Horton-Strahler classification of hydrographical network - Bârlad basin

In the case of the Bârlad catchment there were analyzed the morphometric patterns of drainage and slopes as well as the laws that determine them, both for the entire catchment and also for a series of sub- basins at the hydrometric stations which have determined the water flows and the suspended sediments.

To determine the morphometric features of the hydrographic network on catchments the law of the number of river segments was used. From the statistical analysis of the number of river segments of constantly higher order, it is noted that in the end there are obtained a series of data with 7 values corresponding from the 2nd to the 8th order. By representing these values in semi-logarithmic coordinates depending to the order, it is found that the number of river segments of successively higher order tends to form a decreasing geometric progression where the first term is given by the number of 1st order (2nd order) river segments and the ratio is given by the confluence ratio (Rc). To calculate the confluence ratio there are used the weighted arithmetic average through number of segments and the rule of chosen points (Fig. 2Aa). In this case the geometric progression ratio was determined by the method of chosen points, respectively for the values obtained for the 2nd and 4th order using the formula:

$$Rc = \sqrt{N2/N4}$$

When using this formula there was taken into account the fact that to determine the ratios of these progressions there should focus on the lower orders which statistically speaking have the highest rate in comparison to the higher segments, which being in a very small number they may deviate more or less from the rule. The obtained series of data and their verification through graphic representation proves the fact that we have a decreasing geometric progression which states that the number of river segments of successively higher orders tend to form a decreasing geometric progression where the first term is given by the 1st order river segments and the ratio is the confluence ratio (Fig. 2Aa). Using the confluence ratio to calculate the values starting from one of the values involved in its determination, respectively the 2nd order, the differences appear to be very small and hence we can calculate the number of river segments of 1st order. In this case the high value of the confluence ratio shows a high degree of branching and relief fragmentation favored also by the relatively soft geological formations with a low resistance to erosion.

Study area

The Bârlad river, a left tributary of the Siret river covers a catchment area of 7253km^2, with an average height of 212 m and a minimum of 15 m (close to the confluence with Siret) and a maximum of 564m in the Doroşanu Hill. The average slope of the basin is of 5/1000 with small variations between the subunits of landform that it drains (Panaitescu E. V., 2008). The annual average flow is 10.4 m^3/s at the Tecuci hydrometric station, without receiving any important tributary to the mouth of the river.

In terms of geomorphology, the catchment covers the Central Moldavian Plateau in the north, the Tutovei Hills in the west, the Fălciului Hills in the south-east, and a small part of The Tecuci Plain in

the south. The entire morphography is the direct result of the interaction between the geological structure, lithology and the subaerial agents. The geology is represented by sedimentary formations, dominated by sands, marls, clays intercalated with more consolidated layers of sandstones and limestone arranged in a dominant monoclinal structure. The tectonics within the basin does not show a significant mobility without consequences upon the current geomorphologic processes.

The current landforms resulted from the modeling of the Sarmato- Pliocene plain, which suffered tilting movements and a slight elevation, are fragmented and transformed into a region with a morphography dominated by structural plateaus, hills and even hilly aspect, arranged largely in interfluves generated by the tributaries of the Bârlad river with a consequent and less obsequent and subsequent orientation. The shape of the slopes varies from those rectilinear to the corrugated ones affected by intense degradation processes (landslides and gullying).

The declivity is dominated by low sloped areas which do not exceed 5° located on structural surfaces, generally with southern exposure, but there are values of declivity which exceed 20° on the escarpment slopes oriented generally north or north-west. The structural relief has the print of the interaction between the agents and the current processes on the geologic substrate. Given the general inclination of strata from north-north-west to south-south-east we notice that the structural plateaus and the escarpment ridges have also influenced the rivers` flow direction.

The sculptural landforms are determined by structural and lithological characteristics and by their modeling, carried out predominantly by the normal erosion of the hydrographic networks from the early forms to the well organized ones, being whether temporary or permanent.

In the plateau, the current processes are located mainly on slopes and especially on the escarpment ones. Among the dominant processes in the Bârlad Plateau, there are noted landslides, torrents and gullies and sheet wash. The landslides are on almost all the catchment area, but have higher dimensions in the south of Central Moldavian Plateau and sporadically in other subunits (Vasiliniciuc and Ursu, 2007).

Results and discussions

From the measurement of the river segments length for each order, summed by orders, a range of data is obtained which represented on the same graph, also on the logarithmical coordinates depending on order, and it highlights also a decreasing geometric progression. It states that the amounts of the summed lengths of the river segments of successively higher orders tend to form a decreasing geometric progression where the first term is given by the sum of the first order segments length and the ratio by the measured and summed length ratio (RL) (Fig. 2Ab). To calculate the summed lengths ratio, the same rule applies as for the number of river segments.

Comparing the range of the summed lengths to the number of river segments a third set of data is obtained representing the average length of river segments. It states that the average lengths of river segments of successively higher orders tend to form an increasing geometric progression where the first term is given by the average length of first order segments and the ratio by the average lengths ratio (r_l) (Fig. 2 Ac). In this case the ratio can be determined by the multiplication of the confluence ratio (R_C) and the summed lengths (R_L).

Another important element for the development of transport and accumulation processes of erosion along water courses is the slope of the river segments network which can be determined by using data obtained from the use of the same classification system. In the case of Bârlad catchment, the law of watercourses length included in the drainage pattern which can be checked very well with only a single deviation, respectively a higher value for the river segments length of the last order (Fig. 2Bb).

To calculate the slopes it is necessary to determine the rules by which the sums of the differences of level of the river segments of different orders vary. For this, in testing areas there were determined for each river segment of higher order the height of the start and end points and there were compared with those extracted from the Numerical Model of Land using GIS.

The insignificant differences between the obtained values in the two ways, it allowed using the latest method, easing substantially the work. From summing up the differences of level by order, there were achieved a series of seven values which represented in logarithmical coordinated outlines the

law of sums of differences of level. This states that the sums of differences of level of river segments of successively higher orders tend to form a decreasing geometric progression where the first term is represented by the sum of the differences of level of the first order, and the ratio is given by the ratio between the differences of level (R_H) (Fig . 2Ba).

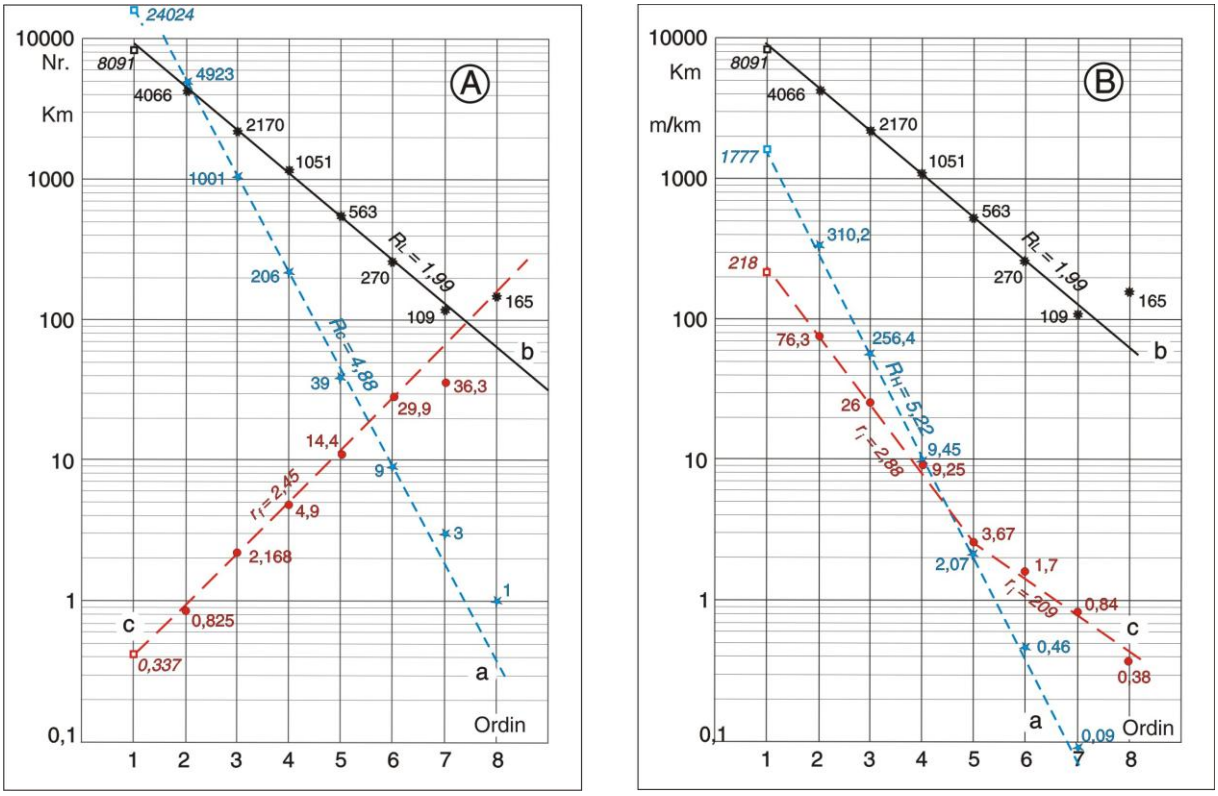

Fig. 2: The Bârlad Catchment. A. The drainage pattern; a, the law of the number of river segments, b, the law of the summed lengths by order (in km); c, the law of average lengths (in km), B. The slopes pattern; a,the law of sums of differences of level (in km)

Knowing that the slope of a stream is given by the ratio of the difference of level and the main course length, this reasoning may be also applied in the case of law of sums of differences of level and the sum of length of different orders courses (Fig. 2Bc). Thus, by the simple relation between the two rows of data of corresponding order, we may obtain a third set of data of the average slopes of streams which also represented in the same graph in logarithmical coordinates outlines the law of average slopes which can be formulated as follows: the average slopes of the successively higher order watercourses tend to form a decreasing geometric progression where the first term is given by the average slope of first order segments and the ratio by the slopes ratio (r_i) (Fig. 2Bc). The ratio can be easily determined as the ratio of the ratios of the two laws of the sums of differences of level and of the summed lengths (Zavoianu I., 1974, 1985, 2006).

The same result is reached also if instead of the summed values there is used the geometric progressions of the average differences of level and of average lengths of courses of successively higher orders. In the case of the average slopes of river segments of different orders it is found to be the law which verifies the best, and can be explained if we consider the fact that the slope is the most dynamic morphometric element, able to adapt quickly to environmental conditions and matter and energy flow moving through the catchment and bed rivers networks. In this case there is found that two line segments are different from the slopes law, respectively one segment from the 1st to the fifth orders and the second segment of line for higher orders with a value of slope coefficient less than 2.08 instead of 2.88 (Fig. 2Bc). The difference between the lower orders slope much higher and the higher slopes which is lower, can be explained by differences between the drainage regime of lower order segments where the temporary drainage and the more powerful erosion processes over time are predominant, while at the higher order courses predominates a drainage regime more balanced with a decrease in the

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intensity of erosion processes and the predominance of transport and accumulation processes which highly contribute to reduce slopes and to configure a different pattern of evolution.

To check whether the laws thus defined in the case of large catchments are also valid for sub-basins at the hydrometric stations that control catchments with very different surface sizes, there have been seen more sub-basins carved also in sedimentary formations with small differences in the resistance to the subaerian agents action. The Bârlad catchment was analyzed at the Vaslui hydrometric station located entirely in the Central Moldavian Plateau where the erosion action of the hydrographic network has encountered the resistance of the deposits of clays, marls, sand with oolitic limestone and sandstones intercalations. From the second highest landform in Bârlad Catchment, The Tutovei Hills carved in unconsolidated deposits of sands, loamy sands, clays and marls (Jearenaud J. Saraiman A., 1995) there was studied the Berheci catchment at the Feldioara hydrometric station.

The morphometric pattern of the drainage of the Bârlad catchment at the Vaslui hydrometric station suits well to lower orders streams with minor deviations in the case of the higher ones (Fig. 3A).

The law of the river segments of successively higher order can be checked very well with the exception of the seventh order segment which deviates (Fig. 3Aa). Calculating the total number of the river segments of successively higher order, there is found very small differences compared to the measured values, in this case we may conclude that the seventh order course is made only in proportion of 49%, requiring yet lower orders segments to fully realize the order that it has.

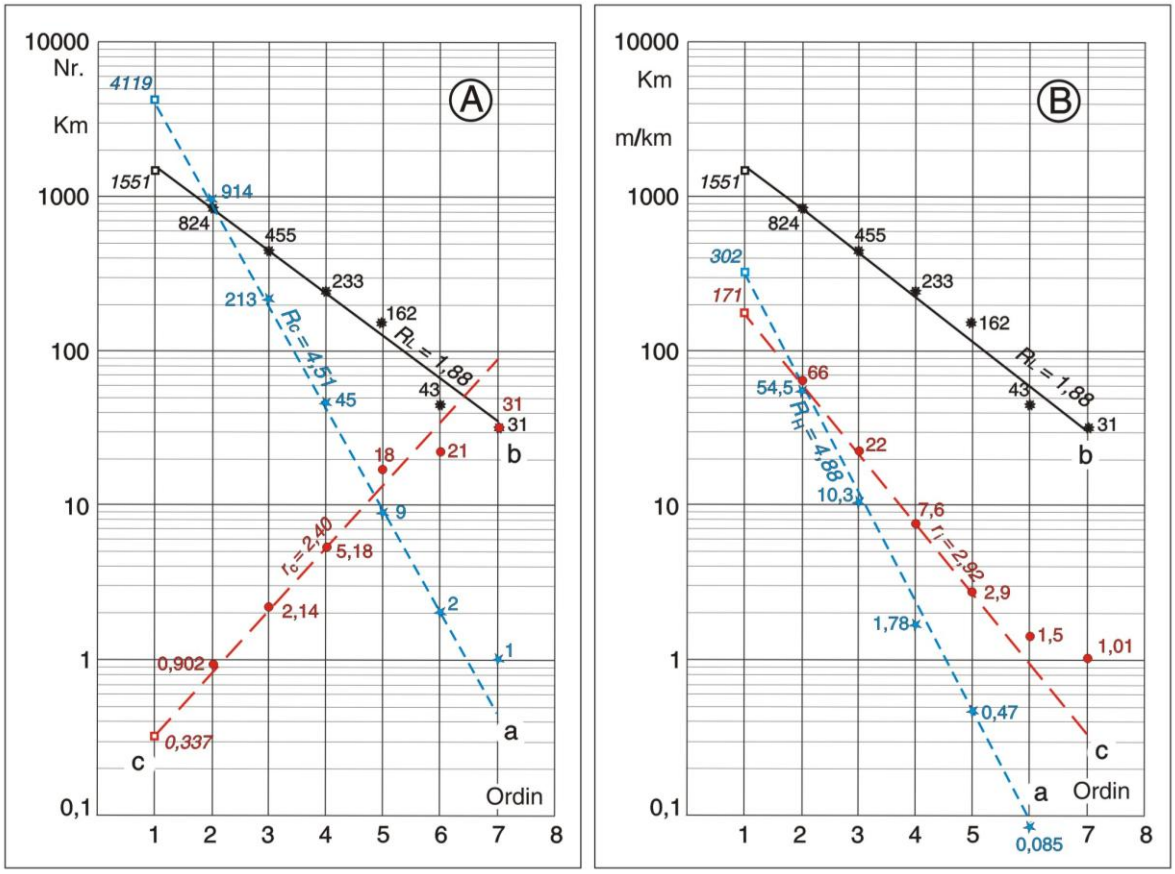

Fig. 3: The Bârlad catchment at the Vaslui hydrometric station. A. The drainage pattern; a, the law of the number of river segments; b, The law of the summed lengths by order (in km); c, the law of average lengths (in km); B. The slopes pattern; a, the law of differences of level sums (in km); b, the law of summed lengths by order (in km); c, the law of average slopes (in m / km)

The law of the sum of river segments length of successively higher order can be well verified up to 4th order with small deviations for the 5th and 6th orders which reflects upon the law of the average lengths (Fig. 3Ab,c). The fact that the morphometric laws can be checked well for the lower orders allows the determination of values for the first

order and the calculation of indices in order to characterize the catchments.

For the slopes morphometric pattern, we already have the law of sums of river segments lengths of successively higher order, and we will determine the law of the summed differences of level also by orders of the river segments. These values (in km), represented in semi-logarithmical coordinates verify very well the law of differences of level with a small deviation of the values for the 4th and 7th orders (Fig. 2Ba). The third law of the pattern determined as a result of the ratio between the sequence of the summed differences of level and of the lengths sums is the law of the average slopes of successively higher order river segments (Fig. 3Bc). In terms of the environmental factors from the Central Moldavian Plateau, this law checks very well for the lower orders from two to five but the values are deviating for the last two orders, indicating a tendency to define a second straight line as it may be indicated in the case of the entire catchment (Fig. 3Bc).

As a representative catchment for the Tutovei Hills, the Berheci catchment was chosen at the Feldioara hydrometric station with a pronounced degree of elongation. The analysis of the drainage morphometric pattern in this case proves that all the three laws of the number of river segments, of the sums of lengths and of the average lengths of river segments of successively higher order, can be checked well enough (Fig. 4Aa, b, c).

The deviation from the law of the lengths for the 3rd and 6th orders with higher values in comparison to what would foreshow the law may be a consequence of the elongation degree of catchments and drainage valleys.

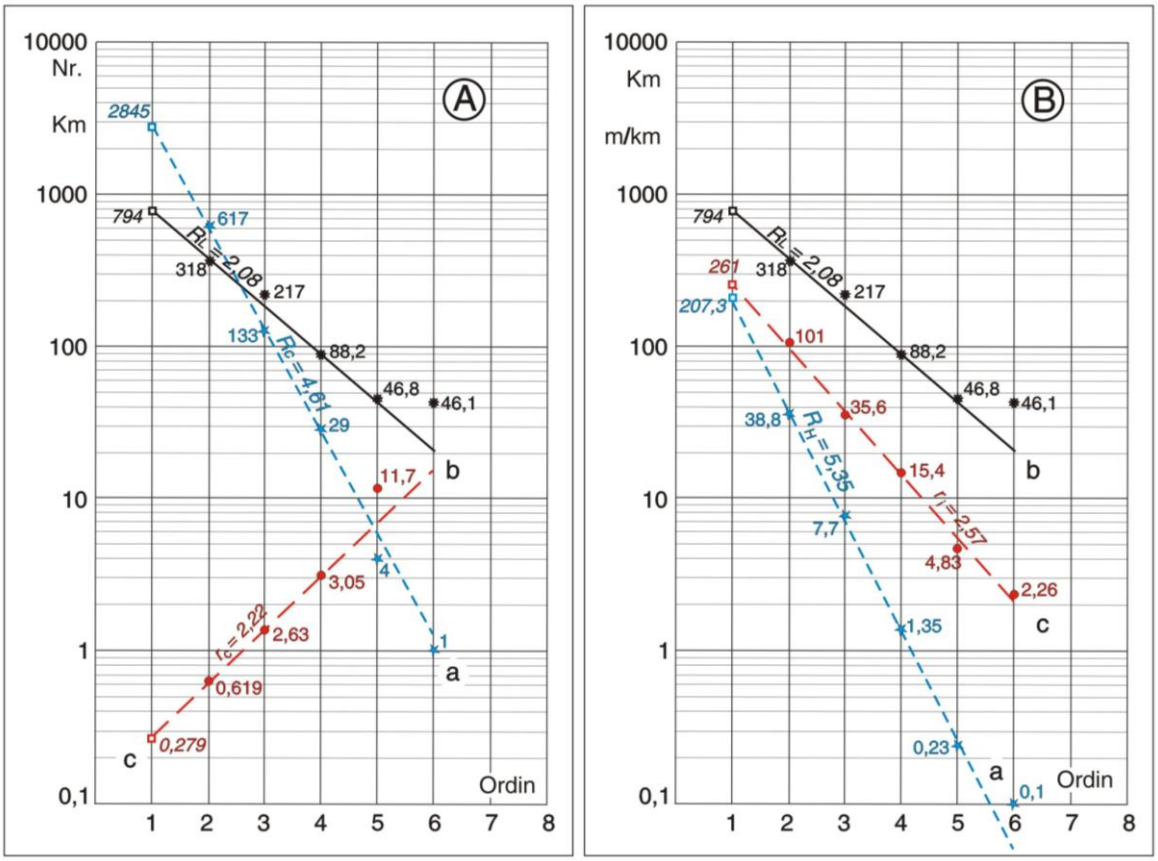

Fig. 4: The Berheci catchment at the Feldioara hydrometric station. A. The drainage pattern; a, the law of the number of river segments; b, the law of summed lengths by order (in km); c, the law of average lengths (in km); B. The slopes pattern; a, the law of sums of differences of level (in km); b,the law of summed lengths by order (in km); c, the law of average slopes (in m / km)

The slopes morphometric pattern defined by the law of differences of level and the one of the sums of river segments length configures the law of average slopes (Fig. 4Ba,b,c). The representation of the obtained values in logarithmical coordinates shows the fact that the slopes law is the law that best verifies, being the most dynamic in adapting to the conditions provided by the environmental factors and particularly to the flow of matter and energy flowing through the bed rivers network.

The determination of the patterns for all the hydrometric stations which have data on water flows and suspended sediments of the Bârlad catchment and their checking proves the fact that these morphometric laws can be analyzed both on catchments at confluences and at the hydrometric stations to be correlated with the liquid and solid flow. Based on the drainage morphometric pattern there was calculated the frequency of the river segments as ratio between their total number and the area controlled by the hydrometric station, the length of first order segments and the drainage density. In the slopes morphometric pattern there was calculated the average slope of the first order segments and the average slope of the entire network of rivers from the studied catchment. The average length of slope drainage, important for the calculation of drainage time on the slope, it was calculated using the formula recommended by Horton (1945) as being equal to the reverse of the double of the drainage density.

From the analysis of the specified parameters in the catchments controlled by the hydrometric stations there can be seen that there are some differences between the catchments located in the Central Moldavian Plateau and the ones in the Tutovei hills. There can thus be seen that the frequency of the river segments in the Tutovei Hills is almost double than that from the Central Moldavian Plateau, while the length of the first order segments is higher in the Plateau. There are obvious differences in terms of drainage density that has values between 2.06 and 2.33 km/km^2 in the Central Moldavian Plateau while in the Tutovei hills it can reach up to 4 km/km^2. Differences can be observed also in the analysis of the slopes of the first order river segments and of the average slopes of the network for the whole catchment controlled by hydrometric stations. An important factor for the processes of drainage on slope is the length of the drainage on slope. If it has lower values it implies a fast gathering of waters in the bed rivers network, while a high value implies a longer duration for crossing the slope, so small lengths of slope drainage associated with reduced lengths and large slopes of 1st order watercourses favor the rapid process of formation of flood waves during downpours and a high power of erosion and transport (Table 1).

Table 1 The morphometric features of the hydrographic network at the hydrometric stations in the Bârlad catchment

River	Station	Sb (km^2)	Fr.$_{s.}$	l_1 (m)	Dd (km/km^2)	i_1 (m/km)	$i_{m.r}$ (m/km)	l_{sp} (m)
Sacovăţ	Şofroneşti	295.8	3.20	361	2.06	147	79.9	243
Bârlad	Negreşti	805.7	3.25	369	2.06	180	100.9	243
Bârlad	Vaslui	1537.1	3.45	361	2.15	147	112	233
Bârlad	Bârlad	3988	3.85	354	2.24	212	124	223
Bârlad	Tecuci	6791	4.34	340	2.36	222	133	212
Vasluieţ	Codăieşti	170.2	3.84	380	2.33	203	121	214
Tutova	Plopana	15.3	6.73	472	3.95	246	172	126
Tutova	Rădeana	172.7	6.83	485	4.13	253	183	121
Berheci	Feldioara	514.6	7.05	279	3.06	261	162	163
Zeletin	Galbeni	403.7	7.35	291	3.17	254	201	158
Racova	Ivăneşti	180.9	4.63	344	2.54	261	155	197
Durduc	Frenciungi	158.1	4.15	320	2.25	193	110	222
Simila	Băcani	246.7	5.05	235	2.21	267	145	226

Sb – the controlled area; Fr.$_{s.}$- frequency of river segments; l_1 – the lenght of 1st order segments; Dd – the drainage density; i_1 – the slope of the 1st order segment; $i_{m.r}$ – the average slope of the entire segments network in the catchment area; l_{sp} – the length of the drainage on slope.

Conclusions

From the analysis of the morphometric patterns determined for the Bârlad catchment and for the sub-basins within the Central Moldavian Plateau and the Tutovei Hills, there can be concluded that in all the cases, the morphometric laws can be verified very reliably for the lower order basins and with small deviations in the case of the higher ones (higher than five). All physical-geographical factors and in particular rocks and the geological structure have a bearing on the degree of relief fragmentation and on the size of some morphological parameters.

The checking in good conditions of the morphometric laws that define the drainage and the slopes of the rivers network allows the calculation of

indices that can be used both to characterize the situation in the catchments and with practical purposes related to the assessment of the hydric potential of the territory. From the analysis of these indices, in the Bârlad catchment there are significant differences between the values of the parameters calculated for the sub-basins located in the Tutovei Hills compared with those from the Central Moldavian Plateau, having a higher intensity of erosion processes in the former case.

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The Studineţ Basin (Tutova Hills). Morphometric Indicators and Correlations

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Abstract

The morphometric analysis doesn't imply just the quantitative description of the relief, although it is frequently limited to it, but also a methodological approach that allows the typological classification of landforms and establishing some significant correlations between the selected parameters and other geomorphologic, geologic indicators etc. The testing and validation of such analyses is performed upon representative samples on different scales. This article aims to interpret some morphometric indicators and correlations within the Studineţ hydrographical basin (9669 ha), located in the central part of the Tutova Hills, in the eastern part of Romania. The region's relief is grafted on sandy-clayey and clayey-loamy deposits from the Kersonian and Meotian, being characterized by a relatively high fragmentation for a hillyregion (Jeanrenaud, 1971, 1995). The maximum altitude gap ranges between 108.9 and 485.5 m, and the relief energy values facilitate morphodynamic imbalances expressed through different geomorphological processes. The main characteristic is the presence of cuestas with morphometric, morphodynamic and land use asymmetries. The present scientific approach analyzes every derived map by interpreting the unclassified rasters (pixel value) and the classified ones (class value), comparing the relevance of the results to obtain the optimal number of classes and to establish the limits that have the best geomorphological level of significance. Given the region's features, the analysis of cuestas was favored to differentiate the cuesta fronts and backslopes. Finally, on a representative perimeter within the basin, the raster histograms (hypsometry, declivity, exposition) were compared, to highlight the differentiations caused by the map scale and pixel resolution.

Keywords: *the Studineţ basin, morphometry, indicators, correlations, GIS*

Rezumat

Bazinul Studinețului (Colinele Tutovei). Indici și corelații morfometrice. Analiza morfometrică nu implică doar o descriere cantitativă a reliefului, deși frecvent se limitează doar la acest lucru, dar și o abordare metodologică cară să permită stabilirea unei tipologii a platformelor și individualizarea unor corelații semnificative între parametrii selectați și alți indici geomorfologici, geologici etc. Testarea și validarea unei astfel de analize se face pe baza unor mostre semnificative la scări diferite. Prezentul articol prezintă unii indici și corelații morfometrice în bazinul hidrografic Studineț (9669 ha), localizat în partea centrală a Colinelor Tutovei, în estul României. Relieful regiunii este dezvoltat pe depozite nisipo-argiloase și argilo-marnoase din Kersonian și Meotian, caracterizat printr-o fragmentare relativ ridicată pentru o zonă deluroasă. Altitudinile variază între 108,9 și 485,5 m, energia reliefului favorizând dezechilibrele morfodinamice, vizibile în diferitele procese geomorfologice. Principala caracteristică o reprezintă prezența cuestelor, cu asimetrii morfometrice, morfodinamice și din punct de vedere al utilizării terenurilor. Studiul de față analizează fiecare hartă rezultată prin interpretarea rasterelor neclasificate (valorile unui pixel) și clasificate (valorile claselor), comparând relevanța rezultatelor pentru a obține numărul optim de clase și pentru a stabili limitele pentru cea mai mare semnificație din punct de vedere geomorfologic. Ținând cont de particularitățile regiunii, s-a preferat analiza cuestelor pentru diferențierea frontului și reversului cuestei. În final, pentru un perimetru reprezentativ pentru bazin, histogramele raster (hipsometrie, declivitate, exposiție) au fost comparate pentru evidențierea diferențelor datorate scării hărții și rezoluției.

Cuvinte-cheie: *bazinul Studinețului, morfometrie, indici, corelații, SIG*

Introduction

The Studineţ hydrographical basin (9669 ha) is located in the central-eastern part of the Tutova Hills, being an affluent of the Tutova River (Fig. 1).

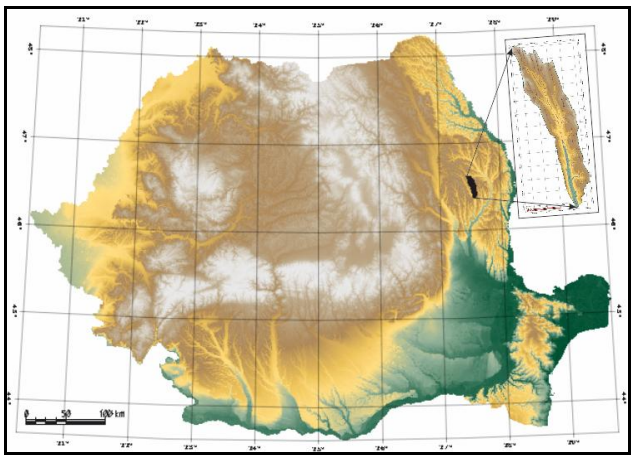

Fig. 1: The geographic position of the Studineț basin

The Studineț catchment, althought it is located in a hilly area, monotonous in terms of morfometric aspects, represents a very complex area of study, with morphometric particularities typical to Tutova Hills. This entails the need for a closely knowledge of genesis an relief evolution, and the main types and landforms in the catchment.

Although, apparently, this study follows a classical structure, is will overlap a schema of analysis that will include:

- a detalied morphometric analysis, in order to define and frame the dominant typological landforms, in the concerned area
- the analysis of all derived maps and the corroboration of all numerical data, extracted from the unclassified rasters and from the classified ones, in order to achieve a geomorphological characterization
- to create a digital cartographical support for a representative area, with different scales of analysis, to emphasize the errors that may appear in a geomorphological analysis, if it used a wrong pixel value resolution.

Among the authors with outstanding works on the theme of our research, it is worth mentioning Richards'contributions (1982, 1995) - requiring new approches with regard to the dynamics of the relief.

A modern approach, using different digital systems and statistical and mathematical equations, formed the basis of outstanding works, that focused on data integration of land use parameters in digital models: Pennock, B.J. Zebarth, E. De Jong (1993), Mc Brateney, Odeh, Bishop, Dunbar, Madison, Shatar (2000); - the use of GIS and remote sensing analysis of geomorphological processes: Haidu I., Haidu C.(2003), Condorachi (1999, 2005 a, b), Niacşu , Ursu (2007), Patriche (2009), Posea (2003) etc.

Data and methods

The present scientific approach starts from the digital elevetion model (10x10m), based on the 1:25000 topographic maps, made with the TNTmips 7.3 software. The derived maps – hypsometric, declivity, slope exposition and fragmentation depth maps – were created and classified starting from the primary model. These maps were complemented with the drainage density map and a series of representative cross sections. The analysis of each map was made by interpreting the unclassified rasters (pixel value) and the classified ones (class value), comparing the relevance of the results to obtain the optimal number of classes and establish the limits that have the best geomorphological level of significance.

On a representative perimeter within the basin, the raster histograms (hypsometry, declivity, exposition) were compared, to highlight the differentiations caused by the analysis scale and pixel resolution (1:25000 and 10x10m, 5x5m, 2.5x2.5m; 1:5000 and the same resolution values).

Results and discussions

From a hypsometric point of view (Fig. 2), the Studineț basin has an average altitude of 297.5 m, with a maximum variation gap of 370 m. Regarding the proportion of altitudinal steps, the altitudes between 250 and 300 m are dominant (21.25 per cent), followed by those between 200 and 250 m (19.72 per cent) and those between 300 and 350 m (18.17 per cent), altitudinal steps which correspond mostly to the slopes. The altitudes over 450 m have the smallest share (only 0.34 per cent); these cover very small areas on interfluvial hilltops, at the Studineț headwater and on the Iezer-Studineț interfluvial hilltop. The altitudes between 100 and 150m represent a relatively small proportion also (5.25 per cent), these altitudes corresponding to the Studineț floodplain and to the correlation of terraced in the central-southern part of the basin.

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Regarding the declivity of the land, it can be noticed an oveall dominance of lands with slopes between 5 and 10˚, representing 29.59 per cent, and between 10 and 15˚, representing 30.52 per cent (Fig. 3). Through this gap, which totals a value of 60.11 per cent, it is highlighted the fact that slopes create the dominant landscape within the basin. Land declivity decisively influences the erosion processes on slopes by progressively potentiating raindrop erosion or modifying the runoff speed, the slope's high values determining an acceleration of the gullying.

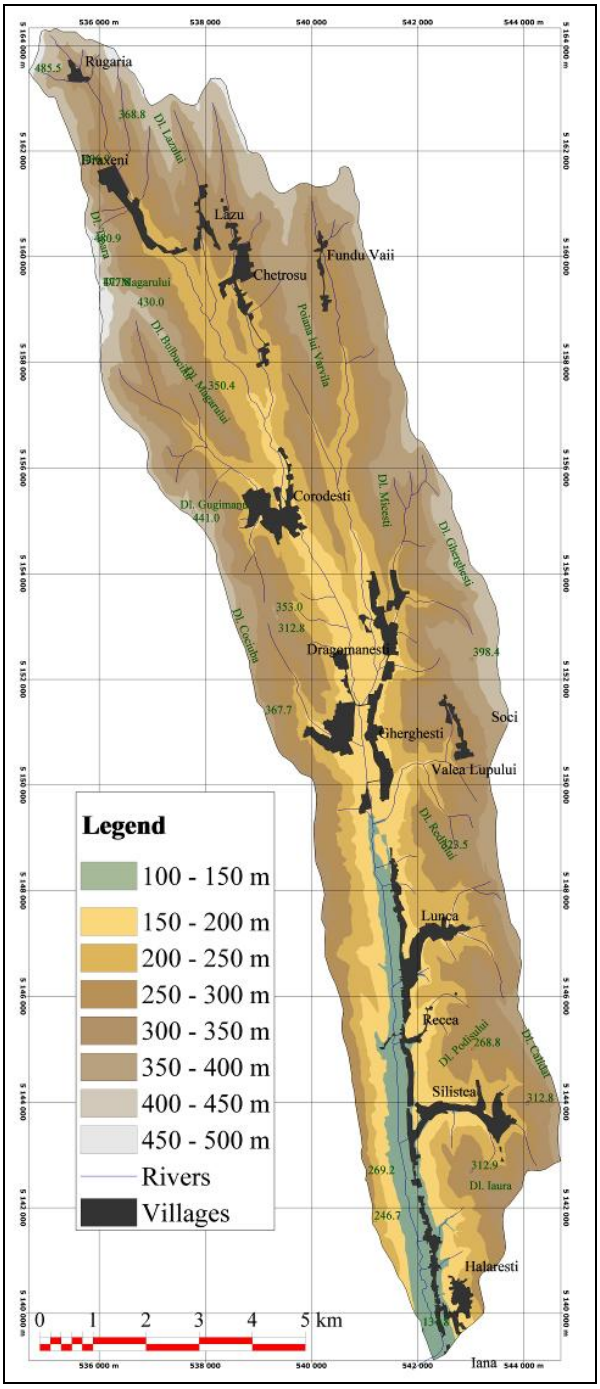

Fig. 2: **The Studineț basin. Hypsometric map**

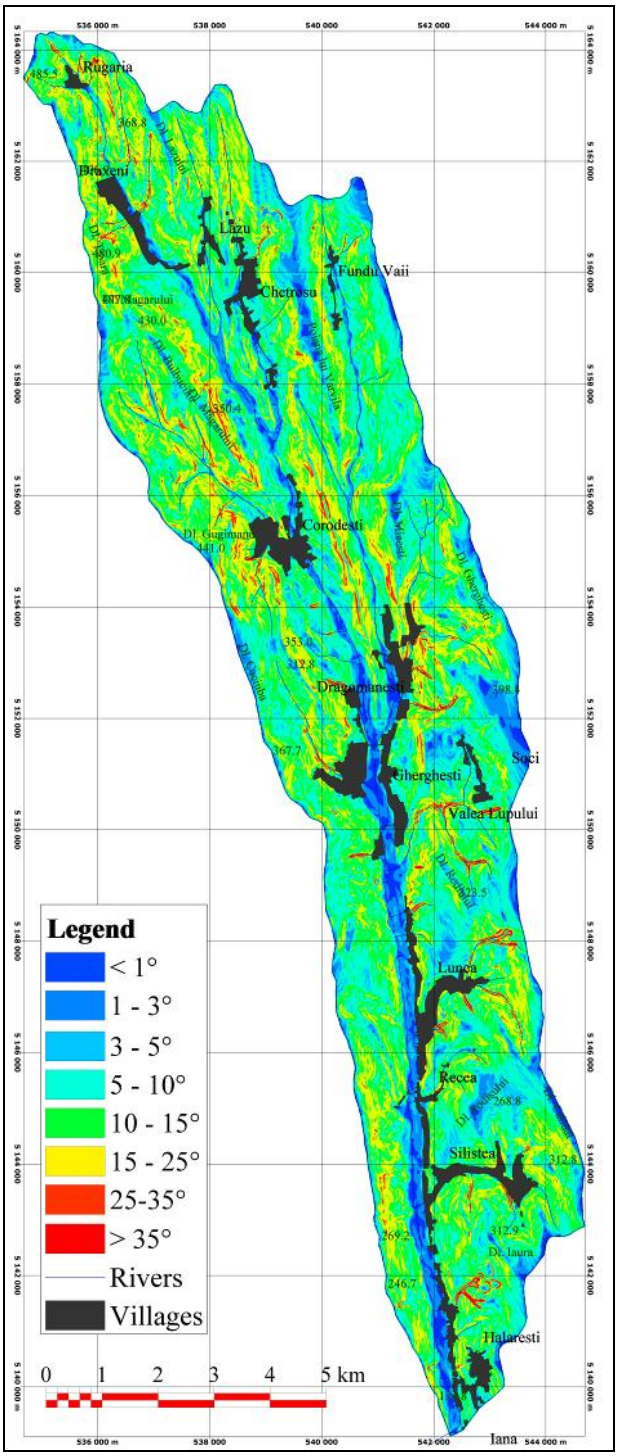

Fig. 3: The Studineț basin. Slope map

Within the analyzed basin, declivity varies proportionally to the relief fragmentation depth. To calculate this parameter, there were created grids with areas of 0.25km^2 , which show that in the Studineț basin the average value of relief fragmentation depth is 74.7m. The value class differentiations are eloquent, being at the same time closely related to the other morphometric parameters. Low values, of less than 40 m, represent

a very low proportion (3.15 per cent), being mostly distributed in the lower and middle basins. Conversely, fragmentation depth between 80 and 100 m holds the highest percentage in the basin, with a 30.01 per cent share, followed by the values between 100 and 120 m (21.43 per cent). This shows that the Studineț basin is characterized by a very high relief fragmentation (Fig. 4).

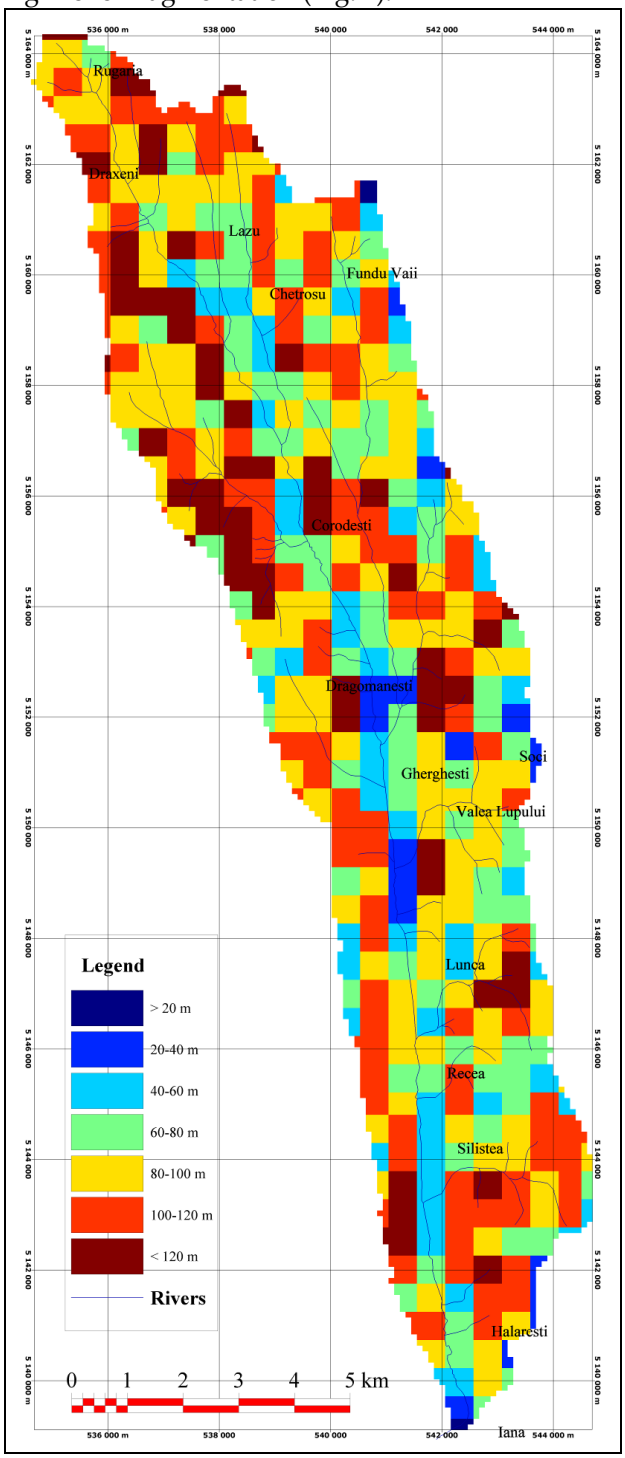

Fig. 4: The Studineț basin. Fragmentation depth map

Slope exposition (Fig. 5) depends on the general pattern of land fragmentation, being generally defined by the orientation of the interfluvial hilltops on the north-south direction and implicitly a dominant orientation of the slopes on the eastern and south-eastern components, and western and north-western respectively. The first component includes the slopes with eastern exposition (30.12 per cent) and south-western exposition (35.30 per cent).

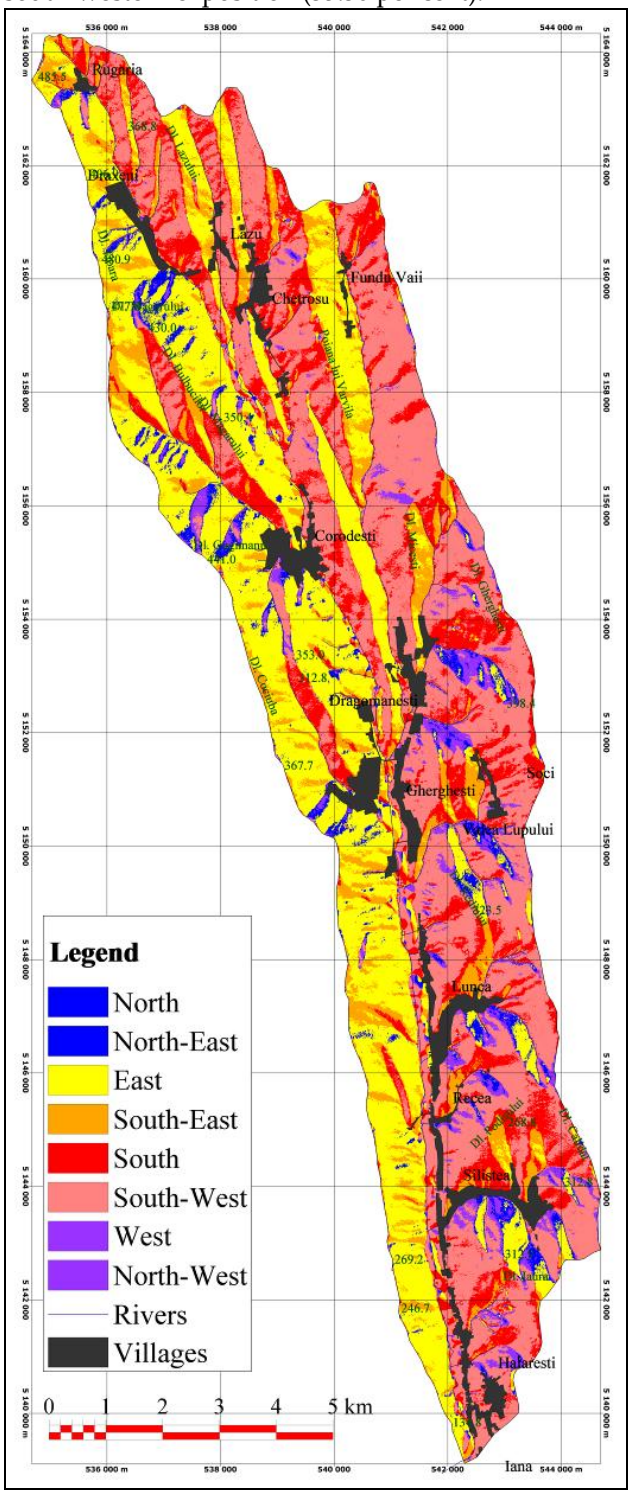

Fig. 5: The Studineț basin. Slope exposition map

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The slopes with an eastern exposition represent cuesta backslopes. The second component includes slopes with south-eastern exposition (10.73 per cent) and southern exposition (15.93 per cent), corresponding to the general layer inclination, thus to the terminal parts of the rolling hills, and also slopes with north-western (0.04 per cent) and northern (0.29 per cent) exposition, characteristic to the cuesta forehead typical to the primary asymmetry found on the small, subsequent affluents on the left side of the Studineţ, an area intensely fragmented by such torrential formations.

This study aims to accomplish both a complex analysis of the morphometric variables and the analysis of some correlations between these variables to depict the types of relationships that succeed in a geomorphologic system. The most significant correlations that offered satisfying results to this study were achieved between the frequency of fragmentation depth classes and the frequency of slope length classes, and the frequency of slope classes, respectively. If the first case shows a good correlation, where very large deviations from the regression step occur on the extreme values of the classes, the second case shows weak correlation, deviations from the regression step occurring due to the extreme classes, the exception being the middle classes, where correlations are relatively good (Fig. 6).

Considering the features of the region, special attention was paid to the analysis of the cuesta relief, to differentiate the cuesta forehead and backslopes. The specificity of the local landscape is given by the structural asymmetry (Ioniță, 2000), which predominates through unequal length of the slopes, different land inclination, distinctive dynamic of geomorphologic processes on the slopes and differentiated land use (Stângă, 2009, Niacșu, 2009). The primary structural asymmetry includes the following types of valleys: typical subsequent valleys, with a direction perpendicular on the layers N-S major inclination, having E-W-oriented directions, such as the affluents on the left slope of the Studineț: Siliștea, Lunca and Valea Lupului; and diagonal subsequent valleys, which intersect the geologic layers in a sharp angle, such as Valea Rece, NE-SW-oriented. All these subsequent valleys present an asymmetric cross sections (Fig. 7), in which the slopes with a generally northern exposition are steeper and more degraded, having the shape of cuesta forehead, and the opposite slopes, with a generally southern exposition, represent less inclined backslopes.

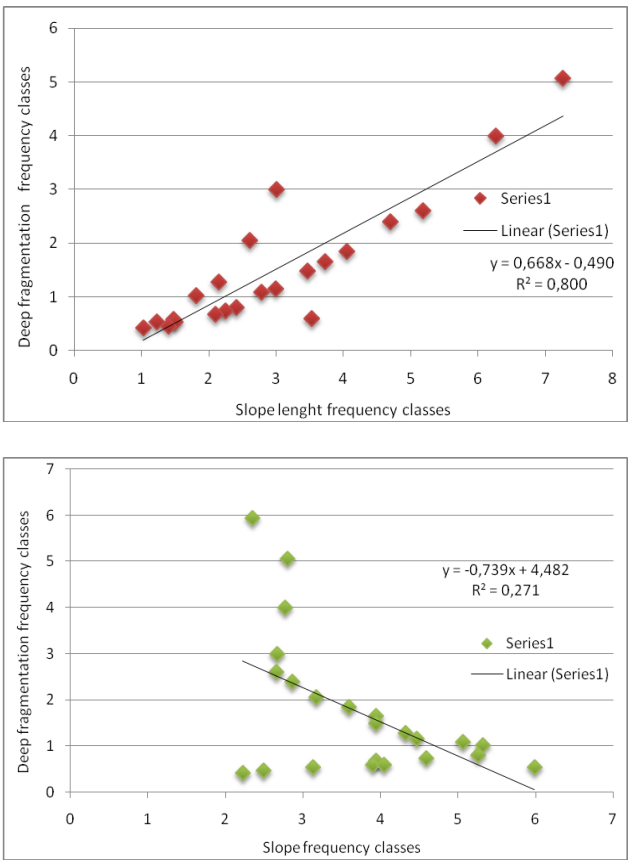

Fig. 6: Correlations between the frequency of fragmentation depth classes and frequency of slope length classes (a) and frequency of slope classes, respectively (b)

Regarding the structural asymmetry of second order, the left slope, with a general western and south-western exposition, is part of the extremely prominent cuesta fronts class, being very fragmented by torrential organisms presenting as subsequent valleys in a highly advancing stage (the Siliștea, the Lunca, the Valea Lupului basins). The cuesta front holds a larger share of the entire area of the basin, 66.34 per cent (64.15km^2), compared to the backslope (32.54 per cent), which was consumed by the installation and the evolution of the parallel river in the west, the Iezer (Ioniță, 2000). This difference gives a note of peculiarity to the Studineț basin (Fig. 8).

The ratio between the cuesta front and backslope of the main valley highlights the features of the region, considering the differences that occur at inclination, fragmentation depth and slope length levels. Thus, by analyzing Figures 9, 10 and 11 and table 1, we notice that the considered morphometric variables hold different weight for the two slopes:

lower inclination values dominate the cuesta forehead, while the backslope is characterized by higher inclination values. Being the case of a typical cuesta forehead, very fragmented by torrential organisms, large areas of the sculptural plateaus remained, presenting low inclination values. Combined, these low values created this atypical front-backslope ratio.

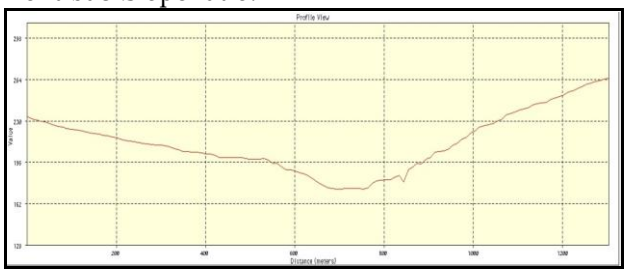

Fig. 7: N-S cross sections in the Lunca basin

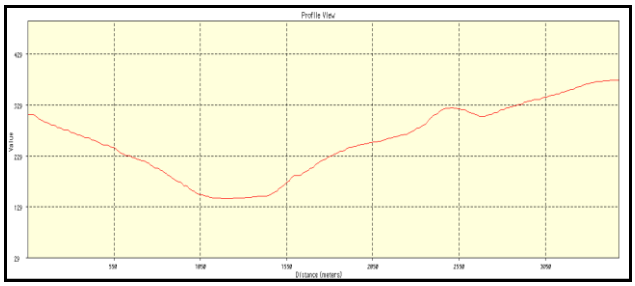

Fig. 8: W-E cross sections in the Studineț basin

The proportion of fragmentation depth classes highlights a balanced ratio between the two slopes. Very large variables dominate the cuesta front, feature given by the high fragmentation caused by torrential organisms. Regarding the length of slopes, the ratio between the two slopes shows a tendency of changing the asymmetry: low values of the slope lengths are typical to the cuesta forehead, while high values dominate the backslope. The R^2 coefficient expresses a tendency to lower the front/backslope ratio with raising the slope length.

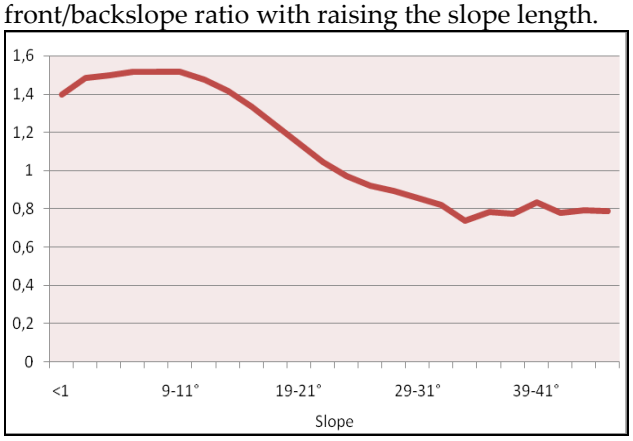

Fig. 9: Slope inclination categories ratio on the cuesta forehead and backslope

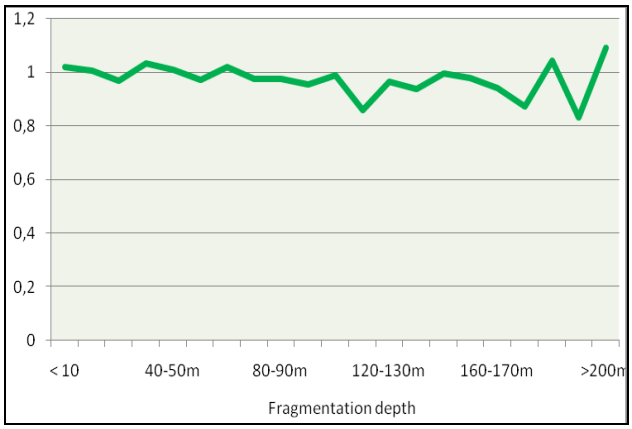

Fig. 10: Fragmentation depth categories ratio on the cuesta forehead and backslope

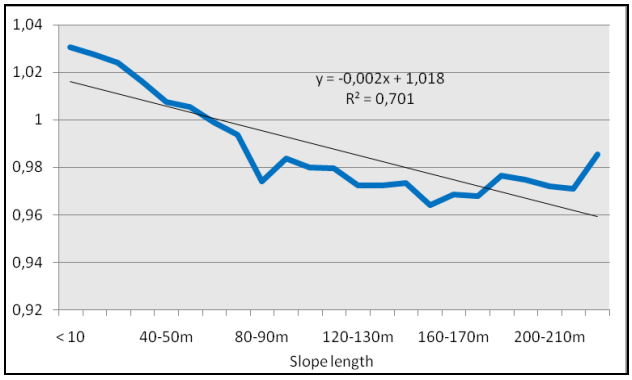

Fig. 11: Slope length categories ratio on the cuesta forehead and backslope

On a representative perimeter within the basin, the raster histograms (hypsometry, declivity, exposition) were compared to highlight the differentiations caused by the map scale and pixel resolution (1:25000 and 10x10m, 5x5m, 2.5x2.5m; 1:5000 and the same resolution values).

When comparing the histograms of the altitudinal classes, on different scales of analysis (1:25000 and 1:5000), there resulted a relatively good correlation, which remains for all three pixel resolution values that were taken into account, the 10x10m resolution, the 5x5m resolution, and the 2.5x2.5m resolution (fig.12-20). For all three correlations, discrepancies occur in the intermediary altitudinal classes, where much higher frequencies are registered. By analyzing the situation from this point of view, it can be noticed that both the pixel resolution and the map scale are extremely important to the geomorphologic analysis. Thus, with lower values of these two components, we get higher accuracy and detail level of the information extracted from the analysis maps.

By comparing the histograms of the slope classes on different scales (1:25000 and 1:5000), it was

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noticed a visibly lower correlation compared to the previously presented situation. At a 10x10m pixel resolution, much larger correlation errors occur, considering that in this case, the slope value calculated per each pixel is the result of a difference between two points. However, as the resolution increases, the correlations progressively reduce their interpolation errors (Fig. 22, 25, 28).

Representative samples (Chetrosu - Fundu Văii perimeter), were selected on different resolutions and scales, for testing and validating these correlations, thus depicting the differences induced by these analysis criteria (Fig. 12, 14, 17, 18, 20 – analysis details, hypsometric map; Fig. 21, 23, 24, 26 – analysis details, slope map).

Table 1. Proportion of the different slope inclination, fragmentation depth and slope length categories on the front and reverse

Slope inclination			Slope length			Fragmentation depth		
Front-F	Reverse-R	F/R	Front-F	Reverse-R	F/R	Front-F	Reverse-R	F/R
0,73	0,58	1,39	10,17	9,92	1,03	54,95	53,92	1,02
2,67	1,86	1,48	3,12	3,00	1,03	5,95	5,92	1,00
3,20	2,14	1,50	7,32	7,14	1,02	5,00	5,17	0,97
3,15	2,08	1,51	6,29	6,20	1,02	4,03	3,90	1,03
3,01	2,03	1,51	3,04	2,95	1,01	3,01	2,98	1,01
3,02	1,96	1,51	5,18	5,17	1,01	2,57	2,65	0,97
3,24	2,14	1,48	4,68	4,73	1,00	2,41	2,36	1,02
3,57	2,40	1,42	2,63	2,56	0,99	2,03	2,09	0,97
3,99	2,80	1,33	4,02	4,09	0,97	1,83	1,88	0,97
4,30	3,22	1,24	3,69	3,79	0,98	1,63	1,71	0,95
4,61	3,74	1,14	3,42	3,55	0,98	1,48	1,50	0,99
4,65	4,07	1,05	2,16	2,13	0,98	1,20	1,40	0,86
5,12	4,92	0,97	2,95	3,07	0,97	1,14	1,18	0,96
5,22	5,50	0,92	2,74	2,85	0,97	1,06	1,14	0,93
5,10	5,55	0,89	1,81	1,83	0,97	1,02	1,02	1,00
4,36	4,89	0,86	2,38	2,47	0,96	0,79	0,81	0,98
3,78	4,36	0,82	2,22	2,30	0,97	0,72	0,77	0,94
3,61	4,43	0,74	2,07	2,15	0,97	0,64	0,74	0,87
3,69	4,71	0,79	1,46	1,50	0,98	0,59	0,57	1,04
2,86	4,65	0,77	3,49	3,61	0,97	0,55	0,67	0,83
5,56	5,80	0,84	1,22	1,24	0,97	0,54	0,50	1,09
2,24	2,97	0,78	1,49	1,53	0,97	0,98	0,55	1,78
2,04	2,57	0,79	1,39	1,45	0,99	0,43	0,48	0,90
16,28	20,64	0,79	1,02	1,04	1,00	5,45	6,10	0,89
						5,45	5,71	0,96

Data source: data processed with the Mips 7.3 software, based on the derived maps

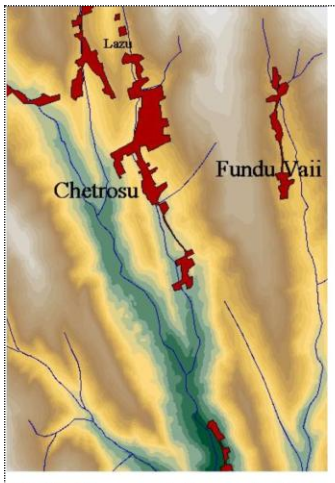

Fig.12. Representative perimeter sc. 1:5 000 (10x10m resolution)

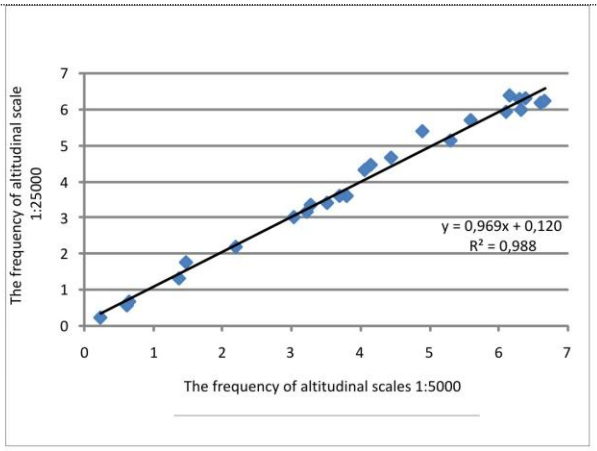

Fig.13 Correlation between the frequency of altitudinal scales on different analysis scales (1:25000/1:5000)

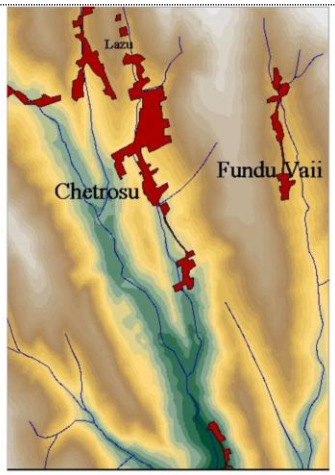

Fig.14. Representative perimeter sc. 1:25 000 (10x10m resolution)

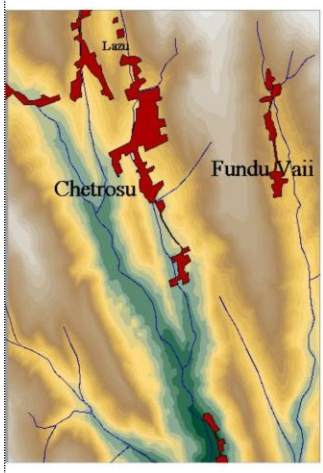

Fig.15. Representative perimeter sc. 1:5 000 (5x5m resolution)

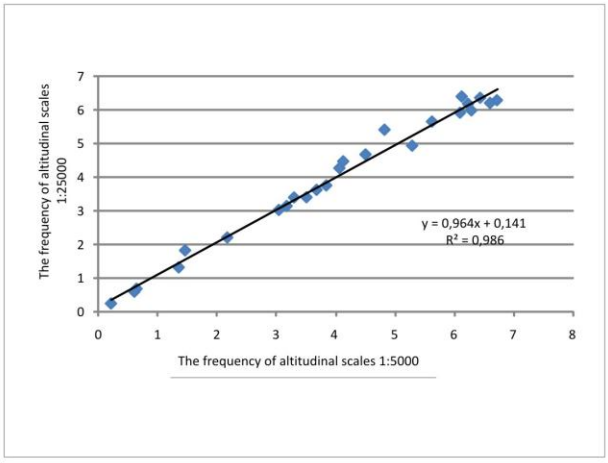

Fig.16. Correlation between the frequency of altitudinal scales on different analysis scales (1:25000/1:5000)

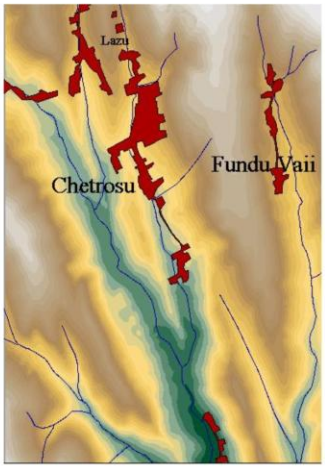

Fig.17. Representative perimeter sc. 1:25 000 (5x5m resolution)

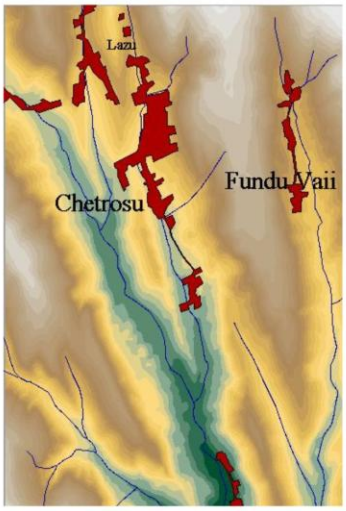

Fig.18. Representative perimeter sc. 1:5 000 (2.5x2.5m resolution)

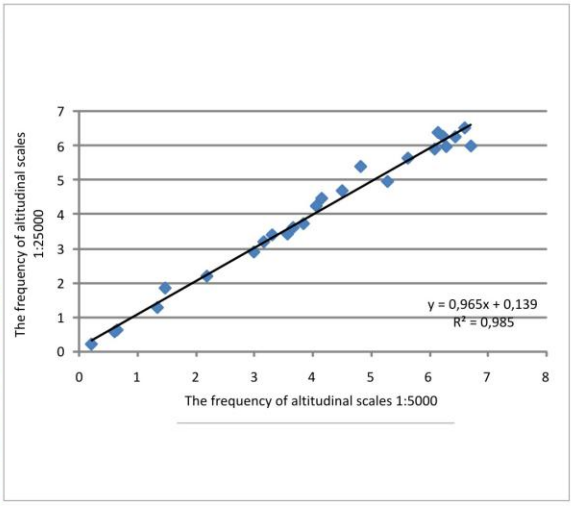

Fig.19. Correlation between the frequency of altitudinal scales on different analysis scales (1:25000/1:5000)

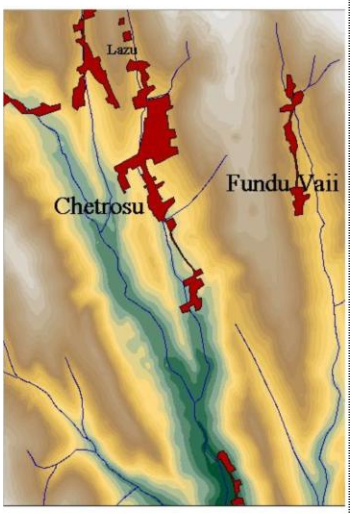

Fig.20. Representative perimeter sc. 1:25 000 (2.5x2.5m resolution)

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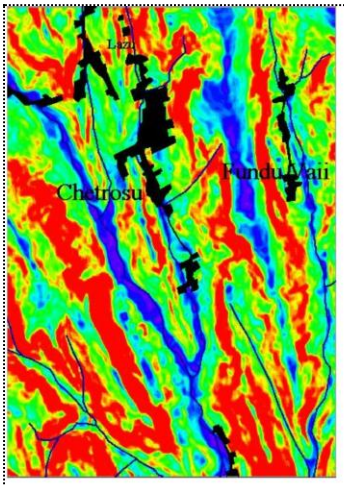


Fig.21. Representative perimeter sc. 1:5 000 (10x10m resolution)

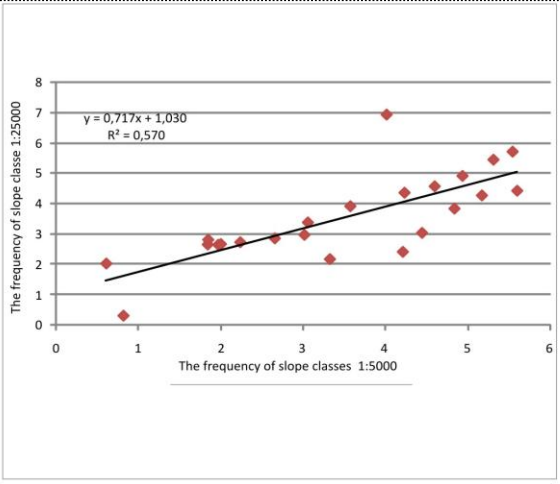


Fig.22. Correlation between the frequency of slope classes on different analysis scales (1:25000/1:5000)

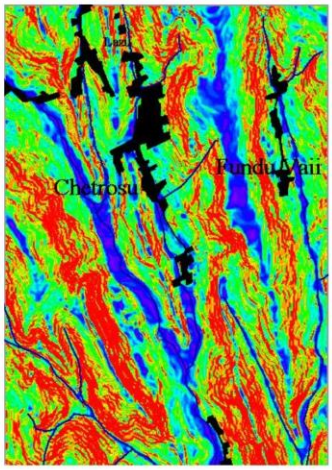
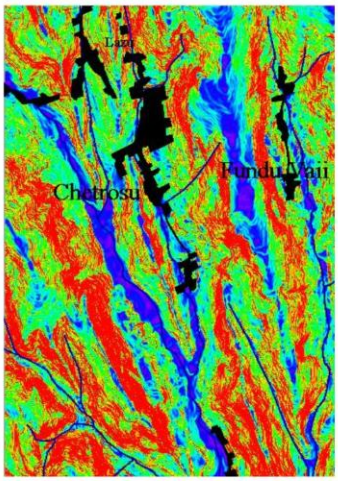


Fig.23. Representative perimeter sc. 1:25 000 (10x10m resolution)



24. Representative perimeter sc. 1:5 000 (5x5m resolution)

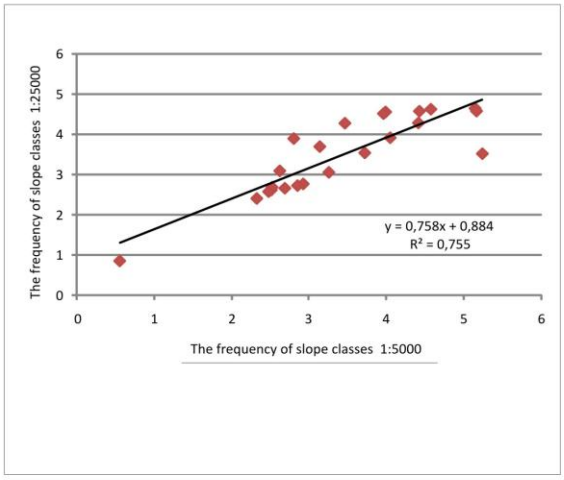


Fig.25. Correlation between the frequency of slope classes on different analysis scales (1:25000/1:5000)

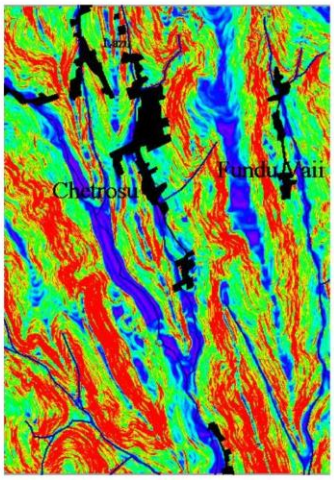


Fig.26. Representative perimeter sc. 1:25 000 (5x5m resolution)

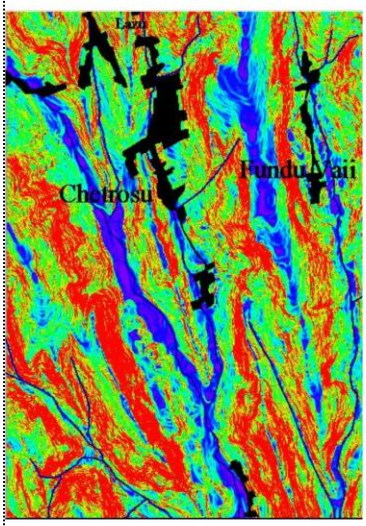


Fig.27. Representative perimeter sc. 1:5 000 (2.5x2.5m resolution)

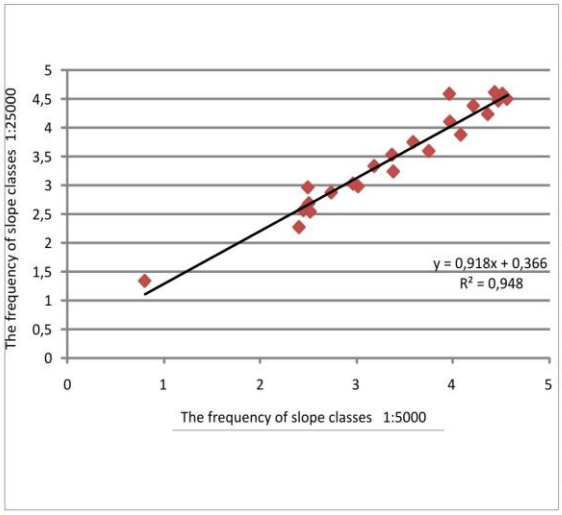


Fig.28. Correlation between the frequency of slope classes on different analysis scales (1:25000/1:5000)

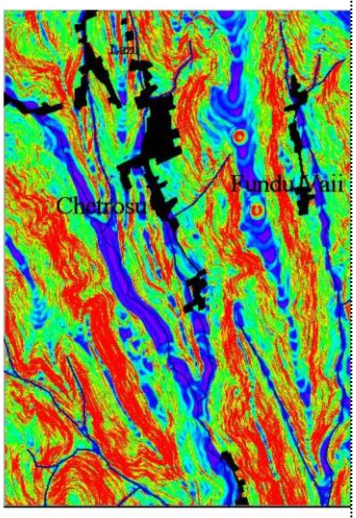


Fig.29. Representative perimeter sc. 1:25 000 (2.5x2.5m resolution)

Conclusions

This study aims to accomplish both a complex analysis of the morphometric variables and the analysis of some correlations between these variables to depict the geomorphologic features that are present in the Studineț basin. The ratio between the cuesta front and backslope of the main valley highlights the features of the region, considering the differences that occur at inclination, fragmentation depth and slope length levels.

The comparison of the raster histograms (hypsometry, declivity) aimed to highlight the differences induced by the map scale and pixel resolution (1:25000 and 10x10m, 5x5m, 2.5x2.5m; 1:5000 and the same resolution values). By analyzing the situation from this point of view, it can be noticed that both pixel resolution and map scale are extremely important to the geomorphologic analysis. Thus, with lower values of these two components, we get higher accuracy and detail level of the information extracted from the analysis maps.

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Changes in Air Temperature and Precipitation and Impact on Agriculture

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Abstract

Air temperature and precipitation are among the main factors for agricultural production. The aim of the present research work is to analyse changes in air temperature and precipitation in non-mountainous part of Southern Bulgaria in terms of the opportunities for the development of agriculture in the region. The trend in variability of seasonal and annual air temperature and precipitation is determined by the linear regression method. An analysis of the combination between air temperature and precipitation gives a tool to classify the climate according to dry and wet conditions of the territory. For this purpose the Gaussen-Bagnouls classification method is used in the present paper. In terms of air temperature, the investigated area is favourable for growing thermophilic plants. In order to investigate thoroughly the impact of climate change, the quantitative research has been complemented by a qualitative study – case study of farmers from the region of Stara Zagora. Case studies show that farmers are vulnerable to various degrees to the expected annual variability and average changes in yields depending on farm size, crop varieties and availability of irrigation.

Keywords: *air temperature, precipitation, Gaussen-Bagnouls classification, case study of farmers, climate change, agriculture*

Rezumat. Schimbările în regimul temperaturii aerului și al precipitațiilor și impactul acestora asupra agriculturii

Temperature aerului și precipitațiile se numără printre principalii factori ce influențează producția agricolă. Scopul acestei cercetări este să analizeze schimbările din regimul temperaturii aerului și precipitațiilor din parea sudică a Bulgariei, cu relief mai jos, prin prisma oportunităților pentru dezvoltarea agriculturii în regiune. Tendința variabilității anotimpuale și anuale a temperaturii aerului și a precipitațiilor este determinată cu ajutorul metodei regresiei liniare. O analiză a interacțiunii dintre temperatura aerului și precipitații reprezintă un instrument util în clasificarea climatului în funcție de condițiile de uscăciune și de umezeală ale teritoriului. În acest scop a fost utilizată clasificarea Gaussen-Bagnouls. În ceea ce privește temperatura aerului, arealul analizat este favorabil culturii plantelor termofile. Pentru o analiză amănunțită a impactului schimbărilor climatice, cercetarea cantitativă a fost completată de un studiu calitativ – studiul de caz al fermierilor din regiunea Stara Zagora. Studiile de caz arată că fermierii sunt vulnerabili într-o măsură diferită la variabilitatea anuală și schimbările medii în producție în funcție de dimensiunea exploatației agricole, varietatea culturilor și posibilitățile de practicare a irigațiilor.

Cuvinte-cheie: *temperatura aerului, precipitații, clasificarea Gaussen-Bagnouls, studiu de caz al fermierilor, schimbări climatice, agricultură*

Introduction

Many research works (Majstorović et al, 2008; Eitzinger et al., 2008; Alexandrov and Hoogenboom, 2001) point out that climate is one of the main factors for agriculture. Air temperature and precipitation are very important climate elements which determine the thermal resources and humidity necessary for crops. The knowledge on spatial and temporal variability of the main climate elements and its impact on agriculture may help developing long-term agricultural policies and various strategies for mitigation and adaptation to climate change.

Most of the publications for Bulgaria consider climate change in regard to past or future tendencies in air temperature and precipitation variability (Alexandrov, 2004; Topliisky, 2005; Nikolova and Boroneant, 2011 etc.). Scenarios developed by research works in recent years show an increase of air temperature and decrease of rainfall in Bulgaria during the warm half of the year. The results of CLAVIER project (http://clavier-eu.org/) indicate that for the 2011-

2050 period, the annual air temperature in Bulgaria will increase by 1.78°C and the annual precipitation total will decrease by 32 mm. According to a number of climate models the number of consecutive dry days in the country will increase (Jacob D., 2009). Climate change impact on agriculture has been investigated mainly by analyses of changes in air temperature, precipitation, humidity. Various specific indices as De Martonne index (Vladut, 2010; Majstorovic et al., 2008), SD (spatial-dryness) index (Tran et al., 2002) are also applied. The impact of climate change on agriculture has been investigated by Alexandrov, 2008, Kazandjiev, 2008; Slavov and Alexandrov, 1994, CLAVIER project.

During the recent years the necessity of climate impact studies, especially on a local level increased (Mochurova, 2010). In spite of growing knowledge about climate change and its impact on agriculture, many questions still look for their answers.

The object of this study is air temperature and precipitation in Southern Bulgaria. The scope of the research work includes also a case study of farmers from one of the most important agricultural regions in Bulgaria, the region of Stara Zagora. The aim of present research work is to analyse changes in air temperature and precipitation in non-mountainous part of Southern Bulgaria in terms of opportunities for the development of agriculture in the region. In order to achieve this aim, two main tasks are defined: 1) determination of the trend and main features of the annual cycle of air temperature and precipitation and 2) conducting surveys and interviews with farmers in the region to determine which of their interests and areas of activity are affected most by climate.

Data and methods

Monthly and annual data for air temperature and precipitation from five meteorological stations are used for the research. The stations are situated in agricultural areas of Southern Bulgaria - lowlands and valleys (Fig. 1). The climate is transitional between moderate continental and Mediterranean.

The main period under investigation is 1931-2010. On the base of monthly data seasonal and annual values are calculated. The seasons are determined as follows: winter – December, January, February; spring – March, April, May; summer – July, June, August; autumn – September, October, November.

The climate impacts are driven not only by changes in mean annual temperature and/or precipitation regime, but also by site-specific monthly relationships between the two (Priceputu and Greppin, 2004).

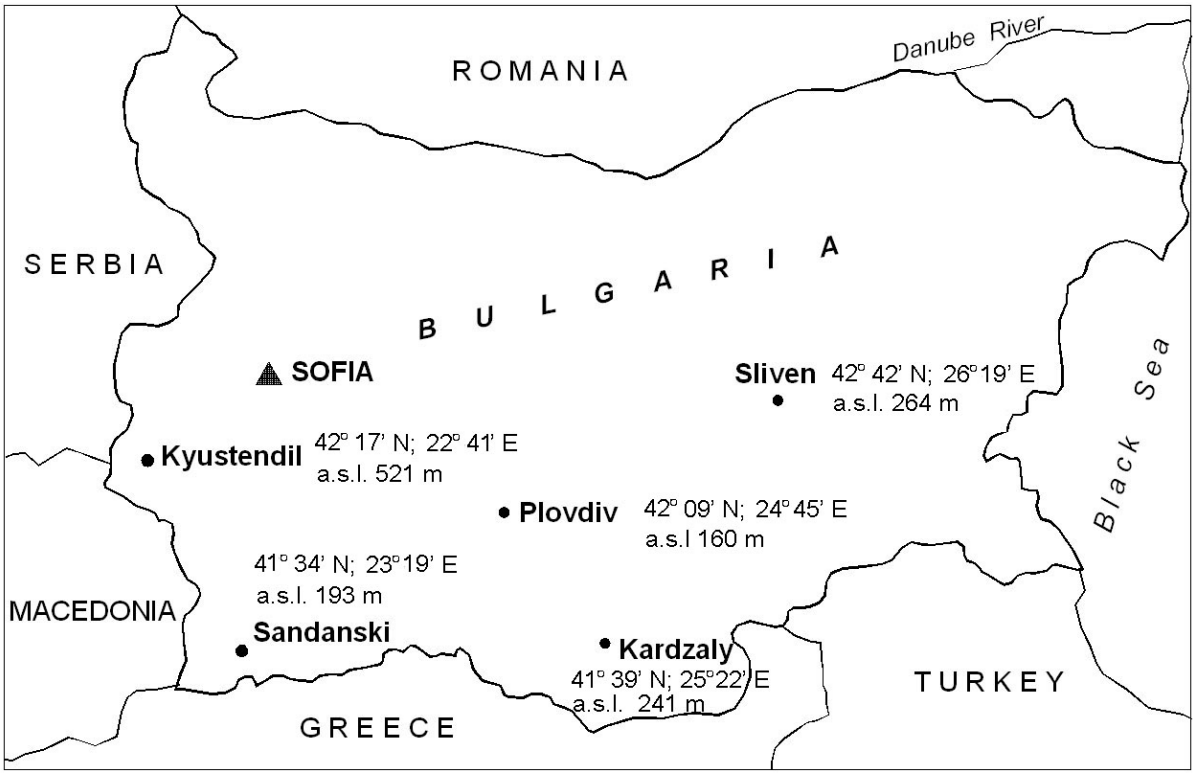

Fig. 1: Meteorological stations used in the study

Analysis of the combination between air temperature and precipitation gives a tool to classify the climate according dry and wet conditions of the territory. For this purpose the Gaussen-Bagnouls classification method is used in the present paper. The advantage of this method is that it is based only on monthly air temperature and precipitation data and it gives more precise climatic information by determining separately the numbers of dry and wet months. Gaussen-Bagnouls index is used by many authors (Priceputu and Greppin. 2004; Simota and Dumitru, 2010; Parvari et al., 2011 etc.) in order to determine precipitation deficit from a meteorological point of view. The Gaussen-Bagnouls classification method allows determining the aridity of the climate as a long-term climatic phenomenon (permanent pluviometric deficit) unlike drought, which is a short-term phenomenon (temporary pluviometric deficit). On the base of monthly data for air temperature and precipitation, the Gaussen-Bagnouls classification method was applied and the three types of climate are determined: humid if P > 3T; semi-humid - 3T>P>2T and arid - P<2T, where P is monthly precipitation total and T – average monthly temperature (Ernani and Gabriels, 2012).

The trend in variability of seasonal and annual air temperature and precipitation is determined by a linear regression method.

In order to investigate thoroughly the impacts of climate change, the quantitative research has been complemented by a qualitative study – case study of farmers from the region of Stara Zagora. A case study is "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units" (Gerring, 2004; Yin, 2003). The following definition of a case study is applied in present research work – the case study is an intensive study with qualitative methods of a single economic unit (a farm) for a given period of time in order to understand the economic impacts and vulnerability of climate changes. Taking into account that climate change economic impacts are a complex social and economic phenomenon, case study is a very beneficial method also due to its capacity of a triangulated research strategy. Triangulation is the use of two or more methods of data collection to test hypothesis and measure variables in order to minimise the degree of specificity or dependence on particular methods that might limit the validity or scope of findings (Frankfort-Nachmais et al., 2000). In the case study the following sources of information are used: documentation, interviews, and direct observations. The method of the in-depth structured interview has been applied and a scenario with topics formulated in advance and open-ended questions have been used. The interviews were conducted by the authors in July 2011. The aim is to study how farmers perceive the dependence of their farms on the climatic conditions.

Results and discussions

1. Air temperature

The analysis of winter air temperature shows a relatively high temperature level in the study area in comparison with the rest of the country. The mean winter temperature for the period 1931-2010 is between 0.8 °C in the north part of the area (station Kyustendil) and 3.7 °C in the south part (station Sandanski), tabl. 1. For the last 30 years (1981-2010) of the investigated period the mean winter temperatures are quite similar to these for the period 1931-2010. The maximum values are above 6°C and are observed in 1966 and 1951. The maximum of winter temperature for the period 1931-2010 is observed in various years for different stations, while the minimum is in 1954 for all of investigated stations. The year 2007 makes impression with the hottest winter for the period 1981-2010.

The positive trend is characteristic for winter temperature for both periods – 1931-2010 and 1981-2010, but the values are close to 0 and the trend is not statistically significant (Table 1).

In spring, seasonal temperatures are between 11 and 14°C (Sndanski 13.9°C in 1981-2010). The maximum temperature is around 14-16°C and the hottest spring for whole period has been registered in 1947. The minimum values for spring temperature (8.6 – 8.9°C) has been observed mainly in 1987 (Table 2.). The positive trend of seasonal temperature during spring is better established for the period 1981-2010, but it is not statistically significant.

Mean summer temperatures range from 20.7°C (Kyustendil station) to 24.0 (24.4)°C, Sandanski station. There is no difference between seasonal temperatures for summer for the 1931-2010 and 1981-2010 periods. Maximum summer temperatures (22.8 – 26.6°C) are observed mainly in 2007. For the stations Kyustendil and Kyrdzali the hottest summer is in 1946. Minimums of summer temperatures in various stations are between 17 and 20°C and were observed in 1976 or after 1980. In

most cases the trend of summer temperature is positive. The negative trend is established in the Kyustendil and Plovdiv stations for the 1931-2010 period, but the values are close to 0 and the trend is not statistically significant. A statistically significant positive trend of summer temperature is established for the period 1981-2010 (Table 3).

Table 1. Statistical characteristics and trend of winter air temperatures

Meteorological stations	mean	std.dev	max	year	min	year	trend/10 years
1931-2010							
Kyustendil	0.8	1.6	4.4	1951	-3.7	1954	0.0
Plovdiv	1.7	1.6	5.7	2009	-3.8	1954	0.190*
Sliven	2.5	1.4	5.5	1936	-1.8	1954	0.0
Kyrdzali	2.7	1.7	6.3	1966	-3.4	1954	0.1
Sandanski	3.7	1.3	6.7	1951	-0.2	1954	0.1
1981-2010							
Kyustendil	0.7	1.4	2.9	2007	-1.9	1985	0.3
Plovdiv	2.1	1.3	5.7	2009	0.3	1985,1993	0.2
Sliven	2.4	1.3	4.9	2007	0.0	1994	0.2
Kyrdzali	2.7	1.2	4.9	2007	0.7	1985	0.2
Sandanski	3.8	1.1	5.9	2007	2.0	1985,1990	0.4

Table 2. Statistical characteristics and trend of spring air temperatures

Meteorological stations	mean	std.dev	max	year	min	year	trend/10 years
1931-2010							
Kyustendil	10.9	1.1	13.8	1934	8.6	1987	0.0
Plovdiv	11.8	1.2	14.6	1947	8.5	1997	0.0
Sliven	11.4	1.2	14.4	1947	8.9	1987	0.0
Kyrdzali	11.7	1.1	14.6	1947	8.8	1987	0.0
Sandanski	13.5	1.0	16.0	1947	11.3	1940	0.104*
1981-2010							
Kyustendil	10.9	1.0	12.4	1994	8.6	1987	0.3
Plovdiv	11.6	1.5	13.8	1983	8.5	1997	0.1
Sliven	11.4	1.2	13.3	2008	8.9	1987	0.4
Kyrdzali	11.6	1.1	13.2	1994	8.8	1987	0.3
Sandanski	13.9	0.9	15.3	1983,1988	12.0	1997	0.2

Table 3. Statistical characteristics and trend of summer air temperatures

Meteorological stations	mean	std.dev	max	year	min	year	trend/10 years
1931-2010							
Kyustendil	20.7	1.1	23.4	1946	17.2	1976	-0.1
Plovdiv	22.0	1.3	24.6	2007	17.8	1997	-0.1
Sliven	22.2	1.0	25.1	2007	20.0	1976	0.0
Kyrdzali	22.3	1.0	24.3	1946	19.9	1976	0.0
Sandanski	24.0	1.0	26.6	2007	21.1	1976	0.116*
1981-2010							
Kyustendil	20.7	1.0	22.8	2007	18.7	1983	0.609*
Plovdiv	21.8	1.9	24.6	2007	17.8	1997	0.4
Sliven	22.3	1.2	25.1	2007	20.2	1998	0.735*
Kyrdzali	22.4	1.2	24.3	2000	20.0	1983	0.628*
Sandanski	24.4	1.1	26.6	2007	22.0	1983,1988	0.789*

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The average temperature for spring and summer characterizes the thermal optimum for plants during the period of their high biological activity and helps to identify the most typical plants under thermal conditions of a given territory. In terms of air temperature for the warm half of the year, the investigated area is favourable for growing thermophilic plants. The values of mean autumn temperature are between 11.5°C in the north and 14.6°C in the southern part of the study area. The maximum values reach 15.8–17.0°C in 1932 (Table 4). The minimum autumn temperatures range between 8.6 and 11.4°C and are observed in various years during the 1941-1978 period. For the last 30 years (1981-2010) of the investigated period the minimum autumn temperatures are in 1988, 1995 or 1996. The trend of autumn temperature is negative for the 1931-2010 period and positive for the 1981-2010 period, but it is not statistically significant in most of the cases.

The annual air temperatures in the study area range from 11°C (Kyustendil) to 14°C (Sandanski), table 5. The maximum mean annual temperature is about 14°C and reaches more than 15°C in the south-western part of the region (Sandanski station). The synchronization is not established in the occurrence of years with the highest temperature for the periods 1931-2010 and 1981-2010. For most of the investigated stations, the maximum mean annual temperature occurs in 1994 or 2007 (2008). The minimum mean annual temperatures (9.4–13.4°C) are observed in 1940 and the '90s. The positive trend of annual temperature is statistically significant for the period 1981-2010 and the values of the coefficients are 0.3 – 0.4 °C/10 years (Table 5).

Table 4. Statistical characteristics and trend of autumn air temperatures

Meteorological stations	mean	std.dev	max	year	min	year	trend/10 years
1931-2010							
Kyustendil	11.5	1.1	14.1	1932	8.6	1978	-0.172*
Plovdiv	12.5	1.1	14.3	1932	9.0	1995	-0.115*
Sliven	13.1	1.2	15.8	1932	9.7	1996	-0.125*
Kyrdzali	13.2	1.0	15.7	1932	10.3	1941	-0.1
Sandanski	14.6	1.1	17.0	1932	11.4	1978	-0.1
1981-2010							
Kyustendil	11.1	1.0	12.9	1994	8.7	1988	0.2
Plovdiv	12.2	1.4	14.2	1984	9.0	1995	0.2
Sliven	12.7	1.4	14.6	2010	9.7	1996	0.3
Kyrdzali	13.0	0.9	14.5	1994	10.9	1988	0.3
Sandanski	14.5	1.0	16.2	1994	12.6	1995	0.2

Table 5. Statistical characteristics and trend of annual air temperatures

Meteorological stations	mean	std.dev	max	year	min	year	trend/10 years
1931-2010							
Kyustendil	11.0	0.7	12.7	1952	9.6	1940	-0.1
Plovdiv	12.0	0.8	13.9	2008	9.4	1997	0.0
Sliven	12.3	0.8	13.8	2007	10.3	1998	0.0
Kyrdzali	12.4	0.6	13.7	1966	11.0	1940	0.0
Sandanski	14.0	0.6	15.4	1994	12.4	1940	0.058*
1981-2010							
Kyustendil	10.8	0.6	12.0	1994	9.9	1991	0.379*
Plovdiv	11.9	1.1	13.9	2008	9.4	1997	0.2
Sliven	12.2	1.0	13.8	2007	10.3	1998	0.410*
Kyrdzali	12.4	0.6	13.7	1994	11.5	1991	0.386*
Sandanski	14.2	0.6	15.4	1994	13.4	1983,1988,1997	0.414*

2. Precipitation

The comparisons between seasonal and annual precipitation amount show that there is not a big difference between precipitation total for various seasons (Fig. 2). In the northern part of the study area (stations Kyustendil, Sliven) spring and summer precipitation has the main contribution to the annual precipitation total, with 25-27% of annual precipitation for each season. In the southern part of the investigated territory (Sandanski and Kardazali stations), autumn-winter maximum in rainfall regime is typical. The amount of winter precipitation represents the total amount of water derived from solid and liquid precipitation. In terms of rainfall and water resources, the cold half of the year is not less important than the warm one. During cold periods, water accumulates in the soil and can be used during the first phenological phases of plants.

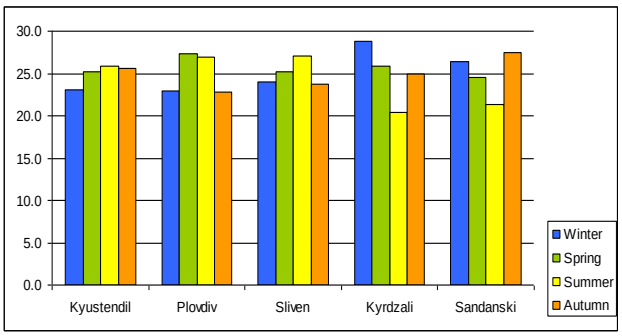

Fig. 2: Seasonal distribution of precipitation totals (% of annual values)

The linear regression equations for the 1931-2010, 1981-2010 periods point out to some important changes in the precipitation patterns. Decreasing trend of precipitation for each of the seasons and annual precipitation has been identified for the 1931-2010 period (Table 6).

Table 6. Linear regression of winter precipitation (trend/10 years)

Meteorological stations	Winter	Spring	Summer	Autumn	Annual
		1931-2010			
Kyustendil	-5.9	-4.5	-0.8	-3.3	-14.56*
Plovdiv	-1.7	1.3	0.8	-2.3	-2.3
Sliven	-7.05*	-4.91*	-4.4	-3.7	-20.13*
Kyrdzali	2.0	6.0	3.9	5.8	17.2
Sandanski	-3.4	-3.2	1.2	-4.1	-9.6
		1981-2010			
Kyustendil	-1.1	9.1	13.1	12.3	36.1
Plovdiv	16.6	12.3	8.9	19.8	49.9
Sliven	6.3	-5.8	4.5	5.0	6.4
Kyrdzali	34.7	39.06*	4.5	67.89*	138.79*
Sandanski	4.4	7.3	6.7	19.2	37.5

The exception is the station Kyrdzali with a positive trend. During the 1981-2010 period, the trend of seasonal and annual precipitation total is positive with a few exceptions (Kyustendil station, winter and Sliven station, spring). In most cases, the trend is not statistically significant.

3. Aridity index. Gaussen-Bagnouls classification method

The analysis of combination between air temperature and precipitation and application of Gaussen-Bagnouls classification method shows that climate in the investigated area during most months (from October to May, with a few exceptions) is humid (Table 7).

Aridity is established during August and September in most of the investigated stations. At some of the stations, arid climate is also registered in July and even June (Sandanski). In Sliven and Sandanski stations, the number of arid months increases during the period 1981-2010 in comparison with 1931-2010.

In spite of the positive trend of precipitation for the 1981-2010 period established by linear regression, Gaussen-Bagnouls method shows that due to high temperature in July, August and September, there is a precipitation deficit during summer and at the beginning of autumn. The tendency of aridity is not observed in Kyustendil and Kyrdzali stations.

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Table 7. Types of climate according to Gaussen-Bagnouls classification method

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Kyustendil	1931-2010	Humid						Semi-humid			Humid		
	1981-2010	Humid						Semi-humid			Humid		
Plovdiv	1931-2010	Humid					Semi-humid		Arid		Humid		
	1981-2010	Humid					Semi-humid		Arid		Humid		
Sliven	1931-2010	Humid						Semi-humid	Arid		Humid		
	1981-2010	Humid				Semi-humid		Arid			Semi-humid	Humid	
Kyrdzali	1931-2010	Humid						Arid		Semi-humid	Humid		
	1981-2010	Humid					Semi-humid				Humid		
Sandanski	1931-2010	Humid				Semi-humid		Arid			Humid		
	1981-2010	Humid			Semi-humid		Arid				Humid		

4. Qualitative study - case study of farmers

In order to investigate thoroughly the impacts of climate change, the quantitative research has been complemented by a qualitative study. The method of the in-depth structured interview has been applied. The first interview has been with a manager of a limited liability company – situated in Stara Zagora. The company was established in the mid-1990s, cultivates about 6000 dka land – mainly grapes and fruit gardens, but also crops and vegetables. Only about 25-30% of the land is irrigated. The irrigation network that existed in the past has been destroyed. About fourteen people work on permanent labour contracts, temporary workers are hired during watering sessions.

According to the interviewee the meteorological conditions are very important for the farm. The farm has equipment for measuring precipitation and measurements are recorded in a diary. Moreover, weather forecast on mass media is watched every day. The most important problem for the farm is the drought. In his opinion winters have become predominantly dry; crops are not able to develop normally, fertilizers cannot dissolve in the soil. That is why the farm has begun to apply leaf fertilization in recent years. On the one hand, climate changes in spring give rise to a number of problems. E.g. in dry years the fruits of cherry trees cannot reach the necessary size; if springtime cultures are "deceived" to germ by the unusual warmth, they may be damaged by frost after that. On the other hand, grapes are impacted positively by warming.

The manager explained also about another change observed by farmers – the shift of spring precipitation to summer months June and July. Farmers try to adapt to the change by looking for plants (and seeds respectively) with a longer vegetation period, which could endure drought. It is a problem that the seeds supplied on the market by French and American companies do not thrive well in Bulgarian conditions. Also the seeds offered by the Institute of Plant Genetic Resources, Sadovo do not correspond to the local climatic conditions.

The farm incurs losses because of the unfavourable climatic conditions. Although they perform all the necessary agronomic activities and use contemporary agricultural equipment, yields do not reach the maximum levels. Concerning the compensation of losses – on principle the company does not insure the production, except in cases when it is required by a bank when it extends credit for a certain production. Farm's experience with insurances in recent years shows that compensations are quite small, but the procedure for getting them is very slow. The costs of the insurance were bigger than the benefits.

The second interview was conducted with a representative of the agricultural cooperative in the

village of Hrishtene cultivating 9000 dka land. The main crops in the farm are corn, sunflower, tobacco and small areas with grapes. No areas are under irrigation. There are about fifteen workers permanently employed by the cooperative, as well as a number of seasonal workers. The structural changes in the farm are caused mainly by the changes in prices and markets.

Like in the first case study, here farmers also observe some climate changes – increase in the number of extreme events (hail storms), irregularity of precipitation, lack of snow cover in winter, the four seasons are not well differentiated, spring and summer have become shorter. The high amplitudes in temperature are stressful for the crops. According to the interviewee warming is visible (tangible) in the region – snowless winters with dry frost are dominating, there is irregularity in precipitation regime – e.g. it is raining continuously one week and after that it does not rain at all for a long time. People in the village have started growing subtropical plants in their gardens. All these changes lead to reduction in the yields and financial losses, respectively. Drought has a negative impact especially on cereal plants. However, the losses do not influence directly the number of employees in the farm – on the contrary, in some cases if the crops are destroyed by unfavourable climatic conditions, sowing begins again and more workers are hired.

In addition, the interviewee drew our attention especially to the problems related with air pollution and acid rains.

The cooperative does not insure the production for reasons similar to that described above. Like the farmers in the first case study, farmers in Hrishtene keep track of the current meteorological conditions, forecasts and measure precipitation in the farm. The farm takes actions for adaptation such as change in the sowing dates, growing of drought- resistant varieties. However, this is not always a solution to climate change problems, because it is not possible to foresee the succession of dry and wet years. There were cases when they cropped fields of drought-resistant sunflower, but the year turned to be wet.

Conclusions

The analysis of air temperature shows high temperature levels in the study area. During winter, mean seasonal temperatures are positive. In summer mean temperature reaches 22-24°C. The trend of seasonal temperature is positive for all seasons and annual values also. The positive tendency is established for two investigated periods, 1931-2010 and 1981-2010, and it is better expressed during the second period. Exceptions are autumn temperature with negative trend in 1931-2010 and changes to positive trend in 1981-2010. The temperature conditions in the investigated area are favourable for growing thermophilic plants.

The distribution of seasonal rainfall is relatively evenly throughout the year. In the northern part of the study area, spring and summer precipitation register higher values, while in the southern parts maximum values have winter or autumn precipitation. Linear regression shows different tendencies in seasonal and annual precipitation for both investigated periods: negative tendency during 1931-2010 and positive during 1981-2010. In spite of the positive tendencies during the second period, due to high temperature, the arid climate is characteristic for July, August and September.

As a result of the interviews, the following conclusions could be made and hypotheses formulated concerning climate change and agriculture. Farms are vulnerable to various degrees to the climate changes and average changes in yields depending on farm size, crop varieties and availability of irrigation. It could be assumed that larger farms are less vulnerable, when and if they have opportunities for diversification of production. It is expected that they could even make profits from global warming because most climate models predict increase in average crop yields in the mid-term. On the other hand, small farms will be impacted negatively by the cyclic variations and they are vulnerable to possible losses in a given financial year. The support by the government will be very important during unfavourable years. Climate changes do no influence directly employment in farms.

According to the farmers during the recent years climate has been changed. This leads to various problems, e.g. the crops are not able to develop normally because of dry winters or shifting of spring precipitation to summer months. The farm incurs losses because of the unfavourable climatic conditions. Case studies show that farmers are quite active, take initiative and look for ways to adapt to changes on a micro-level through suitable crop varieties, shifting of the sowing dates, irrigation techniques, etc.

However, most of the possible adaptation measures are out of their control – reconstruction of irrigation facilities, research and selection of new varieties, development of the insurance market for agriculture products, etc.

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The Sediment Transport of the Siret River during the Floods from 2010

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Abstract

Beginning with 2004 in the Siret River Catchment there occurred exceptional flash floods that exceeded the maximum historical values recorded, on the main river and on its tributaries (2004, the Trotuş River; 2005, the Siret River, the Trotuş River, the Bistriţa River, the Putna River; 2006 - the Clit River from the Suceava River Catchment; 2008, the Siret River, the Suceava River). The 2010 summer flood from the Siret River also falls in this category. This paper uses hydrological data (water discharge, suspended sediment discharge) between the 20th of June and 10th of July 2010 from 5 gauging stations located on the Siret River: Siret, Hutani, Lespezi, Dragesti, Lungoci, and also meteorological data (rainfall) measured at different gauging stations from the Siret River Catchment. The rainfall recorded in this time of the year in the catchment was very high, with values up to 210 l/m² in approximately 10 days. The hydrographs of the flash flood indicate the fact that the transit of the water trough the reservoirs system from the Siret River (Rogojeşti - Bucecea and Răcăciuni – Bereşti –Călimăneşti - Movileni) reduced the maximum water discharge with values between 7-27%. The values of the maximum sediment discharge also recorded a reduction while transiting this reservoirs system with approximately 60%. The evolution of the Siret river bed channel during this flood (aggradations with values between 15-100 cm and degradations starting from 65 cm until 200 cm, in different moments of the flood) is influenced by the high values of the water and sediment discharge and by anthropogenic interventions on the river bed (pit-ballast, regularization of the river bed, reservoirs). Processing the hydrological and meteorological data recorded during the flood (20th of June – 10th of July 2010) indicates two important features of this event: the climatic variability – exemplified by the big values of precipitations from the catchment and the anthropogenic impact revealed by the transit of the flood wave and the evolution of the river bed.

Keywords: *flash flood, suspended sediment, human impact, reservoir, gauging station*

Rezumat. Transportul de aluviuni al râului Siret în timpul viiturii din anul 2010

Începând cu anul 2004 în bazinul hidrografic Siret s-au produs viituri excepţionale cu depăşiri ale valorilor maxime istorice înregistrate, atât pe râul principal cât şi pe mai toţi afluenţii (2004 râul Trotuş; 2005 râurile Siret, Trotuş, Bistriţa, Putna; 2006- râul Clit – bazinul hidrografic Suceava; 2008 râurile Siret, Suceava). Tot în această categorie se încadrează şi viitura din vara anului 2010 de pe râul Siret. Lucrarea de faţă utilizează date hidrologice (debite lichide şi solide-aluviuni în suspensie) din perioada 20 iunie-10 iulie 2010 de la 5 staţii hidrometrice situate pe râul Siret: s.h.Siret, s.h.Huţani, s.h.Lespezi, sh.Drăgeşti şi s.h.Lungoci, precum şi date meteorologice (precipitaţii) măsurate de asemenea la staţii hidrometrice din bazinul hidrografic Siret. Precipitaţiile înregistrate în această perioadă în bazinul de recepţie au fost destul de ridicate, cu valori de până la 210 l/m² în aproximativ 10 zile. Hidrografele undei de viitură indică faptul că tranzitarea acesteia prin sistemelor lacustre existente pe acest râu (Rogojeşti-Bucecea şi Răcăciuni-Bereşti-Călimăneşti-Movileni) a redus scurgerea lichidă maximă cu valori cuprinse între 7-27%. De asemenea şi valorile maxime ale transportului de aluviuni s-au redus a cantităţilor în urma tranzitării acestor sisteme lacustre cu aproximativ 60%. Analiza evoluţiei talvegului râului Siret în timpul viiturii (agradări cu valori cuprinse între 15-100 cm şi degradări de la 65 cm până la 200 cm, în diferite faze ale scurgerii) este influenţată atât de valorile mari ale scurgerii lichide şi solide cât şi de componenta antropică de la nivelul albiei majore şi minore (balastiere, regularizări de albiei, lacurile de acumulare). Prelucrarea materialelor hidrologice şi meteorologice din perioada viiturii (20 iunie – 10 iulie 2010) indică două trăsături caracteristice ale acestei viituri: variabilitatea climatică – exemplificată prin valori mari ale precipitaţiilor înregistrate în bazin şi impactul antropic evidenţiat atât prin propagarea undei de viitură cât şi prin comportamentul albiei minore.

Cuvinte-cheie: *viitură, aluviuni în suspensie, impact antropic, lac de acumulare, staţie hidrometrică*

Introduction

The problem of the flash floods and also of the sediment transport during these events in Romania was a very important research topic for many scientific papers (Diaconu, Serban, Lăzărescu, Platagea, Mustaţă, Miţă, et.al. in Hydrological Studies and Research, 1961-1998; Diaconu, 1970; Ichim, Rădoane M, Rădoane N, Olariu, Urziceanu-Roşca, Bătucă, Duma et.al. în "P.E.A." Conferences, 1986, 1988, 1990, 1992; Olariu, 1997; Olariu et.al., 1998; Mustăţea, 2005; Rădoane M. et.al., 2005; Rădoane N. et.al., 2007; the scientific papers of the "Hidrotehnica" Journal, 1964-present day).

The papers of the authors mentioned above approache the manner of flash floods forming, the causes and their effects, propagation times, types of hydrographs, discharge coefficients, methods of forecasting and calculating the maximum discharge and the runoff, estimating the volume of the water and the sediment load transported through the channel, the efficiency of the reservoir in trapping sediments, evolution of the river bed during the floods.

The Siret has also been the subject of some detailed studies on the manner of flood forming and evolution (Diaconu et.al., 1970; Podani, Zăvoianu, 1992; Mustăţea, 2005; Olariu et.al., 2009, 2010), on the sediment transport during these events (Diaconu et.al., 1970; Rădoane N. et.al., 2007; Olariu et.al., 2010; Romanescu, 2006), on the evolution of the river bed and concerning the anthropogenic impact (Ichim et.al., 1990; Rădoane M. et.al., 2005, 2008; Popa-Burdulea, 2007).

The Siret River is the biggest river from Romania. It springs from the Paleogene flysch of the Wooded Carpathians (in Ukraine) at an altitude of approximately 1238 m and drains, within its catchment the central-eastern part of the Eastern Carpathians and a part of the South-Eastern Carpathians, the Moldavian Sub-Carpathians and the northern part of South-Eastern Sub-Carpathians, the Moldavian Plateau and the Lower Siret Plain. The catchment area of the Siret River covers an area of 44 871 sq km from which 42 890 sq km in Romania. The total length of this river in Romania is 548 km, while there are another 110 km from its springs to the point it enters Romania.

The main relief lines decrease in height from west to east and from north to south. The morphographical and morphometrical features depend on lithology. This way in the Carpathians area, from west to east, there align the main morphological units:

-***Volcanic mountains***, with massive forms and hard rocks. In this area the runoff is high (15 – 20 l/s/km^2) and the sediment yield is low (0,5 – 0,7 t/ha/yr).

-***Crystalline mountains***, also with massive forms, and very high, because of the hard rocks, and with limestone intrusion. The runoff is still high (12 – 16 l/s/km^2) while the sediment yield is low (0,8 – 1,2 t/ha/yr).

-***Flysch mountains*** are characterized by a great lithological variability, because of the overthrust layers. Here the runoff has values between 8-14 l/s/km^2, and the sediment yield become high (20 – 25 t/ha/yr in the South-Eastern Carpathians).

-***Sub-Carpathians*** are located on the eastern part of the Carpathians, characterised by the presence of some depressions bounded by anticline hills. In this area the runoff is between 8 – 10 l/s/km^2, and the sediment yield between 5 – 15 t/ha/an, but there are a lot of variations.

The main relief units from the platform region are the Moldavian Plateau, the Lower Siret Plain and the north-east part of the Baragan Plain. In the plateau, the runoff has values between 2 – 6 l/s/km^2, and the sediment yield between, de 2 –5 t/ha/yr. In the plain area the values of the runoff and the sediment yield are much smaller.

Olariu P. et.al. (2009) mention for the geography of the Siret River Catchment a few hydro-climatic features which influence the rainfall and runoff regime:

a) The location of the Siret River Catchment in the temperate continental climate, with frequent thermal and rainfall discontinuity.

b) The location on the eastern part of the Carpathians, which represents a complex barrier for the air mass movement from west, more humid and heat moderate.

c) The presence in the vicinity of the space around the Black Sea, which is characterized through an excessive temperate climate.

d) Landscape fragmentations, the local relief and the general orientation of the relief forms, of the valleys and depressions.

e) The early human impact in this river catchment with big influences in modifying the landscape.

The human impact from the Siret River Catchment present a few aspects that need to be mentioned:

-the existence of big reservoirs (Rogojeşti, Bucecea, Galbeni-nonfunctional at the moment of

the flood from 2010, Răcăciuni, Bereşti, Cosmeşti, Movileni) that have a big impact in the annual regime of sediment transport (Fig. 4).

-the presence of a big number of pit-ballast in the Siret flood-plain (approximately 150, with an annual extracted quantity of gravel around 3 mil. tones in 2009, source:"Siret" Water Branch, Bacau).

-numerous hydrotechnical projects (channel regularization, river bank consolidation, damming).

-deforestation and irrational utilization of the agricultural land from the river catchment. Giurgiu V. (2010) presents an evolution of the forest area in Romania, indicating for the present a surface of 27% from Romanian territory. After analyzing the **CORINE Land Cover data set**, it can also be said that between 1990-2006 the forest area was reduced with approximately 15 000 ha and the arable land increased for the same period with almost 5700 ha for the entire catchment.

This study analyzes the flood routing (water and suspended sediment discharge) from the 20th of June – 10th of July 2010 on the Siret River and the efficiency of the reservoirs in attenuating the flood wave and trapping the sediments. The study area covers the Siret River from the border of Ukraine (Siret Town) until the last gauging station located on the lower course of this river, with suspended sediment measurements, Lungoci, in the Vrancea County, downstream the confluence with the Putna River.

Data base and methods

In this paper, there were analysed the time series of hydrological data and instant dates from the gauging stations of the Siret River and from the closing sections of the main – tributaries on the right bank (the Suceava, the Moldova, the Bistriţa, the Trotuş, the Putna Rivers) before the confluence.

The data base is from the archive of the Hydrological Service of the Siret Water Branch Bacau and consist of: water discharge during the flood; suspended sediment discharge during the flood; annual maximum water and suspended sediment discharge; recorded runoff during the study period, that contributed to the intensity of the flood.

The gauging stations that provided materials for this study are: for the Siret River – Siret, Huţani, Lespezi, Drăgeşti, Lungoci, and for the main tributaries: Iţcani – for the Suceava River, Roman – for the Moldova, Bacău (Albia veche, Canal UHE) – for the Bistriţa River, Vrânceni – for the Trotuş and Boţârlău – for Putna (Table 1, Fig. 4).

Table 1. Morphometrical data

River	Gauging station	The distance from the confluence with the main river (km)	River catchment	
			Area (km^2)	**Mean height (m)**
Siret	Siret	559	1637	572
Siret	Huţani	483	2115	515
Siret	Lespezi	410	5888	513
Siret	Drăgeşti	282	11846	525
Siret	Lungoci	77	36098	539
Suceava	Iţcani	44	2334	629
Moldova	Roman	5	4274	678
Bistriţa	Bacău	7	7029	919
Trotuş	Vrânceni	37	4092	734
Putna	Botârlău	11	2450	554

Source: Romanian's Water Cadastre – „Siret" Water Branch, Bacău

The instant data are obtained by measurements during the flood (the 22th of June – 10th of July 2010) with water discharge measurement tools and by taking samples of water with some special containers for detecting the suspended sediment concentration.

For the situation when the measurements weren't possible, in different moments of the flood, the values of the water and sediment discharge were obtained by using different correlations for each gauging station and by comparison with other flood events similar with the one in 2010 (e.g. at Dragesti station after the 5th of June 2010, because of some technical problems, measurements have not been made anymore, making impossible a full analysis of the phenomenon in this section).

In the data gathered were processed in Microsoft Excel and there resulted 2 types of graphics that show very well the main features of the flood from the 20th of June-10th of July 2010: the hydrographs of water and sediment discharge (Fig. 2, 3) and the diagrams of the evolution of the river bed channel in the sections of measurements, during 2010 and especially during the study flash flood (Fig. 5).

Creating the flood hydrographs required only the preparation of the table and drawing the graphs. The other type of method is a little bit different. To obtain the tendency of the river bed evolution we need some data recorded in the so-called "Water discharge summary" for each gauging station ("0 level" of the staff gauge, maximum depth of the river-Hmax, water level at the staff gauge –H, dates obtained after measuring the water discharge with current meter).

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The method to obtain the needed data is presented in figure 1 and consists of decreasing the maximum depth of the river (H max) from the water level at the staff gauge (H), considering the absolute value of the "0 level". The difference between these two parameters is the river bed channel evolution from a measurement to another (normally during a hydrological year at a gauging station there are made 40 to 60 measurements).

Beside the graphical materials of this paper, a comparative analysis of the rainfall recorded in the river catchment, of the maximum values of the water and sediment discharge was also done. Comparisons were made relative to the values of the control sections of main tributaries and to the average annual values.

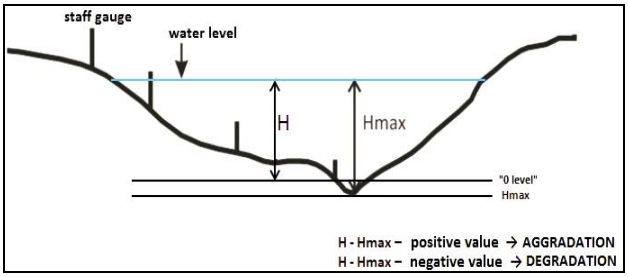

Fig. 1: Method of calculating the height of the river bed

Results and discussions

The data base that we possessed and the methods applied to process these data have allowed the analysis of the flood from different points of view: the evolution of the precipitation, flood routing and river bed channel evolution. This way, the results and the discussions around them were structured by the topics mentioned above.

1. Rainfall variability

The flood occurred in 2010 on the Siret River was a big flood for the hydrological regime of this river and was determined by the rainfalls from the 20th of June-1st of July. This flood and the precipitations that generate it were very well monitored. Table 2 features the most representative values of rainfall from the period mentioned above comparing to the mean multiannual values from the month of June.

Table 2 presents only the gauging stations considered representative for the study area and where there were recorded important values of rainfall for the study period.

The analysis of the data from this table indicates that the quantity of the precipitation from 20th of June-1st of July is higher or equal with the mean multiannual value of the month of June for most of the stations (Siret, Zvoriştea, Ţibeni, Horodnic, Pârhăuţi, Lunguleţ) or significant compared to the mean value (Brodina, Fd. Moldovei, Pr. Dornei). The big amount of rainfall during the flood compared with the mean value were also mention by other authors, referring to similar events from the Siret River Catchment (Diaconu et al, 1970; Zăvoianu and Podani, 1992; Mustăţea, 2005; Rădoane N. et al, 2007; Olariu et al, 2010).

Table 2. Rainfall from the Siret River Catchment, June-July 2010

River	Gauging station	Rainfall 20.6-01.07 (l/m^2)	Mean multiannual rainfall – June (l/m^2)
Siret	Siret	133,4	95,0
	Zvoriştea	202,5	81,8
Suceava	Brodina	109,1	140,8
	Ţibeni	209,7	110,8
	Iţcani	32,8	96,8
Pozen	Horodnic	115,2	97,2
Soloneţ	Pârhăuţi	120,3	90,6
Moldova	Fd. Moldovei	79,8	95,6
	Pr. Dornei	94,8	115,8
Moldoviţa	Lunguleţ	125,6	130,3

Source: „Siret" Water Branch, Bacău

Considering all these values, it is clear that the excessive nature of the rainfall was also present in other areas from the northern part of the Siret River Catchment, unmonitored unfortunately, but with an important effect in producing and intensifying the flood. The main rivers affected by floods were the Siret, the Suceava, the Moldova, the Bistrita (downstream Izvorul Muntelui Reservoir) and their tributaries. This flood has flowed – with maximum values of the water discharge – downstream of the Siret River. The maximum water discharge recorded is mentioned in table 3.

2. Water discharge

The water discharge during the studied flood is presented presented in the graphics from figure 2. These hydrographs were made for all the gauging stations from the Siret river with suspended sediment measurements.

The gauging stations were grouped by the reservoirs system that influences their discharge: Siret, Hutani, Lespezi for Rogojesti and Bucecea reservoirs and Dragesti, Lungoci for the group of reservoirs: Răcăciuni, Bereşti, Călimăneşti, Movileni (Fig. 2). Galbeni reservoir at the moment of the flood it was drained and nonfunctional for catching and transiting the wave of flood. This reservoir had no influence for the water and sediment discharge.

The graph for the first group of stations indicates very well the attenuation of the wave flood while passing through the mentioned reservoirs (Rogojesti, Bucecea) between Siret and Hutani and also the significant contribution of the Suceava River for Lespezi station. The maximum water discharge between these 2 gauging stations (Siret, Hutani) decreased with 27 percent (Table 3). Taking into consideration the other two gauging stations, Dragesti and Lungoci, it also can be observed an attenuation of the flood wave after transiting the 4 reservoirs, but smaller that in the north of the basin. For this area the water discharge decreased only with 7 percent from Dragesti downstream to Lungoci even if the tributaries inflow was quite small (Bistrita, Trotus, Putna). This situation can be explained only by using some maneuvers to transit big quantity of water through the 4 reservoirs mentioned above.

Table 3. Maximum water discharge from the study area

River	Gauging station	Qmax 2010 (m^3/s)	Qmax hystorical (m^3/s)	Observations
Siret	Siret	1115	1193/1969	
Siret	Huţani	815	866/1969	After passing through Rogojeşti and Bucecea reservoirs Qmax decreased with 27%
Suceava	Iţcani	1050	1710/2008	
Siret	Lespezi	2049	2414/2008	
Moldova	Roman	990	1415/1991	
Siret	Drăgeşti	2850	2930/2008	
Bistriţa	Bacău (Albia veche + Canal UHE)	915	-	
Trotuş	Vrânceni	1280	2845/2005	
Putna	Boţârlău	284	1598/2005	
Siret	Lungoci	2643	4650/2005	After passing through Răcăciuni, Bereşti, Călimăneşti, Movileni, Qmax decreased with 7%

Source: „Siret" Water Branch, Bacău – Hydrological Service

According to "SIRET" Water Branch, Bacau, for the middle and lower sector of the Siret River, at Racaciuni, Beresti, Calimanesti and Movileni reservoirs, took place correlated maneuvers took place for transiting important quantities of water in such a way that downstream the Movileni reservoir the maximum water discharge to be around 2300 – 2500 m^3/s, which really happened (Qmax Lungoci – 2643 m^3/s). The Siret river channel downstream Lungoci station has a capacity of transiting such amount of water without causing any floods for the localities downstream until the inflow to the Danube.

Normally this type of evolution happens almost every time such a big flash flood occurs – attenuation between Siret and Hutani stations and between Dragesti and Lungoci stations. The only situation that can be different is the percentage reduction of the maximum discharge which can be influenced by the tributary inflow.

The type of water discharge evolution is due to the reservoirs that gives a certain mode of flood wave propagation from upstream to downstream. This situation was also observed and mentioned by other authors for the floods occurred in 1991 (Podani, Zăvoianu, 1992) and 2008 (Olariu et.al., 2010).

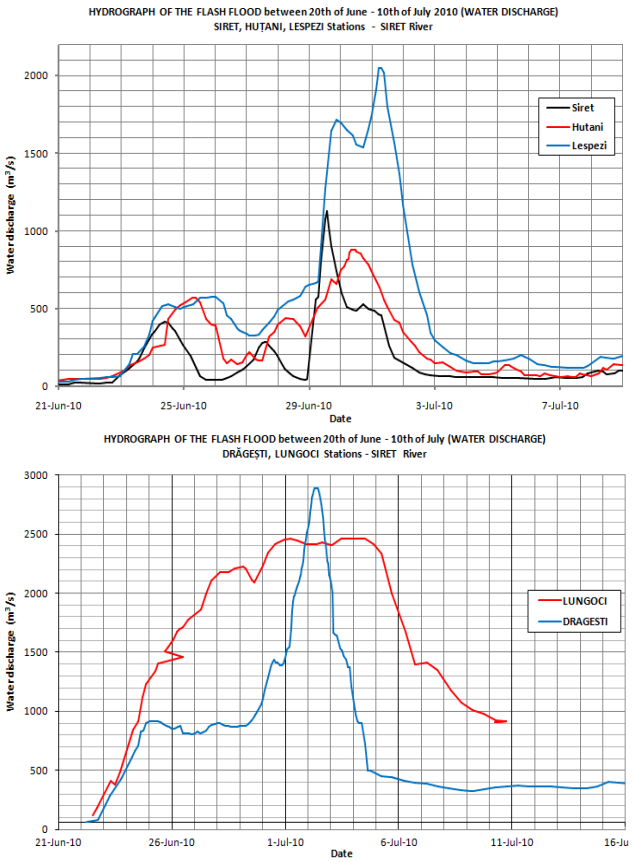

Fig. 2: The attenuation of the flash flood by the reservoir on the Siret River

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3. Sediment transport

The water discharge of the flood transported important quantities of sediments (Table 4, Fig. 4). Because this study focuses mainly on the sediment transport during the flash flood, we will analyze the recorded values and their evolution during the flood.

Table 4 presentes a comparative situation of the suspended sediment discharge (R) and the loads transported during the flood and for the entire year. The values indicate certain features for each station and are arranged in the table from upstream to downstream.

The hydrographs of the suspended sediment discharge also indicate some patterns of the sediment transport of Siret River (Fig. 3).

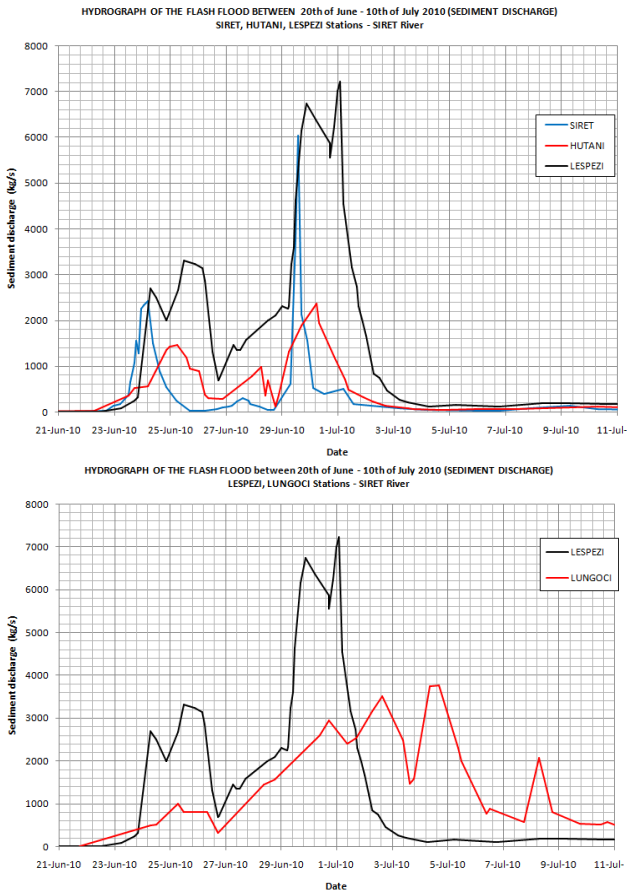

Fig. 3: Hydrographs of the sediment discharge during the flood on the Siret River

The maximum suspended sediment discharge recorded at Hutani station is 60% lower than that registred at Siret station (Fig. 4). Even so the sediment load transported during the flood is much bigger at Hutani (almost 0.3 mil t). This indicates very well the sediment trap efficiency of the two reservoirs – Rogojesti and Bucecea. These reservoirs reduce the maximum sediment discharge by silting an important amount of sediments at the inflow the reservoir. In the same time, through the outflow of the reservoir there is evacuated important quantities of sediments which influence the sediment load of the flood event downstream.

It should also be mentioned the existence of a big pit-ballast upstream Hutani station, where that with the machinery activity from the channel, disturb the alluvial material, thus facilitating its transport.

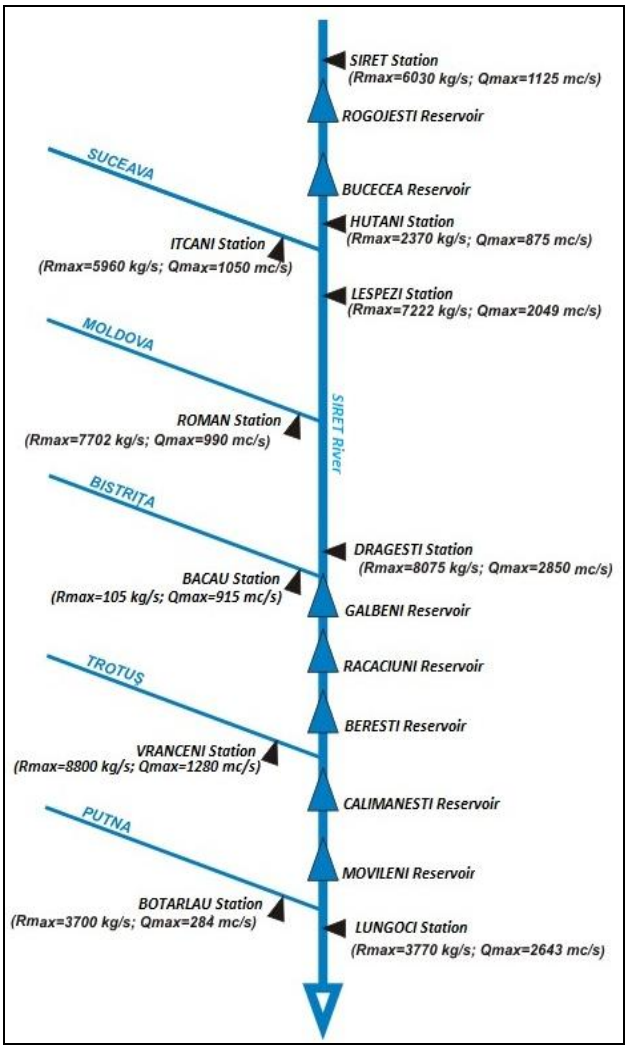

Fig. 4: The location of the reservoirs and the gauging stations on the Siret River and its tributaries

The contribution of the Suceava River to the sediment transport is also important as it can be seen from table 4. The maximum suspended sediment discharge at Lespezi station is significant comparing to the one at Hutani station and the sediment load is much bigger than at the station upstream (Fig. 3).

The data from table 4 regarding Lespezi, Roman and Dragesti stations indicate an important silting of the sediments between Lespezi and Dragesti. The discharge of the Moldova river does not cause any significant increase in the maximum sediment discharge and not even the sediment loads doesn't show an important increase compared to Lespezi station. The sediment discharge and the sediment loads of the Bistrita are very small because of the upstream reservoirs system, starting from Izvorul Muntelui up to Bacau. This indicates the insignificant contribution of this river to the Siret sediment transport.

Even if the Trotus River sediment load has big values, all the quantities are trapped in the reservoirs located downstream the confluence with the Siret. This is why at Lungoci station, the sediment transport is almost entirely the result of the Putna River contribution, which that year wasn't very important because of a small flash flood. Comparing the maximum sediment discharge from Lungoci with the one at Dragesti station, it can be easily observed that it decreased by 53 percent (Fig. 5).

The impact of the reservoir from the Siret river on the sediment transport was also studied by Olariu et.al. (1998) and Rădoane et.al. (2005). These authors indicate also the sediment trap efficiency of these reservoirs.

Regarding the annual sediment load of the Siret River compared with the one during the flood, the data in table 4 indicate the fact that the biggest part of the sediments are transported during the major floods (between 50 and 89%).

Table 4. Sediment discharge and sediment loads for the study area

River	Gauging station	Rmean 2010 (kg/s)	Rmax 2010 (kg/s)	Sediment load 2010 (mil.t/yr)	Sediment load during the flood (mil.t)	Percent from the annual sediment load (%)
Siret	Siret	16,8	6030	0,843	0,450	53
Siret	Huţani	32,6	2370	1,028	0,744	72
Suceava	Iţcani	38,4	5960	1,210	1,083	89
Siret	Lespezi	89	7220	2,807	2,242	79
Moldova	Roman	84,5	7702	2,665	1,648	62
Siret	Drăgeşti	-	8075*	4,645*	3,021 *	65
Bistriţa	Bacău (Albia veche + Canal UHE)	4,9	105	0,154	0,053	34
Trotuş	Vrânceni	68,9	8800	2,172	1,833	84
Putna	Boţârlău	39,9	3700	1,258	0,460	37
Siret	Lungoci	147	3770	4,636	2,372	51

**because there are no measurements form the flood, the values presented in the table were obtained from correlations with floods from the previous years (e.g.2008). Source: „Siret" Water Branch, Bacău – Hydrological Service*

The low values indicate a certain type of hydrological regime: for the Bistrita River (34%), the low percentage is influenced by the upstream hydropower improvement of this river, while for Putna River at Botarlau station, (37%) is determined by the small-scale flash flood from 2010 summer.

The ratio between sediment load during the flood and the annual values was also studied and indicated by C. Diaconu (1970). The big percentages during the flash floods are characteristic for almost all the rivers in Romania.

4. Evolution of the river bed channel

For the analysis of the Siret sediment transport, it is also important to observe the evolution of the river bed channel in the monitoring sections during the floods in order to indicate the moments of erosions and silting.

The method to calculate the river bed channel height is presented in the methods section (Fig.1) and can be achieved by using "Water discharge summaries" for each gauging station, where there are recorded the values of the maximum depth of water, water level, flow velocities, etc.

By processing the data from these "Water discharge summaries" we create the graphs from fig. 5 that point to a few aspects:

-at Siret station it can be observed a stationary situation of the river bed channel during the flash flood, followed by an aggradation (approximately 20 cm) during the decreasing of the water discharge.

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This tendency is determined by the location of the Siret station very close to the inflow of Rogojesti reservoir, that attenuates the flood wave through the afflux, causing also the sedimentation at the entrance into this reservoir.

-at Hutani station, the evolution of the river bed channel is a typical one a river bed channel during a major flood – degradation (65-70 cm) during the discharge increaseand aggradation (80 cm) during the discharge decrease. At this station, the powerful aggradation is also the result of pit ballast located upstream that exploits big quantities of gravel.

-at Lespezi station, there can be observed a decreasing tendency (approximately 200 cm). This atypical situation is due to the fact that in the vicinity of the measuring section regularization works take place in the river bed channel for the Pascani reservoir that will be put in use in 2013. This way the alluvial material from the river bed channel is disturbed and during the 2010 flood this disturbed material was washed away.

-at Lungoci station, there can be seen an aggradation (100 cm) on the discharge increase and a mild degradation (50 cm) during the discharge decrease. This situation is the result of the controlled regime of the discharge upstream this station and to the contribution of Putna River (Rmax Boțârlău = 3700 kg/s, Rmax Lungoci = 3770 kg/s) during the increasing of the water discharge on the Siret.

For the entire 2010, there can be observed a stability of the river bed channel of the Siret River in the monitoring sections of gauging stations, except for Siret station where there appears a slight aggradation, influenced probably by the land use conditions from upstream, in Ukraine, not calculated yet (deforestation, percent of arable land from the catchment area, sheet and rill erosion, gullies and landslides).

Most of the scientific papers (Brânduş, 1984; Rădoane et.al., 1991; Olariu, 2004; Popa-Burdulea, 2007; Rădoane et.al., 2010) indicates for Siret River and for its Carpathian tributaries a general tendency of degradation of the river bed channel, evolution given to the availability of the sediments from the catchments (deficit or surplus) caused by the human impact (reservoirs, pit-ballast, measurements for reduction soil erosion) and by the hydrological regime. Still, for the 2010 flood and for entire annual evolution, this tendency is not clear, mainly because this sort of evolution takes place and can be observed in a much longer time.

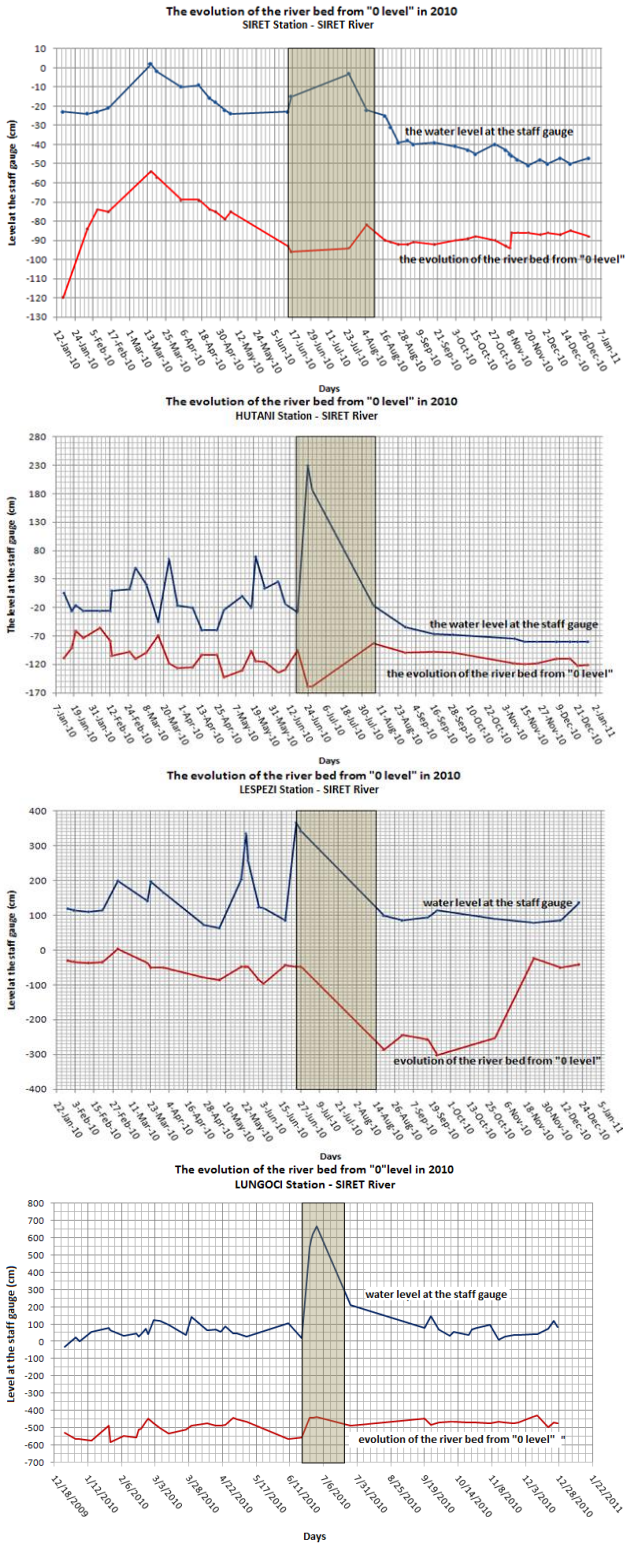

Fig. 5: Evolution of the river bed channel in 2010 in relation with the water level

Conclusions

The 2010 flood from the Siret River was a significant one, evidenced by high values of water discharge (Table 3) and suspended sediment transport (Table 4).

The discontinuity frequency of the rainfall during the summer season contributed decisively, with important quantities to the water discharge of the flash flood. In general, as it was indicated by other authors (Diaconu et al, 1970; Podani, Zăvoianu, 1992; Mustățea, 2005; Rădoane et al, 2007; Olariu et al, 2010) the amount of rainfall that generate a flash flood in the Siret River catchment are most of the time higher or closer to the mean monthly values for the occurring month (table 2- for 2010 flash flood). This increase of the climate modifications, influence the water discharge regime and also the sediment transport, causing a more torrential character of the hydrological regime.

The transiting of the flood wave was directly influenced by the reservoirs located between the border of Romania with Ukraine and upstream the confluence of the Siret River with the Putna River. This occurs during every flash flood on the Siret River as it was also mentioned by Podani, Zăvoianu (1992), Olariu et al (2010).

The influence of the reservoirs caused the reduction of the maximum water discharge of 27% and of 60% for the maximum suspended sediment discharge. Still, these percentages can vary due to the scale of the discharge and to the tributaries contribution.

The response of the river bed channel during the 2010 flood was a dynamical one and in general different from a gauging station to another. For Siret station, the evolution during the flood was of a slight degradation (20 cm). At Hutani station the evolution was of aggradation (70 cm) on the discharge increase and degradation (80 cm) during the discharge decrease. The evolution of Lespezi station river bed channel indicates a powerful degradation (200 cm) during the entire flood. The last station that we analyzed, Lespezi, showed an aggradation (100 cm) during the discharge increaseand of discharge and a degradation (50 cm) on the moment when the discharge decreased.

The causes for this types of evolution are numerous and are mainly determined by anthropogenic component from the studied catchment: the afflux phenomenon at the inflow in Rogojesti reservoir for Siret station; the impact of the pit-ballast and the regularization working on the river channels for Hutani and Lespezi stations; the contribution of tributaries with sediments during the increasing of discharge on the main river for Lungoci station.

The evolution of the 2010 flash flood indicates the importance of the reservoirs on the Siret River in attenuating the flood wave when the spilling maneuvers are well coordinate.

For the study area must be taken in consideration the importance of the reservoirs, especially because the rates of silting are very high (Rădoane, Rădoane, 2005), which will have a negative effect in the future on the capacity of these reservoirs to retain the flood waves.

Acknowledgements

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Rural Development Potential of Peripheral Areas – Case Study Bochov (Bohemia)

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Abstract

This paper analyzes the microregion of the town of Bochov in the Karlovy Vary Region as an example of an area located in the internal periphery of Czechia and at the same time indicating typical characteristics of the borderland, the result of postwar population transfer. Long-term population development can be characterized by a decreasing population and at the same its concentration in the center. Educational attainment statistics indicate unfavorable findings. Employment is dependent on commuting. Possible strategies include ensuring good living conditions for the population, supporting small and medium businesses, regional marketing, developing tourism and landscape stewardship, and maintaining the rural characteristic of the microregion. Microregions such as the Bochov microregion do not nor cannot have the same preconditions for development as central microregions. Their development should be focused on improving quality of life for local residents and visitors.

Keywords: *rural area, peripheries, demographic decline, developing models, Bohemia*

Rezumat. Potențialul de dezvoltare rurală al zonelor periferice – studiu de caz Bochov (Boemia)

Lucrarea analizează microregiunea orașului Bochov din Regiunea Karlovy Vary, ca un exemplu de zonă situată în periferia internă a Cehiei, prezentând în același timp caracteristici tipice unei zone de graniță, în urma transferului de populație după război. Evoluția populației pe termen lung poate fi caracterizată prin scăderea numărului de locuitori, și în același timp prin concentrarea acestora în partea centrală. Statisticile privind nivelul de educație relevă o situație nefavorabilă. Forța de muncă este dependentă de navetism. Strategiile posibile includ asigurarea unor condiții bune de viață pentru populație, sprijinirea afacerilor mici și mijlocii, marketingul regional, dezvoltarea turismului și păstrarea caracteristicilor rurale ale microregiunii. Microregiunile precum Bochov nu au și nici nu pot avea aceleași precondiții pentru dezvoltare ca microregiunile centrale. Dezvoltarea lor ar trebui să se bazeze pe îmbunătățirea calității vieții rezidenților și vizitatorilor.

Cuvinte-cheie: *zonă rurală, periferii, declin demografic, modele de dezvoltare, Boemia*

Introduction

Up until now rural development in Central and Eastern Europe has been synonymous with agricultural development to a certain extent. The Common Agricultural Policy of the EU is even set up this way, although recently there have been attempts to give it a new vision (Dwyer et al., 2007). In reality the rural landscape is particularly connected to the primary sector, whereas the rural population is less frequently employed in the primary sector. The countryside is becoming a more complex space, whose inhabitants frequently must commute to towns for work, and where more and more secondary and in particular tertiary sector activities take place. In addition the rural landscape has other potential beyond intensive agriculture, which can be analyzed and mapped for the purposes of restructuring regional rural policy (van Berkel and Verburg, 2011). The paradigm of rural development research is also changing on both the theoretical and practical level: "Rural development is analyzed as a multi-level, multi-actor and multi-facetted process rooted in historical traditions that represents at all

levels a fundamental rupture with the modernization project" (van der Ploeg et al. 2000). This however is not changed by the fact that these changes take place relatively slowly (Galdeano-Gómez et al., 2011).

The first question we must ask however is what is the countryside? There are several definitions, most of which are based on the countryside - town dichotomy. These definitions have gradually developed from searching for infrastructural differences, through functional differences, to life style differences. Differences have been analyzed on one hand for individual municipalities (whether towns or villages), and on the other for regions including their centres (being rural, urban, or transitional regions). M. Woods (2005) analyzes the definitions on 16 pages in his book on rural geography to come to the conclusion that there is no definitive definition of the rural. This however is no reason for geographers to ignore the countryside. Although there are many arguable cases, bordering on the edges of different definitions, for many peripheral microregions there can be no doubt about their rural character.

In geography, peripheral (micro)regions are understood to be the result of spatial polarization. The Bochov microregion in the Karlovy Vary Region is one such region. As part of a Master's thesis written at Mendel University in Brno, the potential for its development was analyzed. The aim of this study is to characterize the microregion based on various methods, to evaluate its strengths, weaknesses, opportunities and threats, and to address possibilities for development and their implementation. This should result in an attempt at generalizing the issue in relation to other peripheral regions.

Several authors have already dealt with peripheral microregions in Czechia. The "The peripheral regions in Czechia as the part spatial polarization in frames of European integration" project can be named (Marada et al. 2006).

Regional development and rural microregions

According to Wokoun et al. (2008), regional development on the academic level can be understood to mean the application of sciences (especially economics, geography, and sociology) dealing with phenomena, processes and relationships of a given area that are influenced by natural, economic, and social conditions. The primary goals are to find casual relationships, prerequisites for the spatial organization of economic activities, unequal settlement patterns, and related tools for influencing these processes. On the practical level, it involves the greater utilization of and increasing the potential of an area by spatially optimizing socioeconomic activities and natural resource use. The goal is higher competiveness, higher living standards, better environmental conditions, etc.

Rural development is part of regional development. Changes in the economic structure of rural areas and the creation of attractive environments for living and doing business have shown to be crucial. It is necessary to create new jobs by diversifying non-agriculture activities and to improve the quality of life in rural municipalities (ibid).

Microregions form an important territorial framework for analyzing development. In the jargon of public administration and local government experts they are called "voluntary associations of municipalities". In the geographic sense however, a region is understood to be a part of the world that has common functional relationships and the term microregion indicates in economic and social geography an elementary scale in research - as a rule (small) towns and their functional hinterlands as defined by Christaller's central place theory. The dialectical unit of town and the rural hinterland is significant as in most cases there is no sense in studying rural municipalities without taking into consideration the characteristics of their centers. In cases such as the Bochov microregion, the center can have a rather rural character as opposed to urban.

Characteristics of the Bochov microregion

The Bochov microregion is located in the Karlovy Vary district (Fig. 1A, 1b). The actual town of Bochov is located 17 km southeast from the regional capital. The microregion is comprised of one administrative municipality, composed of 17 settlements on 19 cadastral territories. Its area is almost 96 km^2. The population density is extremely low at 22 inhabitants per km^2. In the north, Bochov neighbors the Hradiště military proving grounds. This boundary is a significant

barrier. One of the main roads in Bohemia, the I/6 from Prague to Karlovy Vary and Cheb, leads through the town, from which several lower category roads branch off.

The microregion is located in the Ore Mts. System of the Bohemian Highland on the borders of the Bečovská vrchovina Highland, the Hradišťská hornatina Mountains, and the Tepelská vrchovina Highland geomorphological units. The bedrock is diverse, with granite dominating in the northwest, and shale, phyllite, schist and paragneiss in the southeast. These two parts are separated by a tongue of metamorphic volcanic rock. In places the bedrock contains large amounts of radon. Most of the territory is at an altitude of around 670 m. The area is generally sloped towards the south to the Střela Valley, but it also slopes to the north to Javorná Stream. The highest point is Mirotický vrch Hill (792 m).

Fig. 1a: The position of Karlovy Vary Region within the Czech Republic. Drawn by J. Pokorná

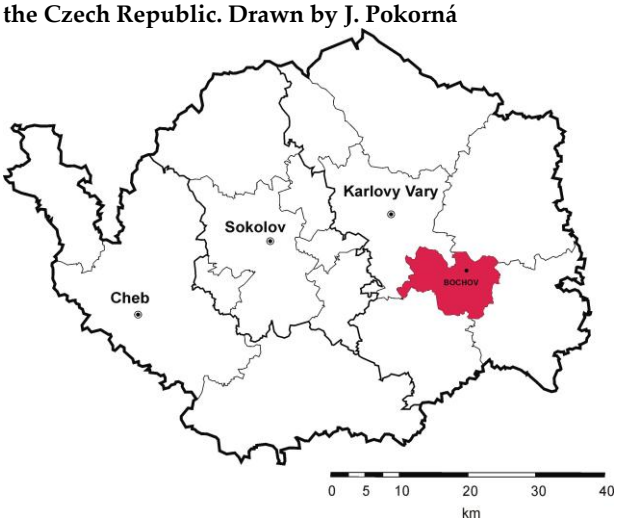

Fig. 1b: The position of Bochov within Karlovy Vary region. Drawn by J. Pokorná

Cambisol is the dominant soil group, with the occurrence of fluvic gleysols in stream valleys. The climate of the microregion is mildly warm, slightly damp, and typical of highlands with an average annual temperature of 6-7°C and 600 – 650 mm of precipitation (Tolasz, 2007). The area is located in between two reservoirs - the Žlutice Reservoir in the Berounka watershed and the Stanovice Reservoir in the Ohře watershed. There are protected zones of natural groundwater accumulation, of natural curative waters and individual water resources. Besides the Střela River which serves as the southern border of the model area, it is drained by several streams. There are many ponds, the most important being in the Údrč pond system. There are a number of wetlands and headwater areas of ecological importance.

The dominant natural vegetation types of the area are *Luzulo-Fagetum* beech forests, dominated by beech with interspersed sessile oak, small-leaved lime, sycamore maple, fir, and spruce (Neuhäuslová, 1998). In reality however, deciduous forests make up only a small part of the species composition. Ecologically unstable spruce monocultures with interspersed pine dominate. About a quarter of the territory is located within the Slavkovský les protected landscape area. Part of the territory has been declared a NATURA 2000 site.

As a result of soil and climatic conditions, almost a third of the area is covered by forest and another third by permanent grasslands. Arable land is found on less than a quarter of the area (Fig. 2). The ecological stability coefficient is 2.13, indicating a favorable situation.

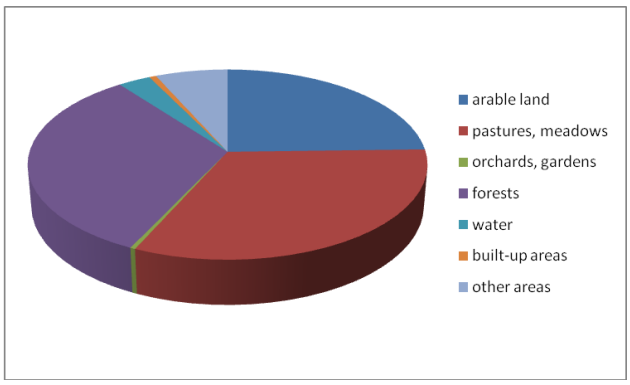

Fig. 2: Bochov: land use structure. Source of data: Czech Statistical Office - Prague

The town of Bochov was founded in the mid-14th century on the road from Prague to Loket by the Lords of Rýzmburk as a mining town (tin). Over the course of history the town was

transferred between many noble families, was destroyed several times, and also burnt down once in 1666. Mining was not very successful and the town remained a poor settlement of farmers, merchants, and tradesmen. Modernization took place at the turn of the 20th century, when at the same time the technical infrastructure was introduced. Development was interrupted by World War I, which together with the Spanish flu epidemic, claimed many victims.

World War II and the events which preceded and followed it however influenced the development of the Bochov microregion far more. In 1930, 95 per cent of the population of Bochov claimed German nationality. In 1938 Bochov was included in the Žlutice district of the Cheb Region of the Sudeten *Reichsgau* within the German Empire. The main transfer of the German population occurred in April 1946.

The resettlement of the area was not particularly successful. Settlers began working the land they had acquired without any previous experience and under difficult conditions. However, before they could develop a relationship to the land, collectivization took place. Many settlers decided to return to the inland. Thus, many settlements disappeared (Helebrant, 2001). The Bochov microregion is still struggling with the consequences of the transfer of the German population and the loss of the sense of community between the inhabitants, the land and the territory.

In the 1960s, apartment buildings and retail infrastructure were built. The integration of settlements started, which gradually resulted in today's town. In 2006 Bochov was once again returned town status.

The first modern census of 1869 counted 7,243 inhabitants, mostly of German nationality, on the territory of the modern Bochov microregion. From that time until the 1991 census, the population decreased (Fig. 3). The town of Bochov itself had only 1,800 inhabitants in 1869. However, besides this town there were several mid-sized villages: Kozlov (population 780), Dlouhá Lomnice (population 675), Rybničná (population 605), and four other villages with populations of between 400 and 500. In total there were 5,440 people living in Bochov's surrounding settlements.

In contrast 1,258 people lived in the core of Bochov in 2001. Since 1869 the population of the town itself has decreased by almost 550. Population decrease outside of the center has affected the surrounding settlements, which have lost approximately 4,750 inhabitants, which is 87per cent of the previous population.

Besides significant population decrease, there has also been a concurrent concentration towards the core of the settlement area. Whereas with the exception of the post-war decrease, the result of historical events, the town of Bochov has more or less maintained a constant population, all the surrounding settlements have lost an absolute majority of their inhabitants.

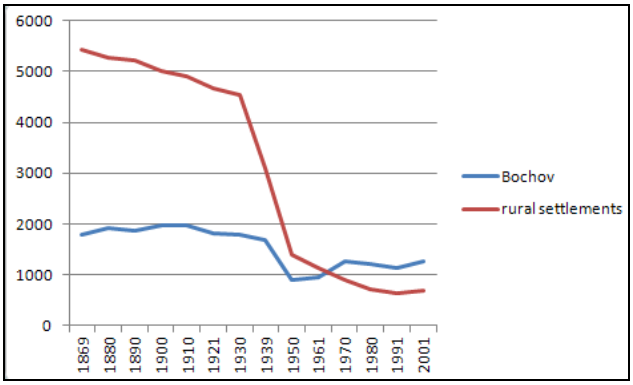

Fig. 3: The population development of Bochov and annexed municipalities 1869 - 2001

Source: Historický lexikon obcí. Praha: Czech Statistical Office; For 1939: Amtliches Gemeindeverzeichnis für das Deutsche Reich auf Grund der Volkszählung 1939. Statistik des Deutschen Reiches, Band 550. Berlin: Verlag für Sozialpolitik, Wirtschaft und Statistik.

The process of concentration took place during the entire study period as part of the process of urbanization. However, after World War II there was a significant decline, when several settlements could have dropped below their critical level of demographic sustainability, and thus population decrease in the settlements continued at a rather rapid pace until 1991. Since then, the population both in the core and in the settlements has risen slightly, which corresponds with the processes of suburbanization and counterurbanization.

In the last decade however, the population of the Bochov microregion has grown slowly, but steadily from 1,937 inhabitants in 2000 to 2,070 inhabitants in 2011 (i.e. about 7 per cent in 12 years). Natural movement as well as migration

contributed to this positive development. Two hundred twenty-six children were born in the microregion in this time, whereas 196 people died, 546 people moved in and 457 moved out.

It is clear that the Bochov microregion with the exception of the core, is made up of very small settlements (Tab. 1), whose local markets are apparently not capable of effective operation or providing basic services. These settlements are therefore practically dependent on the town of Bochov for everything.

Table 1 Population numbers in individual settlements of the Bochov microregions (2009)

Bochov	1,235	Herstošice	38
Dl. Lomnice	123	Něm. Chloumek	32
Kozlov	108	Dl. Ves a Teleč	29
Javorná	77	Nové Kounice	28
Rybničná	70	Polom	22
Těšetice	46	Číhaná	8
Sovolusky	44	Hlineč	5
Mirotice	40	**Total**	**2,064**

Source: Bochovský zpravodaj 1/2010

The age structure of the population of the Bochov microregion in 2001 is quite normal, as can be seen from the population pyramid (Fig. 4). The base of the pyramid, mainly influenced by the birth rate, is growing narrower.

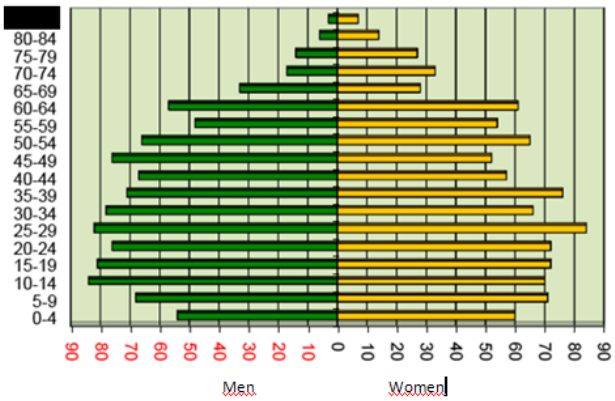

Fig. 4: Age pyramid for Bochov in 2001. Source: Populaiton census 2001, Czech Statistical Office Praha

The percentage of women in higher age categories is increasing. Clearly there is a greater number of people born in the 1970s, when the birth rate of the postwar "baby boomers" combined with the pro-population measures of the contemporary Husák government. Despite this, the population of the Bochov microregion when measured using the old age index is younger than the population of Czechia as a result of the young population base, which resulted during the resettlement of the microregion after World War II, which is today still reproducing.

Only 2.3 per cent of the population older than 15 years has university education, which is extremely unfavorable. Elementary school education and secondary vocational school education are the most common education qualifications (Fig. 5).

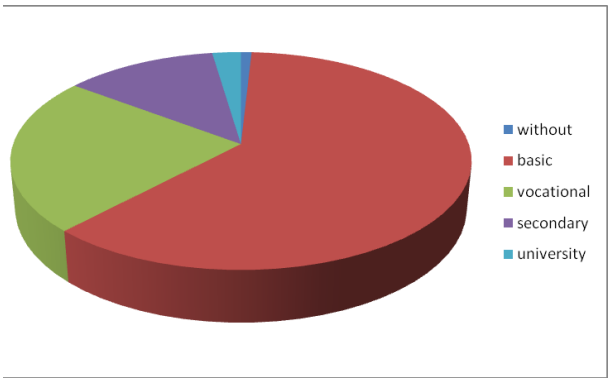

Fig. 5: Education attainment of the population of Bochov 2001. Source: 2011 census

Education attainment corresponds to the economic structure of the population to a certain extent. Most of the population is employed in productive sectors - industry, agriculture, forestry, and construction. Despite the fact that Bochov has town status, the economic structure of its population corresponds to the rural character of the microregion.

Clearly the unemployment rate is affected by this, as even in the most favourable of times it never falls below 12.5 per cent, while in times of crisis it exceeds 20 per cent. Seasonal fluctuations have also increased (Fig. 6).

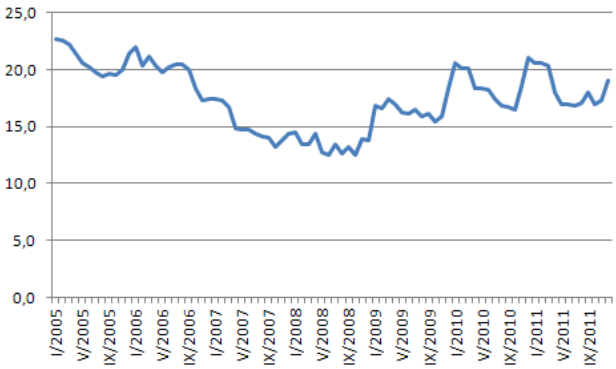

Fig. 6: Unemployment rate [%] in Bochov in the period of January 2005 to December 2011.

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Source: Ministry of Labour and Social Affairs of the Czech Republic.

Due to the recent history of the microregion, the nationality structure of the population could be of interest. The majority nationalities (Czechs and Moravians) make up only 67.3 per cent of the population. The largest minority group are the Slovaks (3.8 per cent). A mere 1per cent are remaining Germans. The rest were mostly either transferred after the war, and remaining individuals have certainly been partially assimilated. About a quarter of population did not state their ethnicity.

Resettlement is reflected in the relatively low religiousness of the microregion (12 per cent), what nevertheless responds to the average of the whole district Karlovy Vary. Of the believers, 42% do not belong to any church, 38 per cent are Roman-Catholic. This has led to the abandonment or ruining of many churches and other church buildings.

The Bochov microregion is almost untouched by industry. Productive businesses – if they exist – involve the primary sector or the processing of its products, or they are more related to the trades or production services including construction. Most businesses are concentrated in Bochov.

Fig. 7: Bochov from the South. Photograph L. Perlingerová

Other settlements have as a rule only lone farmers or smaller trade workshops. Services are essentially lacking. The town employs 511 people (2008)[1], which saturates about half of the employment demand.

Commercial tourism is not very developed. Accommodation capacity is small. The area is attractive for cycling and horseback riding, which however do not bring much money. The existing reservoirs are not well suited for swimming. A large part of the housing stock, especially in the settlements, has been transformed into cottages.

Due to the lack of employment opportunities inhabitants are forced to commute to work. Commuter routes from the settlements head towards Bochov. Due to the sparse public transportation network, private means of transportation are necessary. The population as a whole mostly commutes either to Karlovy Vary, Toužim, or Žlutice. Students also commute to school to those places.

Possibilities for and barriers to development

The main strengths of the microregion are its surroundings that are interesting for tourism, its environmental quality, and its good accessibility from Karlovy Vary and Prague. The most significant weaknesses are the acute lack of job opportunities, the loss of sense of community after World War II, and insufficient tourism infrastructure. Opportunities include supporting businesses, attracting passing through tourists, and utilizing natural potential. Significant threats are the departure of young and educated people from the microregion, a lack of finances, and competition from nearby attractions.

We propose the following strategy for developing the Bochov microregion:

1. ***Achieving overall satisfaction of the population by improving their conditions, keeping them in place, and eventually attracting new inhabitants.*** Despite the recent gradual rise in the population, the threat of young and

[1] Appendix to Regulation No. 276/2009 Coll.

educated people in particular leaving is still real. The main reason for this is a lack of job opportunities and the low amount of cultural and social activities. Town government is focused on completing and maintaining the technical infrastructure. This is certainly important, but is not very effective in small settlements. Supporting community and cultural activities could be important. Certainly residential areas and recreational opportunities for local inhabitants (i.e. swimming) need to be improved.

2. ***Supporting business.*** The largest employer in Bochov is the town itself. Due to this the current economic crisis has only slightly affected the number of jobs in the town. An industrial zone is planned for the northern part of the town, which could offer new opportunities to businesspeople. The question is what for employers should be attracted concerning the size, the branch and the origin of the owners. It is necessary to take into account low qualification level of working force and lower infrastructure (compare with Amin and Tomaney 1995).

3. ***Promoting and marketing the microregion.*** Although the town is located on one of the main roads in Bohemia, it is still little promoted. In today's world advertising is critical (via the Internet, tourism trade fairs, and orientation and promotion in the actual place, etc.). This of course is related to the infrastructure, which the town offers. Bochov is a part of the Association of Communes "Slavkovský les Forest for Rural Renewal" and its territory comes under the LEADER+ Local Action Group "Our Region". Teplá town (in distance 28 km; 3,056 inhabitants in 2011) is the centre of both the associations.

4. ***Developing tourism.*** Due to the character of the territory, it would be appropriate to connect interesting natural attractions, religious architectural monuments, and vernacular buildings via tourist trails (bicycle trails) with the appropriate infrastructure and services. There is also the potential for developing agrotourism on family farms. Some of the target groups could be the original German inhabitants of Bochov or their descendants, families with children, and young people. It would also be appropriate to reconstruct at least several monuments, for example the palace in Javorná. The investors could be local businesspeople with a relationship to the microregion, and whose profits would stay within the microregion. Due to the lack of investment capital in Bochov this is however not very realistic.

5. ***Management of the landscape and the rural character of the microregion.*** The landscape of the Bochov microregion is less disturbed by human activities than other regions in Czechia. Suburbanization is not present here. Single, independent farmers stress the land less than large agricultural concerns. These aspects of the landscape should be maintained and any attempts to build inappropriate buildings should be regulated.

Fig. 8: The landscape of the Bochov microregion Photograph: L. Perlingerová

It is clear that the territory of the town must be differentiated according to development opportunities. Understandably the main focus will be concentrated on the core settlement of the town of Bochov. The construction of the R6 highway will allow for the development around the space of today's busy I/6 road between Prague and Karlovy Vary. The regional plan defines the settlements of Dlouhá Lomnice, Údrč, and Rybničná as developing settlements for living, small-scale recreation, and

mixed use, the settlements of Javorná, Mirotice, and Krhov for living, services, and production, and all other settlements for secondary housing or other recreational functions.

Conclusion

Bochov indicates signs of the internal periphery Czechia, although according to Musil and Müller (2008) it does not belong clearly to the internal periphery. It is located in hilly terrain on the boundary of the influence of two regional centers, in this case the distant Prague and the closer, although much weaker, center of Karlovy Vary. The Bochov microregion, however, also has characteristics of the borderland periphery as a result of population transfer after World War II.

In the global, countrywide, and partially the regional perspective the Bochov microregion is almost unknown and is a low priority. However, it is such microregions that should be focused on in particular within the framework of regional policy. They can very easily become problem areas, sources of trouble, and places requiring financial support from the outside.

Mayors and other local and regional authorities often see the main solution in creating jobs. However, experience shows that there are several other factors which are often more important. The Czech population is not very used to moving for work (with the exception of first jobs after completing school), but they are starting to move for better environments. So-called amenity migration (Bartoš, Kušová, Těšitel 2009) may be one challenge for the Bochov microregion and other similar microregions.

On the other hand, it cannot be assumed that microregions such as Bochov can have the same prerequisites for development as areas in better geographic locations and with larger local resources. In this case development clearly will not take the standard path of economic growth, but instead will manifest itself as attempts to maintain and improve the quality of life of local inhabitants and visitors.

In recent times peripheral microregions have been focused on more highly. Their accompanying characteristics usually include a lack of investment capital, low qualification levels, and higher unemployment of the economically active population. On the other hand, these regions often have attractive natural surroundings and are not necessarily in demographic decline. This offers the opportunity for finding prosperity via the development of tourism. On the other hand, in Czecha, tourism cannot be the only supporting sector even in the most attractive areas. Seasonality, insufficient infrastructure, and the fact that people are still poorly prepared for this stand in the way. Therefore it is essential to combine tourism with regional production and services.

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Author contributions

L. Perlingerová is responsible for empiric research and graphical enclosures. A. Vaishar elaborated theoretical parts, updating the data and the final structure of the paper.

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The Functional Transformation of Settlements in Central Serbia

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Abstract

Because of its natural differences, the Goč Mountain and its foothill was respected and taken as experimental space of Central Serbia. This territory covers 402.1 square kilometers and is spread between 166 and 1127 m above the sea level. Exactly 26 settlements on the territory of the Goč Mountain and its foothill were observed. Functional characteristics were determined for every single settlement. Determination has reclined on the data of employees, by fields of activities. The results from the 1971 census were compared with those from 2002. At the end, the results were illustrated on two different ways. One has had the form of triangle and other has the form of a map. The triangle from 1971 clearly shows that the majority (53.8%) of settlements had "agriculture – industry" characteristics. After thirty years, only two settlements in the mountainous part of the territory didn't change their characteristics. Most of the settlements have "industry – service" or "service – industry" characteristics. In comparison with the micro-regions from Central Serbia, the Goč Mountain and its foothill have very good conditions for agricultural development. More than 45% of the territory does not exceed 300 m above the sea level. Climate conditions are optimal. The space is rich in underground waters and small river streams. The agricultural fields account for more than 41% of the Goč Mountain and its foothill. About 13% of territory covers fertile alluvial soil etc. However, in 2002, there was not registered a single settlement with "agricultural" characteristics.

Keywords: *functional changes, Central Serbia, the Goč Mountain*

Rezumat. Transformările funcționale ale așezărilor din Serbia Centrală

Ca urmare a diferențelor naturale, Muntele Goc și zona adiacentă a fost respectat și considerat un spațiu experimental pentru Serbia Centrală. Cu o suprafață de 402,1 km², se desfășoară între 166 și 1127 m deasupra nivelului mării. Pe acest teritoriu au fost identificate 26 de așezări, pentru fiecare așezare fiind determinate caracteristicile funcționale. Această determinare s-a făcut pe baza datelor statistice privind numărul de angajați, pe domenii de activitate. Rezultatele de la recensământul din 1971 au fost comparate cu cele din 2002 și in final ilustrate diferit, rezultând o nomogramă a funcțiilor așezărilor și o hartă a arealului studiat. Nomograma realizată pentru anul 1971 arată clar că majoritatea (53,8%) așezărilor aveau funcții agro-industriale. După 30 de ani, numai două așezări din partea muntoasă a arealului analizat nu și-au schimbat funcțiile. Majoritatea așezărilor au profil industrial și de servicii sau tertiar cu pondere importantă a industriei. Comparativ cu cellalte micro-regiuni din partea centrală a Serbiei, Muntele Goc și zona de la poalele sale prezintă condiții favorabile pentru dezvoltarea agriculturii. Peste 45% din teritoriu nu depășește 300 m înălțime. Condițiile climatice sunt optime, iar resursele de apă, atât cele de suprafață, cât și cele subterane, sunt bogate. Terenurile agricole acoperă pentru 41% din Muntele Goc și poalele sale, peste 13% având soluri aluviale foarte fertile. Cu toate acestea, în anul 2002, nu a mai fost înregistrată nicio așezare cu profil agricol.

Cuvinte-cheie: *schimbări funcționale, Serbia Centrală, Muntele Goc*

Introduction

Changes of settlements in Europe, as well as in Central Serbia are numerous (Rey, Bachvarov, 1998, Antrop, 2004). The article provides some of them, precisely functional changes. Two registered years have been taken under consideration, 1971 and 2002. The results of the census from the year 1971 show the condition of "welfare" in Central Serbia. It is the time of deagrarization, industrialization, development of urbanization, the time when the generations born after WW 2 were growing up and taught in the socialistic spirit of the time, it is the period when the population standard was on the rise (Ianoş et al, 2010, 163). In the meantime, from 1971 until 2002, in only thirty years, in Serbia there were great social, economic and political changes (Agh, 1999, Bieber, 2004). First, there came the saturation with manpower, because people continued to move from mountain and rural environments into industrial centers (Jordan, 2009, 91). In that way the sense of stagnation was produced. Unemployment "led" half of the population to Western European countries in the next decade. Then, political changes occurred. Following the separation of ex-Yugoslav republics and wars in their territories, Serbia felt in the form of imposed embargo, economical crisis, monetary instability, and influx of large number of refugees and displaced population etc. (Kovačević, Kicošev, 2007, Stepanov and Lazar, 2002, 137). All that time, the country remained the economic subject and the owner of the most important economic factors. After NATO's "Merciful Angel" operation from 1999, political changes occurred, favouring the development of pro-democratic ideas (Jansen, 2001, Vukmirović et al, 2001, Kovačević et al, 2010, 66). This change triggered the process of transition, which was also seen in owners' transformation (Bartlett, 2009). The year 2002 is chosen because that was the last time a census was organized, so there are no newer data. With the owners' transformation, all economic resources have gone in "private hands".

Study area

The Goč Mountain and its foothill are situated in the middle of Serbia. This territory covers 402.1 square kilometers and is spread between 166 and 1127 m above sea level (Kovačević, 2008, 7, 214). The Goč Mountain belongs to the system of the Kopaonik Mountains which are on the north bounded by the valley of the West Morava, to which the northern foothill of Goč belongs. That is, the territory of Goč and its foothill is divided on southern mountain and northern valley territory. The mountainous half, because of its relief, before all, is marked by a small number of population and settlements. The infrastructure is not developed. Local roads are rare and scarce. The valley of the West Morava, known by the highway M-5, which connects western and eastern parts of Serbia, has more population, i.e. has higher population density than the Serbian average. These natural differences represent the reason why the Goč Mountain and its foothill have been taken as an example in researching the influence of entrepreneurial initiatives on functional transformation of settlements in Central Serbia.

Methodology of research

Settlements can have different functions, agrarian, industrial, tertiary and quarterly (Ćurčić, 1992, 139-140). According to Grčić (2002, 266), they are classified into three large groups: agrarian, industrial and service. The only data according to which it is possible to determine functions of settlements are statistical data about the working activities of the population. For example, if majority of population of certain settlement earns their financial resources working in industry, it means that that settlement has dominant industrial function. Every one of three Grčić's (2002) groups matches one economical sectors.

According to Three-Sector-Hypothesis, economy is divided into three sectors. The primary sector consists of agriculture, forestry and fishing, mining, and extraction of oil and gas hunting. The secondary sector comprises activities of producing manufactures and other processed goods. This sector is often divided into light industry and heavy industry, while the tertiary sector means service, handicrafts, traffic, tourism and trade (Clark, 1957, Bell, 1976, Kenessey, 1987, 361, Mayhew, 1997, 373, 415, Ehrig, Staroske, 2009, 262). Every settlement, in that way got three absolute numbers, which showed the number of population that earn their living in primary, secondary or tertiary sector.

Considering the fact that settlements with different number of population were compared, received absolute data were not comparable (Savezni zavod za statistiku, 1972, a,b,c and Internal documents of Statistical Office of the Republic of

Serbia, 2004). Because of that they were transformed into relative, i.e. all of them were shown in percents, i.e. it bore the value of share that the population of certain settlement in certain sector takes. In order to make it more obvious, the graphical method was used, being the simplest way show the functional transformation of settlements. Because of the existence of three data for every settlement, the geometrical picture of equilateral triangle was used. By dividing the equilateral triangle using the methodology of Vujadinović (2006, 264), its space has been divided into three small equilateral triangles and six irregular trapeziums. By positioning some of the settlements in certain triangles it means that there prevails the population that lives from the activities which belong to one of three groups of sectors. If a certain settlement is located in the area of a trapezium, it means that there the majority of population earns their living in two of the three sectors. Depending upon which trapezium the settlement is situated, there is the possibility to establish which transitional type characterizes that settlement. This process is called determination of functional typology of settlements.

Results and discussion

According to the previously stated facts, the basic presumption was that, according to the census from 1971, most of the population was employed in secondary activities. Consequently, it was expected that most of the settlements had industrial functions. Strong industrial centers of Central Serbia, Kragujevac, Kraljevo, Trstenik and Kruševac etc. are situated outside the territory of Goč and its foothill, at the distance of 10 to 40 km. Ever since they were established, they have attracted young and reproductive population from the entire Serbia. Daily migrants from the region of Goč and its foothill have at that time earned their financial resources for living exactly in the centers mentioned above.

The economic and political crisis and transition during the last decade of the 20th century had a negative influence on the industrial production (Veremis, 2008, Hirt, 2008). Enterprises were often in stagnation or went bankrupt, so they had to fire their employees, which led to high unemployment rate (Đurić-Kuzmanović, Žarkov, 1999). In function of preserving tradition and achieving additional financial resources, population was, even in the period of welfare, engaged in small-property agriculture, so they were selling some of their products (Vujadinović, 2006, 264). However, because of the economic crisis, when people were struggling to survive because of the high unemployment rate, it was expected that on the region of Goč and its foothill there would dominate agricultural activities, i.e. that settlements would have agrarian functions.

The most developed and the most visited spa in Serbia, Vrnjačka Spa, is located at the contact between the Goč and its foothill. Spas are also one of the symbols of Serbia, because it is estimated that on its territory there are 14 spas that are often visited by tourists (Statistički godišnjak, 2008, 325) and over 70 unrecognized spas (Rodić, Pavlović, 1994, 168). That is why the influence of services could have also been predicted. The third postulate was that the service functions had to be also according to the census in 1971 and 2002 noticeable.

In Serbia, especially during the last decade of the 20th and the beginning of the 21st century, entrepreneur business became more attractive. It was born out of need of people to survive, but also as a way to preserve the capital during the devaluation of dinar. However, it was not possible to "ad hoc" predict their importance and whether it had influenced the function of settlements at all.

It was necessary to find adequate numerical data, in order to perform wanted analyses. Besides that, it was possible to find some data for this paper only by conducting the poll of the local population.

The results of the research have been shown according to graphical results in the form of a triangle, based on a special analysis and on questionnaire polls.

1. The results of triangle

Regional centers of Western Pomoravlje, Kraljevo, Trstenik and Kruševac, which are the closest to the Goč Mountain and its foothill, have attracted and still attract population. After the World War II, when there began the process of industrialization in Serbia, as well as in the region of Western Pomoravlje, the population working in agriculture gradually shifted towards non-agricultural. Consequently, there also occurred socio-economical and functional changes of the Goč Mountain and its foothill. The young population left their settlements up on the mountains and went towards the mentioned regional centers, Vrnjačka Spa or built their houses in the valley of the Western Morava, by the road M-5 (Kovačević, 2008, 8, Popescu, 2008, 150).

The analysis of functional typology of settlements was performed according to settlements of the Goč Mountain and its foothill for the year 1971 and 2002. In only three decades, settlements have completely functionally changed. Only Kamenica, a settlement in the gorge valley of the Ribnica, and Dragosinjci, a settlement on the foothill of the Goč, have stayed in the same functional typological group during the observed period, keeping their agrarian-industrial character. Their population has lived partly on agriculture, and partly they earned their living by working in industrial entrepreneurs of Kraljevo.

Only six settlements (23.1%) had agrarian function according to the results of the census from 1971 on the territory of the Goč and its foothills (Fig. 1). Those were Vukušica, Goč, Otroci, Stanišinci, Brezovica and Stublica. Those are settlements that are far away from the busiest lines of communication of the Goč and its foothill, mountain settlements, settlements in the Basin of the Popinska River and settlements on the Goč mountain (Fig. 2).

The drawing for the year 1971 predicted their aspiration towards the settlements of agrarian-industrial functions. According to the data from the 2002 census, five out of the six settlements mentioned above found themselves in the category of agrarian-industrial settlements. Their population got employed in the industry of Vrnjačka Spa and other regional centers.

The last census did not register even one agrarian settlement, i.e. not one settlement in which people live only from primary activities, on the territory of the Goč and its foothill. Due to the employment of population of Otrok in secondary activities, they found themselves in the year 2002 in the category of industrial-agrarian settlements (Fig. 1).

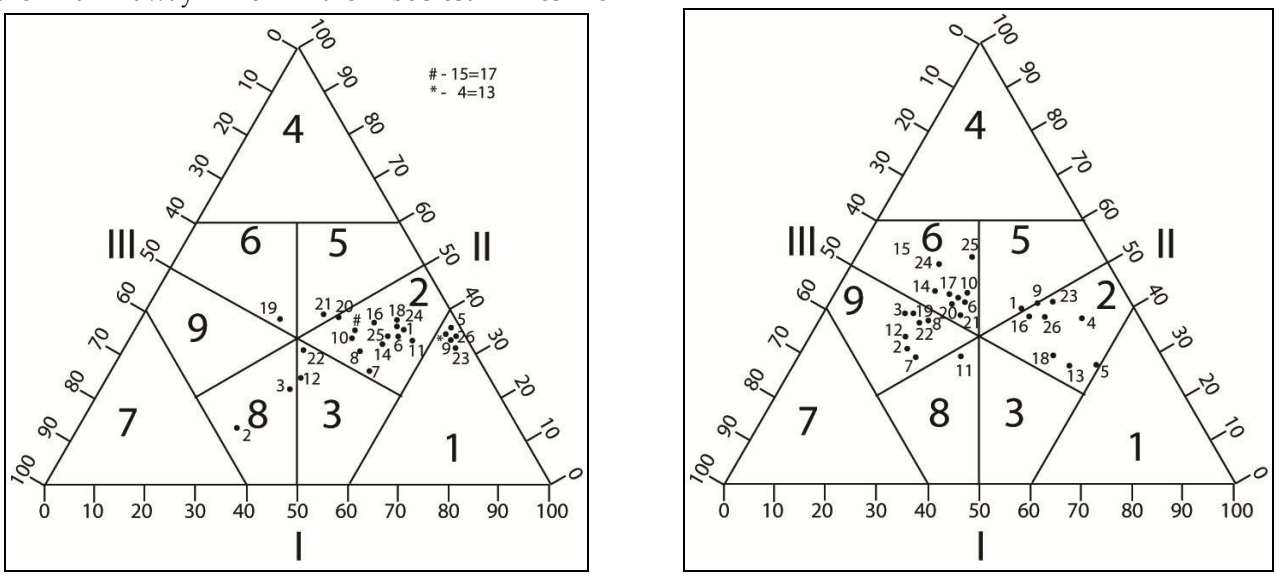

Fig. 1: Functional types of settlements of the Goč and its foothill, according to the censuses from 1971 and 2002

Legend: Economic sectors: I, II, III; Functional types: 1. agrarian, 2. agrarian-industrial, 3. agrarian-service, 4. industrial, 5. industrially-agrarian, 6. industrially-service, 7. service, 8. service-agrarian and 9. service-industrial; Settlements: 1. Vraneši, 2. Vrnjačka Spa, 3. Vrnjci, 4. Vukušica, 5. Goč, 6. Gračac, 7. Lipova, 8. Novo Selo, 9. Otroci, 10. Podunavci, 11. Rsavci, 12. Ruđinci, 13. Stanišinci, 14. Štulac, 15. Vrba, 16. Dragosinjci, 17. Zaklopača, 18. Kamenica, 19. Kovanluk, 20. Metikoš, 21. Ratina, 22. Ribnica, 23. Brezovica, 24. Dublje, 25. Popina, 26. Stublica

In 1971, more than half (53.8%) or the fourteen settlements of the Goč and its foothill had agrarian-industrial functions. According to the census of 2002, only Kamenica and Dragosinjci have kept this functional character. In 2002, eight settlements belonged to the category of industrial-service settlements (Gračac, Podunavci, Štulac, Vrba, Zaklopača, Metikoš, Ratina, Dublje and Popina). Lipova and Novo Selo became in 2002 service-industrial settlements. Lipova connected itself to Vrnjačka Spa and included tourist services, offering rooms to spa's guests in affordable prices. Novo Selo developed service handicrafts. The remaining two agrarian-industrial settlements, Vraneši and Rsovci found themselves in other categories. Vraneši has become an industrial-agrarian settlement in 2002, the number of non-agrarian population being higher than the agrarian one. Although many people from this

settlement began commuting to work in secondary economic jobs, agriculture remained the additional profession of its population. Rsovci is situated partly on the mountain, and partly along the valley. Due to the higher number of population in the valley, in 2002 it became a service-agrarian settlement.

Two settlements of the Goč and its foothill, Ruđinci and Ribnica had agrarian-service functions in 1971. Agriculture was at that time the dominant functional typological category. Ruđinci as suburban area of Vrnjačka Spa offered services in tourism, and Ribnica near Kraljevo service handicrafts. Urbanization and industrialization influenced the change both in Vrnjačka Spa and Kraljevo, so these two areas in 2002 belonged to the category of service-industrial areas.

In 1971, Ratina was the only industrial-agrarian settlement withing the study area while in 2002 it was one of the eight industrial-service settlements. Obviously, the secondary activities stayed profitable, and tertiary activities were more profitable than the primary ones, before all agriculture. Kovanluk was in 1971 the only industrial-service area in the observed territory. Three decades later, Kovanluk was transformed into an industrial-service settlements, just as other six settlements in the analysed area. It can be said that the most developed areas of the Goč and its foothill belong to this category, and that the others long for it.

Vrnjačka Spa and Vrnjci were in 1971 service-agrarian areas, and in the process of industrialization, they were transformed into service-industrial areas, according to data of the census from 2002.

2. Spatial analysis

As it was confirmed by the territorial analysis, the natural factors influence the functional typology of settlements. Mountain settlements and the less accessible areas that are the far away from the lines of communication were agrarian in 1971. Most of the settlements belonged to agrarian-industrial category, except Vrnjačka Spa and its suburban areas which more or less had certain service functions. The other group of settlements in 1971 consisted of three suburban areas of Kraljevo, and closest to it Kovanluk did not have agrarian characteristics. The other two more distant had also industrial (Ratina) or service (Ribnica) activities (Fig. 3).

According to figure 2, the year of 2002, population of mountain settlements (Dragosinjci, Kamenica, Goč, Stanišinci, Brezovica and Stublica) besides the agriculture, worked also in industry. These settlements gained agrarian industrial character. Industrially-agrarian character had settlements equally away from Kraljevo and Vrnjačka Spa (Vukušica and Otroci). Industrially-service functions are dominant in the areas which are connected to the suburban areas of Kraljevo (Metikoš, Ratina, Zaklopača and Vrba) and Vrnjačka Spa (Podunavci, Gračac from the western side and Štulac, Dublje and Popina from the eastern side). The gravitational center of the Goč and its foothill, Vrnjačka Spa, and its suburban areas (Lipova, Ruđinci, Vrnjci and Novo Selo), as well as the suburban areas of Kraljevo (Ribnica and Kovanluk), belonged in 2002 to the group of service-industrial settlements.

3. Survey research

By conducting the survey among the population within the analysed area, it was realized that among the industrial branches there prevail wood-processing and machine industry, then textile, food-processing and liquor industry. According to the census from 2002, 4077 people work in the industrial branches on the territory of the Goč Mountain and its foothill (Republički zavod za statistiku, 2004). Factor analysis should not be done with less than 100 observations (Bartlett et al, 2001). But, in interview studies, sample size is often justified by interviewing participants until reaching 'data saturation' (Francis et al, 2010). One hundred respondents, who were between 20 and 65 years old and half of them were women, have been interviewed on the field. The questions had open character, and the answers not predictable. Enough competent respondents were necessary for the sample. Hence, interview was organized with few managers in every single enterprise. Their answers were compared. Only verified responses are shown in the results. According to this, it could be concluded that some branches of industry, such as wood-processing industry, have developed on the basis of source of raw materials. Exactly 51.1% of Goč and its foothill is covered with forests, but this material is not exploited anymore, instead the lumber is brought from territories out of this region (Kovačević, 2008, 310).

The machine industry was never based on the source of raw material of Goč and its foothill, but it was inherited from the more developed regional centers. Namely, when regional centers began to

lower their production, someone had to satisfy the market demands. Those demands were recognized by entrepreneurs, who estimated that they could financially sweeten such expensive industrial branch.

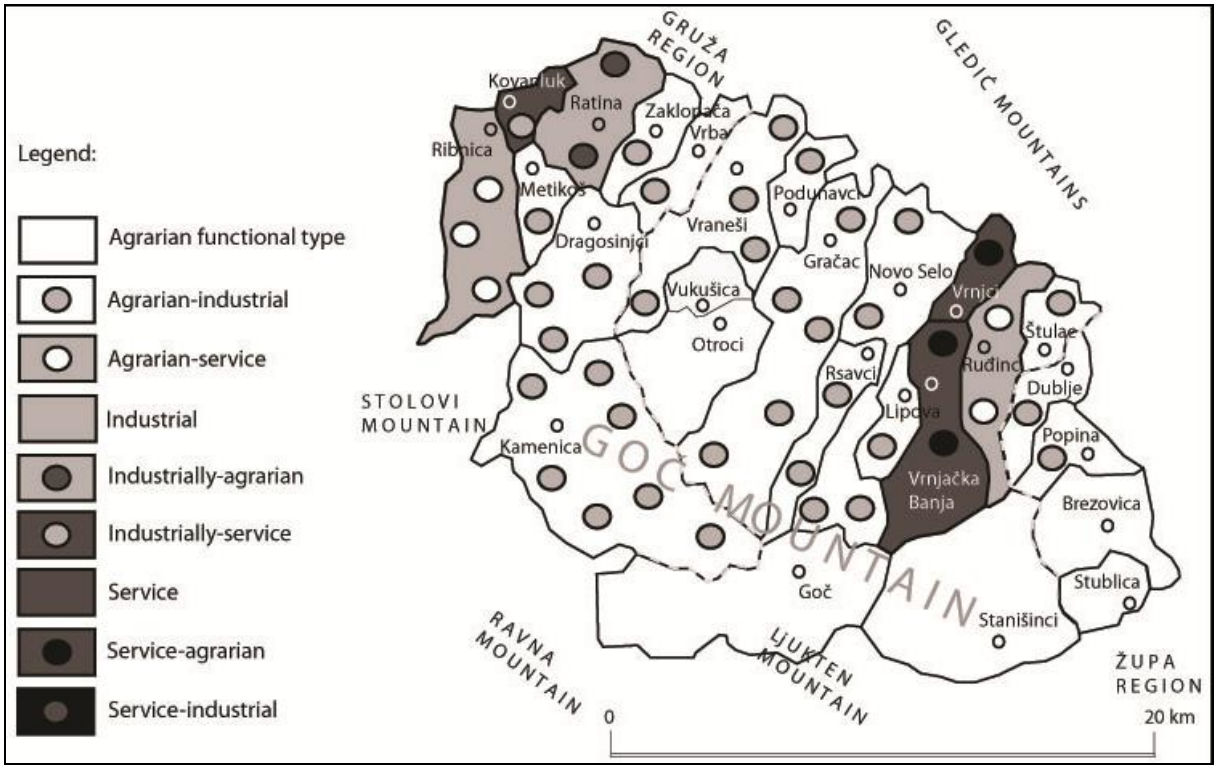

Fig. 2: Functional typology of settlements within the Goč and its foothill in 1971

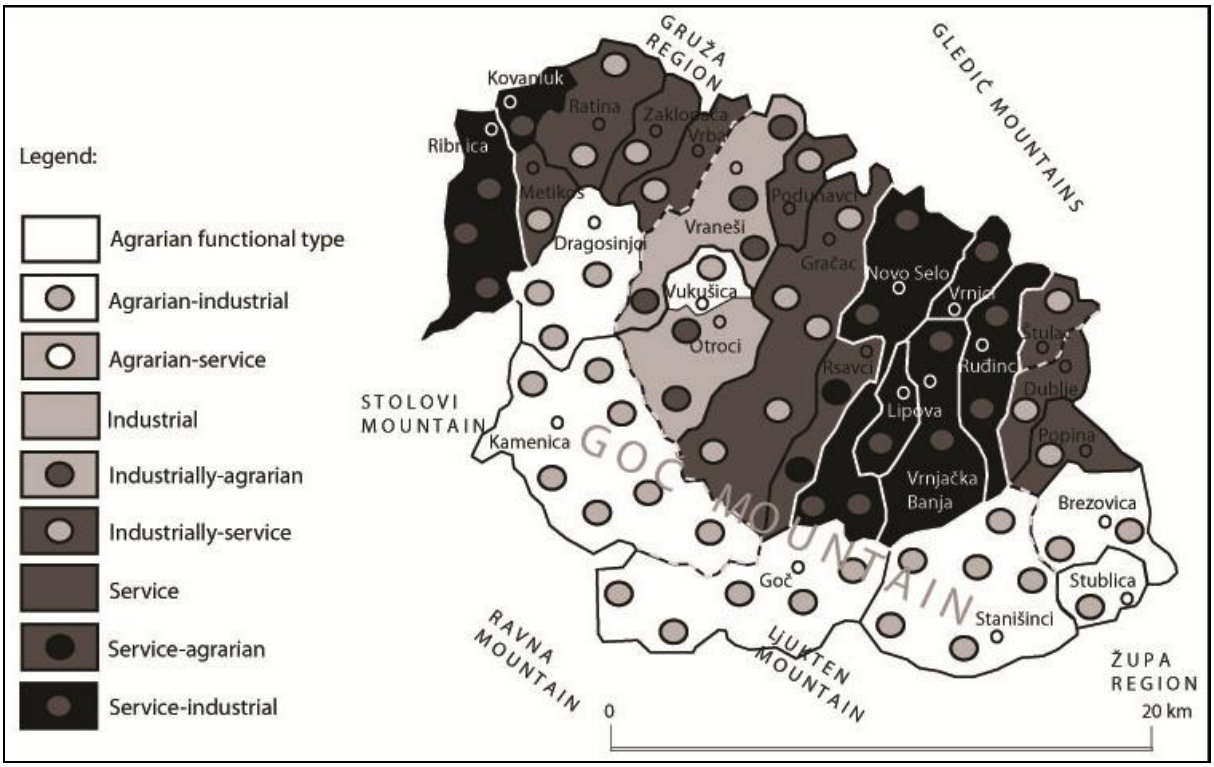

Fig. 3: Functional typology of settlements within the Goč and its foothill in 2002

The textile industry has come from craft production, while the food-processing and liquor industry was inherited from the socialistic period and it mainly uses raw materials from the territory of the Goč and its foothill. Among them, symbols of this territory are factories for bottling mineral waters.

Construction work is also one of the dominant economic branches. The majority of the raw materials is received from the territory of the Goč and its foothill, such as pebbles and sand from the riverbed of the Western Morava, rock that is gained in several quarries on eastern and western mountain sides, or even lime from the valleys of the Popinska and the Brezovačka Rivers. The exploitation of construction materials began with the widening of Kraljevo and Vrnjačka Spa as urban centers, and then with the construction of spa's hotels during the seventies and eighties of the 20th century. Construction of objects for individual living was, in the same period, made easier with the help from the state in form of allowing credits for the development of private rooms and services in tourism of Vrnjačaka Spa. People who worked abroad have, for example, their money earned in Western Europe invested in construction of objects for living in their native region.

Service functions of settlements are based upon the fact that population earns their income in tourism and hotel management, i.e. hotel and restaurant management, then trade, traffic and handicraft. Although it may seem that the development of tourism in Vrnjačka Spa influenced the development of other tertiary activities, it is not the case. However, entrepreneur business influenced the establishment of numerous trade and transport companies. Entrepreneurs develop service handicraft. Traditional handicraft has been put in the function of tourism, in such way that it nourishes production and preservation of souvenirs.

Who are the entrepreneurs?

The concentration of entrepreneur business has in past been connected to Vrnjačka Spa. So, the development of the Spa was laid upon the ideas of rulers (Herder, 1846), influential clergy and aristocracy (Lindermayer, 1856), who had means for such investments. Later the region of the Goč Mountains and its foothill attracted high state clerks and intellectuals (Borović-Dimić, 2005). They mainly developed activities of tertiary sectors.

From the World War II until the disintegration of SFRJ, entrepreneur business did not exist in the right meaning of the word. It was "in hands of the state". The state equally developed activities of secondary and tertiary sectors.

From the beginning of proprietor transformation there appeared new profiles of entrepreneurs. Among them, there should be a distinction between those who formed new companies, and those who used privatization to become the owners of existing ones. The founders of new companies are most often those people who were the leaders in state institutions. Experience and business contacts of these people have appeared as comparative advantage. The owners of former state companies are most often entrepreneurs without experience, but with influential family or political connections.

By analyzing the origin of entrepreneurs it was determined that the largest number of them came from the regions that are distant from Goč and its foothill. The largest number of entrepreneurs came from Kosovo and Metohija. The other entrepreneurs who are citizens of Serbia mainly have origins in Raška region. From foreign citizens the dominant ones are Montenegrins, population that fled from the territories of former Yugoslavia and Serbs from Diaspora, i.e. the regions of European Union (Germany, Austria, France, Sweden etc.) and North America (Canada and the USA). However, it is public secret, as it was found out from the survey polls that entrepreneurs from Diaspora do not succeed to buy state companies.

Conclusion

Results of researches have partly refuted the stated postulates. According to the results of census from 1971 about the working activities of the population, applying the methodology of Vujadinović (2006, 264), it was determined that in most settlements of Goč and its foothill dominated agrarian functions, and not industrial as it had been postulated. From 26 settlements, 6 belonged to agrarian type, 14 to agrarian-industrially functional type, and 2 to agrarian-service type. On the basis of that it can be said that the influential process of industrialization came to the territory of Goč and its foothill later.

Functions of settlements Goč and its foothill have according to listed data on working activities of the population from 2002 been changed into 24 from 26 settlements. All settlements have found themselves in mixed functional types. There should be the distinction of functional transformation of mountain settlements, which is older, from transformation of settlements in the valley.

Functional transformation of settlements on the mountain Goč and its foothill is the consequence of

the process of industrialization and other mentioned that dominated during the seventies and eighties of the 20th century, i.e. social events before the newest entrepreneurial initiatives. Namely, about the third of the settlements in Goč and its foothill has remained in dominant agrarian functions, i.e. agrarian-industrial function. Suburban areas of Kraljevo and Vrnjačka Spa, which made about one third, have received service-industrial function. Settlements in the valley of the West Morava in general, especially in the settlements around the highway M-5, which are also present with around one third, have received industrially-service functions.

Using field researches and observations it was determined that the functional transformation of settlements which was identified according to data from 2002 could have been influenced only the development of entrepreneurial business, which came as a result of changes of proprietor's transformation and the development of small and middle companies, which started after 1990. The newest entrepreneurial initiatives are, compared to those in the past; the most intensively transformed the region of Goč and its foothill. The newest generation of entrepreneurs mainly has no family tradition in entrepreneurial business. The money they own has been gained fast and usually in unfamiliar way.

From the original postulates the influence of Vrnjačka Spa was confirmed, which is the result of its postwar affirmation, urbanization and appointing administrative functions, on its surrounding in that sense that its suburban areas, especially according to data from 2002, gained service-industrial functions.

Every region in Serbia is unique and has certain degree of individuality. In case of Goč and its foothill, the most distinguished feature represents Vrnjačka Spa. On the basis of that we can say that it is very hard to find ideal sample which could completely show the state of entire region in Serbia. However, it was concluded that generally main trends could be registered.

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