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Preliminary Results in Assessing Flood-prone Areas Using UAS System within the Ozana River Upper Basin (the Eastern Carpathians)

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Abstract

The UAV technique, and more recently UAS systems, play an ever important role in various domains of research and practical activities. The increase in number of publications focusing on their applicability is spectacular. The objective of this study is to highlight the efficiency of an integrated command-overflight-taking photo system, in an area with obvious problems related to hydric hazards and risks. The quasi-circular shape, the petrography of the upper Ozana basin, its orientation and its opening to the air masses predominantly movement direction, represent just a few of the reasons why it was chosen as the case study. Also, the settlements are displayed on the valleys thread, and this confluence has a remuu potential, in case of isolated rains in the two related subbasins. The UAV Phantom 4 quadcopter, the UAS system, the DroneDeploy application, the UAVPhoto application, the Visual-SFM application, the Daisy algorithm, the micro triangulation network (mesh), the work surface textures, a hyper-resolution of orthophotoplan, DSM model with a 5 cm resolution etc. are the technical elements that made modelling at a very high detail possible. The probability flow rates that were used, were provided by the two hydrometric stations located very close to the study area. Theywere calculated using professional applications approved at the national gauging network level, using the established Kriţki-Menkel and Pearson III statistical distributions. The cross-section profiles was performed in the 10.x ArcMap module, using the 3D Analyst extension, and the hydraulic calculation to obtain the average velocity was done using the Manning equation; subsequently, the floodable surfaces was delineated on these profiles. Using the same ESRI module, the flood prone area polygon interpolation and it overlapping over the terrain model and over the orthophotomap were achieved. Paradoxically, the analysis of the results indicates a low degree of the anthropogenic habitat damage, but this aspect is due, in large measure, to the intervention of technical teams in the recalibration of the minor riverbed, massively clogged by alluvial transport.

Keywords: *UAS, DSM, GIS, cross-section, flood prone area*

Rezumat. Rezultatele preliminare în determinarea arealelor inundabile folosind sistemul UAS în bazinul superior al Ozanei (Carpații Orientali)

Tehnica UAV, și mai recent sistemele UAS, își regăsesc tot mai mult locul în diverse domenii de cercetare și activități practice. Creșterea numărului publicațiilor privind aplicabilitatea acestora este spectaculoasă. Obiectivul prezentului studiu este de a pune în evidență eficiența unui sistem integrat de comandă-survol-fotografiere, pe un areal cu evidente probleme legate de hazarduri și riscuri hidrice. Forma cvasi-circulară, petrografia bazinului Ozanei superioare, orientarea și deschiderea acestuia pe direcția circulației predominante a maselor de aer, reprezintă doar câteva dintre motivele pentru care a fost ales ca studiu de caz. De asemenea, localitățile se înșiră pe firul văilor, iar confluența aleasă are un potențial de remuu, în cazul unor ploi izolate în cele două subbazine aferente. UAV Phantom 4 quadcopter, sistemul UAS, aplicația DroneDeploy, aplicația UAVPhoto, aplicația Visual-SFM, algoritmul Daisy, rețeaua de microtriangulație (mesh), texturile suprafeței de lucru, ortofotoplan hiperrezolut, model DSM cu rezoluție 5 cm etc sunt elementele tehnice care au făcut posibilă o modelare la un foarte mare detaliu. Debitele cu probabilități utilizate provin de la cele două stații hidrometrice situate foarte aproape de arealul de studiu și au fost calculate în aplicații profesionale omologate la nivelul rețelei hidrometrice naționale, folosind distribuțiile statistice consacrate Kriţki-Menkel și Pearson III. Ridicarea profilelor transversale s-a realizat în modulul ArcMap 10.x, folosind extensia 3D Analyst, iar calculul hidraulic, pentru obținerea vitezei medii, a fost făcut utilizându-se ecuația Manning, ulterior suprafețele inundabile fiind delimitate pe profile. În același mod ESRI a fost realizată interpolarea poligonului de inundabilitate și suprapunerea sa peste modelul terenului și peste ortofotoplan. Analiza rezultatelor indică, paradoxal, un grad redus de afectare a habitatului antropic, însă acest aspect se datorează, în mare măsură, intervenției echipelor tehnice în recalibrarea albiei minore, colmatată masiv de transportul aluvionar.

Cuvinte-cheie: *UAS, DSM, GIS, profil transversal, bandă de inundabilitate*

Introduction

The debut of UAV (Unmanned Aerial Vehicle) technique and more recently UAS (Unmanned Aerial Systems) is related to the military applications and exercises, conducted in the United States of America and other countries with high financial and technical potential. Gradually, the UAV technique is being deployed in more strategic and other areas of the civil sector, from the supervision of natural and anthropogenic risk events, to the territorial management and supplies of products for commercial purposes, the latter being a new trend of the drone uses (Șerban et al., 2016, Ganová et al., 2017, Hackl et al., 2018, UAV Glossary of Terms, 2018).

Starting from the increasingly sophisticated mapping and monitoring needs, based in large part on a multi-scale analysis, it is standard procedure to combine the images collected using the UAV (UAS) technics with the satellite images, in order to achieve various photogrammetric, mapping, 3D modelling applications (Everaerts, 2008, Steffen and Foerstner, 2008, Sung Heuk et al., 2010, Eisenbeiss and Sauerbier, 2011, Remondino et al., 2011, Nadella et al., 2016).

On the other hand, numerous applications of the light flying techniques are implemented in forestry and agriculture, monitoring of vegetation (Sugiura et al., 2005, Hunt et al., 2010), as well as in the assessment of the health status of the forests, assuming the use of any performant electro-optical sensors, with taking pictures in the near-infrared domain (Watts et al., 2012).

In view of some risk generating natural factors manifestation, and the management of the generated crisis situations (Giordan et al., 2018), ever more frequently the UAV technique is used for landslides studying (Niethammer et al., 2010, Niethammer et al., 2011), soil erosion studying (D'Oleire-Oltmanns et al., 2012), but also for the detection of fires (Watts et al., 2009, Ambrosia et al., 2011) or monitoring the areas affected by earthquakes (post-earthquake) (Li et al., 2011, Baiocchi et al., 2013).

The micro-scale remote-sensing technique can be also successfully applied in the monitoring/surveillance of the road traffic, with travel time estimation, trajectories, the lanes occupancy degree (Puri et al., 2007, Remondino et al., 2011, Boccali et al., 2017), as well as in the air quality monitoring (Watts et al., 2012), in archaeology and cultural heritage (Chiabrando et al., 2011, Adjim et al., 2018) or in the resources mapping (Madjidab et al., 2018).

Within the hydric domain, the majority of the studies follow the problems related to the factors that triggered the floods or their effects in the territory. Here, the hydric risk is one of the major focus for researchers, along with structural or non-structural measures, which must be taken in order to mitigate this risk (Vârcol, 1961; Pandi, 2002; Stanciu et al., 2005; Arghiuş & Arghiuş, 2007; Vinet, 2007; Gaume et al. (24 authors), 2009; Pătruţ, 2010; Sarhadi et al., 2012, Cojoc et al. 2015, Zeleňáková, et al., 2017).

Satellite techniques, LIDAR, UAV or GPS have become prevailing in carrying research in the field, due to the ease, detail and speed provided, being already used to a large extent in the elaboration of the flooding maps, at small and large scale (Schumann et al., 2007; Zwenzner & Voigt, 2009; Şerban et al., 2009; Bhatt, et al., 2011; Domeneghetti et al., 2013, Șerban et al., 2016, Coveney and Roberts, 2017). Other studies are organized starting to various hydraulic models, that are constructed based on the cartographic supports or aerial images with medium or high resolution (Sanderset al., 2005; Pappenberger et al., 2006; Neal et al., 2007; Vanderkimpenet al., 2009; Chevereşan, 2011; Altarejos-Garcia, et al., 2012; Dutta, et al., 2013, Șerban et al., 2016).

The current trends seem to guide the research on water courses with torrential character, commonly with drainage basins less than 100 km^2, which, together with rivers that are already known for generating floods, put all the largest and most common problems to human communities, whse habitat lies in their vicinity (Arghiuş, 2007; Șerban et al., 2013, Șerban et al., 2016 etc.). The smaller size (UAV) aircrafts have a serious contribution to this type of research, as it ensures independence, ease of operation, very good accuracy, if they are equipped and properly calibrated, and allow significantly the reduction of the working time (Ellum & El-Sheimy, 2006; Gerke, 2008; Kerle et al., 2008; Choi, et al., 2009; Roeoesli, 2009; Sauerbier, 2009).

The use of obtained high-resolution terrain models, correlated with accurate hydraulic calculations, allows the elaboration of flooding maps for areas with high degree of vulnerability to flooding and with limited accessibility. Also, having many flights during flooding periods facilitates a better monitoring of the flooded areas and making decisions for the optimal management of the post inundation phenomenon (Horritt and Bates, 2002, Merwade et. al., 2008, Hervouet et al., 2011, Taubenbock et al., 2011, Abdelkader et al., 2013, Abdelkader et al., 2014).

Natural and anthropogenic conditions related to the studied territory

Ozana hydrographic basin is located within the Neamt County - Moldavia Region, Romania and overlaps the relief unit represented by the Ozana-Topolița (Neamț) Depression. Its upper sector has developed in the mountainous unit represented by Stânişoara Mountains, that are a "part of the Carpathian flysch geosyncline that evolved between Lower Cretaceous and Upper Miocene" (Fig. 1) (Ichim, 1979).

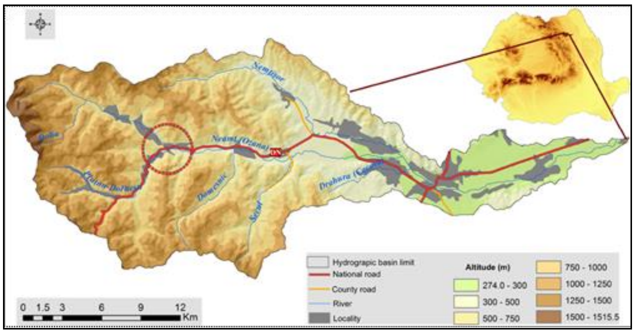

Fig. 1: The general map related to the river basin Ozana

In hydro-climatic terms, the study area is part of the Eastern Europe climate zone, since it has a transitional temperate-continental climate, characteristics that affect the eastern part of Romania, the east of the Eastern Carpathians and

Moldavian Plateau (Ștefănache 2007, Romanescu et al. 2012, quoted by Cojoc et al. 2015).

Geologically, the basin is characterized by a petrographic mosaic, crossing deposits of limestone-sandstone flysch, marls, conglomerates etc. Also, within the study area, slope values are high, the upper sectors exceeding in some parts, 25 degrees, a factor that influences the water propagation velocity. Other morphometric characteristics are given in Table 1 (Nițoaia et al., 2016).

Table 1: Some morphometric characteristics of Ozana basin (according to Romania Water Atlas, 1992, with additions)

River order	Slope (‰)	Average altitude (m)	Basin sector	Area (km^2)	Perimeter (km)	Coefficient of circularity
3	12	683	Upper	347,81	112,97	1,70
			Lower	65,66	69,7	2,42

Generally, the hydrographic basins shape, together with other morphometric characteristics, play a major role in the propagation of flash-flood waves and flood amplitude. Thus, in a basin that has an elongated shape, the concentration of water in the riverbed is more difficult than in basins with a circular, fan shape (Zăvoianu, 1978). This factor influences the magnitude of the flood waves and their effects. Also, the position of the basins in relation to the nearby mountain ranges influences the movement of air masses, and thus, the dynamic of cloud systems that generate rainfalls (Nițoaia et al., 2016).

Why Ozana hydrographic basin? After a quantitative assessment on the shape of the basin, the graphic representation of the coefficient was achieved (Fig. 2). The differences of the circularity (1.70 in the upper sector, respectively 2.42 in the lower sector), make the higher part of the studied space a torrential area, with a destructive potential at the maximum liquid flow.

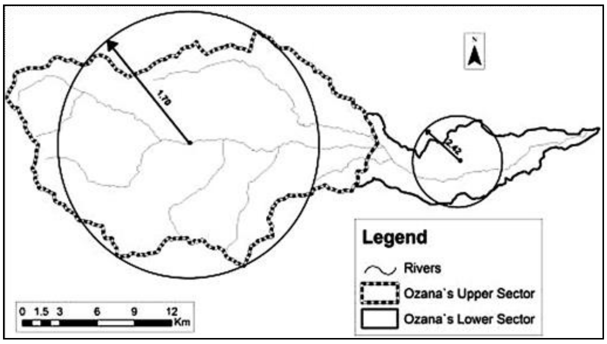

Fig. 2: Graphical representation of the coefficient of circularity for Ozana basin, created with ArcGIS 10.X's XTools Pro extension

The valley corridors are occupied by settlements, especially after the widening of the major riverbed in the lower basin (Fig. 1). These localities constitute the components of vulnerability to flood, in the case of the dangerous weather events occurrence, with the generation of significant amounts of rainfall.

Methods and results

For this study, a prior analysis of detailed cartographic materials (topographic maps 1:5000, aerial photos etc.) was done.

The photogrammetric measurements were performed with Phantom 4 quadcopter UAV technics, in the context of a UAS (Unmanned Aircraft System) work specific technology, which includes the UAV, the ground-based controller and a system of communications between the two. The measurements were aimed at achieving a digital terrain model at a centimetre resolution, in order to develop, as true as possible, the flood prone area. In parallel with the photogrammetric measurements, a topographic survey with Leica total station for the validation of the results was done.

The UAV technique used (Fig. 3) has the following features and amenities:

AIRCRAFT	PHANTOM 4 PRO
Product Position	Entry-Level Professional Drone with Powerful Obstacle Avoidance
Weight (Battery & Propellers Included)	1388 g
Max Flight Time	Approx. 30 minutes
Vision System	Forward Vision SystemBackward Vision SystemDownward Vision System
Obstacle Sensing	Front & Rear Obstacle Avoidance Left & Right Infrared Obstacle Avoidance
Camera Sensor	1" CMOSEffective pixels: 20 M
Max. Video Recording Resolution	4K 60p
Max Transmission Distance	FCC: 4.3 mi
Video Transmission System	Lightbridge
Operating Frequency	2.4 GHz/5.8 GHz
	*5.8 GHz transmission is not available in some regions due to local regulations.

Fig. 3: The Phantom 4 quadcopter used during the measurements (according to *DJI*, 2017)

Drone intrinsic parameters control is provided by the DJI-Go4 "mother" app. Before initializing any flight, it is mandatory to preliminary verify the aircraft status (sensors, batteries charge status, camera settings etc.).

Route defining and drone control has been made using the DroneDeploy app, installed on a HTC phone terminal which uses Android OS (Fig. 4), aiming at an optimal coverage of the proposed survey area.

Initially, the area of interest was established (Fig. 4.1), subsequently choosing the points of inflection from the flight route, for a good insurance of the necessary overlapping percent of the resulting images (Fig. 4.2); afterwards, the flight parameters were set (Fig. 4.3), for a maximum efficiency and a resolution of the images that make it possible to obtain a DSM (Digital Surface Model) with a centimetrec resolution.

Once the necessary data were obtained, these were loaded as input parameters in the DroneDeploy app, after which it proceeded to load the flight mission and conducting it. Subsequently, 720 scenes were retained and used, which have complied with the pre-calculated resulting parameters.

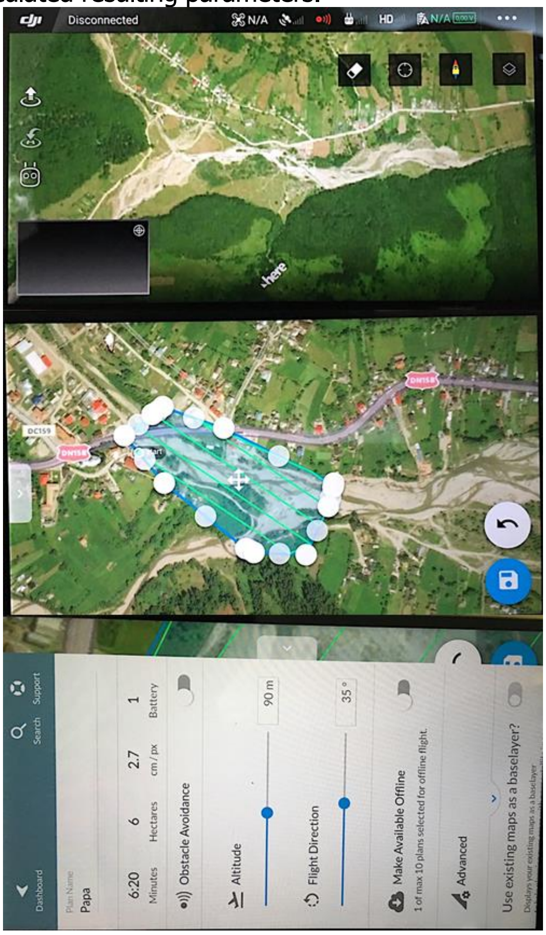

Fig. 4: Drone route configuring and manoeuvring (according to DroneDeploy: Powerful Drone & UAV Mapping Software, 2017)

Primary processing, in order to obtain quantitative data on the route and flight parameters was performed using UAVPhoto 1.0.0.2 app. This open-source app has allowed the ante-calculating of parameters such as: the pixel size of concerned land unit; the blur motion parameter; the velocity and the altitude; focal length of the camera; the used corresponding aperture etc. and ensuring of an overlapping of 80% on the Y-axis and respectively of 60% on the X-axis.

Further, the Visual-SFM open-source was used for information processing; Daisy algorithm was the mathematical algorithm used for determining the nodal points of aerial micro-triangulation network (Tola et al. 2010). It is based on the (logical) conception shown in figure 5.

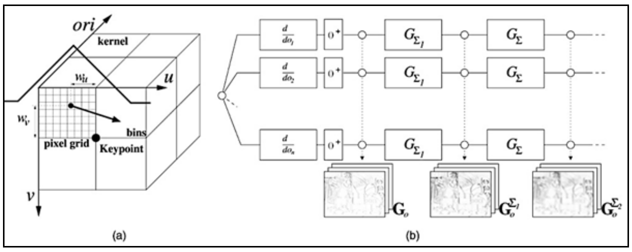

Fig. 5: Daisy mathematical algorithm concept (after Tola et al. 2010)

The nodal points of aerial micro-triangulation network, used for the 3D scene recomposition, are analysed on the basis of proximity and, in this way, the pairs of identical pixels are automatically determined, thus yielding the (mesh) micro-triangulation network.

From this network, it could proceed to the development of textures (Fig. 6), the stage where it has been possible to bind information (held in local coordinates), to the Stereo 70 real coordinates system (assuming the procedures of internal and external orientation established by classical photogrammetry).

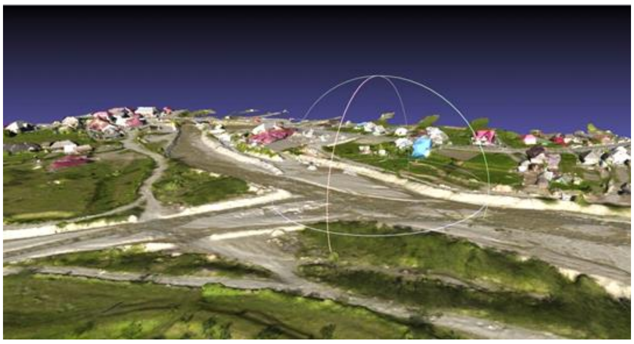

Fig. 6: The work surface textures exportable in the orthophotoplan

The emerged composite picture is one of high resolution (Fig. 7), which made possible the high

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detail export of the numerical model of the land (DSM) (Fig. 8).

For processing of flow rates statistical data, the programs Microsoft Excel and Hyfran were used.

Flows with exceeding probability used in the hydraulic calculation, were: $Q_{1\%}$ river Ozana, Leghin hydrometric station = 380 m^3/s and $Q_{1\%}$ river Pluton-Dolhești, Dolhești hydrometric station = 90 m^3/s. These values have been obtained in the section of gauging stations, on the basis of the observation data, using two theoretical distributions (Krițki-Menkel and Pearson III) and was extrapolated at the actual measuring sections.

These are the generalized gamma distribution and are two of the most popular distributions for hydrologic frequency analysis (Constantinescu et al., 1956; Bobee, 1975; Diaconu and Şerban, 1994).

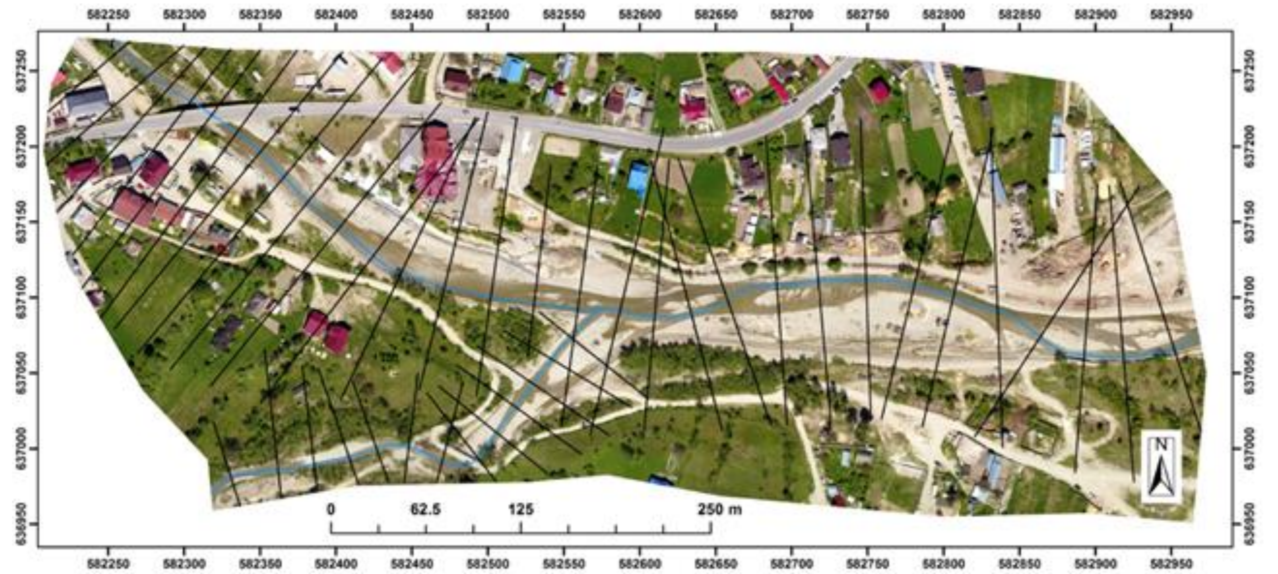

Fig. 7: The composite aerial image of the study area, with the profiles for the hydraulic calculation

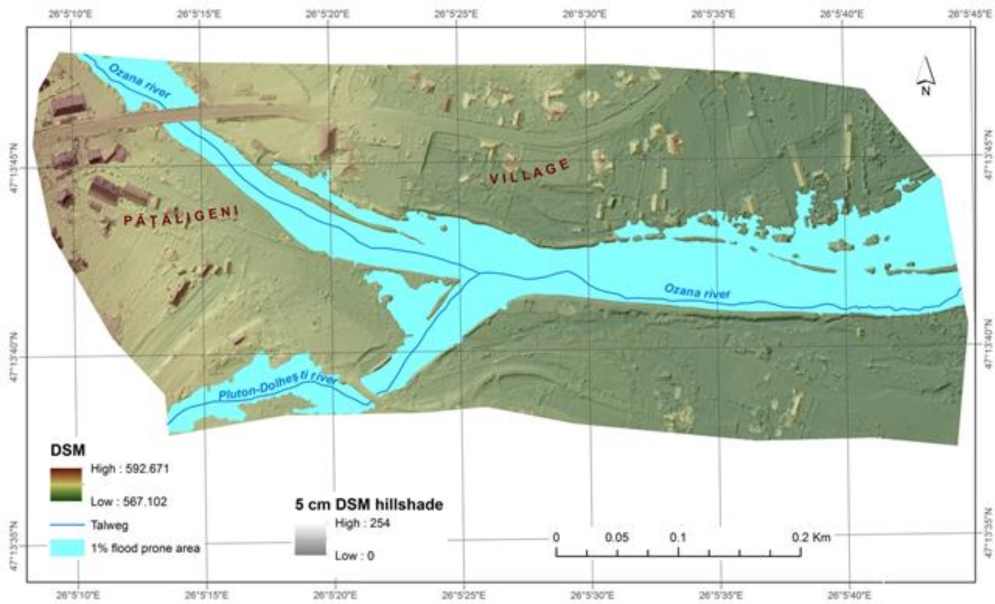

Fig. 8: 1% flood prone area in plan, upstream and downstream of the the two rivers confluence, overlapped on the high-resolution DSM

In the ArcMap 10.x module, on the altitude grid support, we proceeded to the extraction of 43 cross profiles, at a maximum distance of 30 meters between them, for an accuracy similar to the interpolation of flood prone areas.

These profiles have been georeferenced, in the first phase, in local coordinates, for performing to the real scale of the hydraulic calculations, regarding the surface of the cross-section Ω (m^2) and the maximum water depth on the profile, h_{max} (m).

The average velocity V_m (m/s) of water in the 43 sections have been determined on the basis of Manning formula:

$$V_m = \eta^{-1} * R^{0,67} * I^{\ 0,50}$$

where: V_m - average speed of water current (m^3/s);

η – the coefficient of roughness;

R – hydraulic radius (m);

I – slope at the level of the water surface (m/m).

In the second phase, the hydraulic radius R (m) was considered to be 0.9 of the average depth h_{med} (m) on the profile. The hydraulic slope (m/m) was topometrical determined in the field, and the η coefficient from the tables.

The georeferencing of the cross profiles, where the water level was marked at 1% probability of flow, in the projection system Stereo 70 and overlapping them over the grid elevation support constituted the last steps before the delimitation of the flood prone areas for the referred probability (Şerban et al., 2016).

The polygon of effective flood prone area has been obtained by graphic interpolation of in ArcMap between the ends of the cross profiles, according to the elevation grid slope (Fig. 8).

Discussions

After overlapping the flood prone area on the ortophotoplan of the study area, it is observed that the population and local authorities have learned from past experience and they proceeded to a precautionary location/relocation of households and properties (Fig. 9).

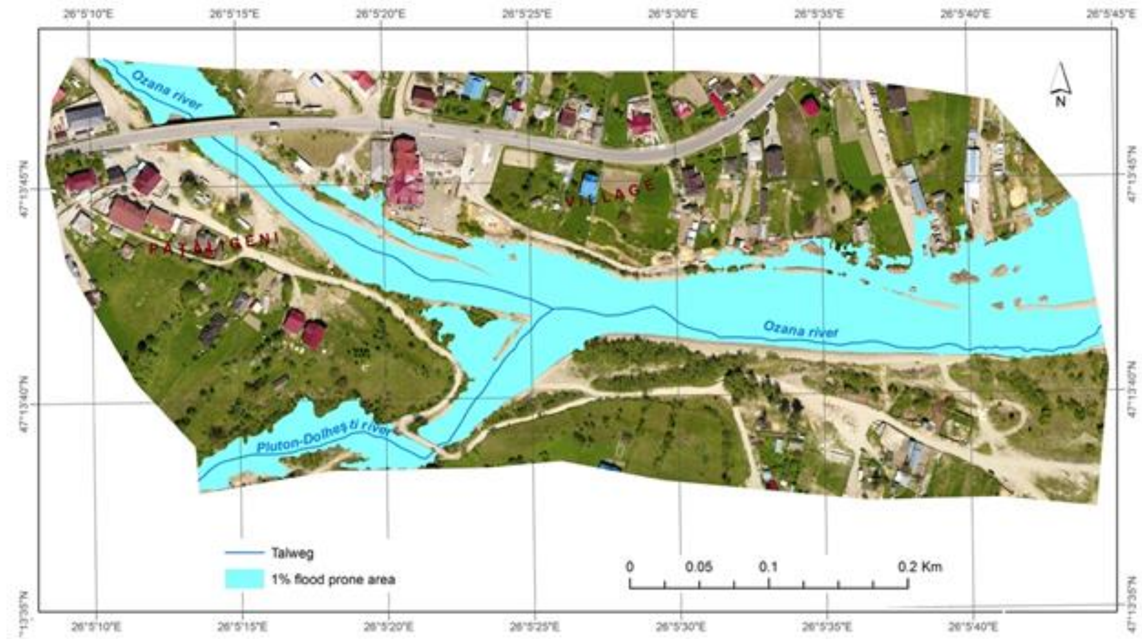

Fig. 9: 1% flood prone area in plan overlapped on the composite orthophotoplan

Few of these households are located within the flood vulnerable area, although the two water courses have a torrential character, and sedimentary petrographic deposits from basin (Carpathian flysch) provide significant quantities of alluvia; this material clogs/remodels in a consistent mode the floodplain at each important flood.

The authorities, which manage the water courses from the basin ("Siret" Water Basin Administration) have intervened wtithin the riverbed, recalibrating it. Following this calibration, most of the flows with low probability pose no threat, without large-scale overflows at maximum flow phase - like flash flood type. Such actions must be periodically repeated, whereas the clogging of the minor riverbed is particularly accelerated.

With respect to the UAS system that was used, there is an increased reliability, compared of the techniques of the older generation; this is possible due to to the preliminary configuration permissiveness of the route and of the overflight area, as well as self-mobilization of the aircraft, which is also, latest technology.

It should be noticed the drone increased autonomy, as well as the better performance of the built-in camera, able to orient themselves during the flight, under more difficult aerial conditions.

The resulting aerial images have a very good chromatic and resolution, and their processing allows the development of ultra-high definition DSM models, of great value in the floodable areas analysis, especially of the minor and major riverbeds.

The speed of land measurement achieving is increased, as compared with the classic topometric measurements or to those with GPS terminal; also, the density of reading of the land surface is the quasi-total.

Conclusions

Testing of new generation of flying machines remotely controlled brings substantial improvements in aerial photography and derived topography surface modelling. The application of the technique and of the new UAS system in the flood prone area study, particularly in the cvasi-circular basins with high torrents offers a higher efficiency for carrying measurements and also encourages a higher frequency of their use, due to the optimization of any work stages.

The improved resolution following the achievement of the DSM allows the study and great detailed modelling of all surfaces located within vulnerable areas, including those of great interest, such as the civil or private objectives, of great economic or cultural value.

The advantages of using this technology are:

- this leads to increasing the autonomy of work and the coverage of a more extensive area on a single flight;
- the 3D reconstruction process based on UAV technology (drone) and on the "Daisy" interpolation algorithm is cheap, relying on open-source solutions;
- the accuracy of the reconstruction 3D (5cm, in this case) is much higher than the traditional aerial surveys;
- the final product (DSM, orthophoto) can be georeferenced in general interest coordinates, overlaid on any data bases brought into the same projection system and integrated in any GIS or CAD type application;
- the procedure allows the rigorous qualitative and the quantitative approach (distances, surfaces, volumes), given the details that the modelling has been done;
- the procedure is non-invasive and is applicable in areas difficult to reach or inaccessible by traditional technology.

Some disadvantages of the application of the technology must also be mentioned:

- the flight is irrelevant if the surveyed area is covered by snow;
- it is recommended the flight should take place during spring, before the vegetation blooms, because this brings a serious shielding and numerous errors in data processing;
- the flight cannot be executed if wind velocity exceeds 60 km/h or there is unfavourable light; in this case, the flight was performed during the calm weather;
- the autonomy of a flight is relatively low and reported to a battery unit (normally, under 40 minutes), to avoid the collapse of the system and the recording significant damages;
- the low temperature in the flight environment is greatly impinging on the mission, causing a quick consumption of the battery;
- important hardware resources are required for data processing; in the present case, a PC with Intel i7 processor, 16 GB of RAM memory, 4 GB of video memory card on GDDR 5 GHz, and a 256 GB SSD was used.

Identifying areas with high risk to flooding, particularly in the cvasi-circular basins with high torrents can contribute to the sustainable development of settlements through the reduction of potential damages. The performed studies allow the imposition of restrictions regarding the location of the various objectives in these areas.

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Assessment of Groundwater Quality and its suitability for Irrigation in Dindigul Corporation of Dindigul District, Tamil Nadu, India

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Abstract

The Habitat Directive (HD) is the main strategy for nature The main aim of the study is to evaluate ground water quality suitable for irrigation purpose in Dindigul Corporation, Tamil Nadu, India. Within the study area 30 water samples were collected to determine the physical and chemical parameters. Sodium Adsorption Ratio (SAR), Sodium percentage (SP), Potential Salinity (PS), Residual Sodium Carbonate (RSC), Kelly's Ratio and Soluble Sodium Percent (SSP) have been determined to analyze the irrigation water quality. The analysis results reveal that SAR value indicates 84% of excellent, 13% of good and 3% of unsuitable water category. Based on sodium percent, only 10% are good, 50% are permissible and 40% are unsuitable for irrigation. Based on PS and RSC ratio about 97% comes under unsuitable category and 3% are suitable water for irrigation. Kelly's Ratio and SSP values indicate 27% of good quality and 73% are unsuitable irrigation water. The high concentration of salinity was found in the western part of the study area. The results show that most of the samples are not suitable for irrigation.

Keywords: *groundwater quality, irrigation, Dindigul corporation, SAR, salinity, USSL*

Rezumat. Evaluarea calității apelor subterane și oportunitatea pentru irigații în corporația Dindigul din districtul Dindigul, Tamil Nadu, India

Scopul principal al acestui studiu este de a evalua calitatea apelor subterane și oportunitatea pentru utilizarea acesteia pentru irigații în Corporația Dindigul, Tamil Nadu, India. Din arealul analizat au fost colectate 30 de mostre de apă pentru a determina parametrii fizici și chimici. Pentru analiza calității apelor pentru irigații, a fost determinat Raportul de absorbție a sodiului (SAR), Procentul de sodiu (SP), salinitatea potențială (PS), Carbonatul de sodiu residual (RSC), Raportul lui Kelly și Procentul de sodiu solubil (SSP). Conform rezultatelor analizelor effectuate, valorile SAR indică că 84% din mostrele analizate prezintă o calitate excelentă, 13% bună și 3% sunt neconforme. În funcție de ponderea sodiului, doar 10% au o bună calitate, 50% permit irigațiile, în timp ce 40% nu întrunesc condițiile. Conform raportului PS și RSC, 97% din mostrele analizate nu prezintă o calitate satisfăcătoare, doar 3% putând fi folosite pentru irigații. Valorile de la Raportul lui Kelly și SSP indică că 27% sunt de bună calitate, iar 73% sunt nesatisfăcătoare. În partea de vest a ariei analizate, apele se caracterizează printr-o concentrație mai mare de săruri. Conform rezultatelor analizelor effectuate, în cea mai mare parte resursele de apă subterană din spațiul analizat nu întrunesc condițiile de calitate pentru a fi utilizate în irigații.

Cuvinte-cheie: *calitatea apelor subterane, irigație, corporația Dindigul, SAR, salinitate, USSL*

Introduction

Ground water is a vital national freshwater resource. It is used for drinking, irrigation and industrial purpose. It is one of the most important components of human life. The quality of ground water depends on a large number of individual, hydrological, physical, chemical and biological factors. Ground water contamination is mostly found in urbanized areas, agricultural and industrial areas as a result of human activities (Martini et al, 2010, Mondal et al., 2005, Pradhan & Chandrasekharan, 2009, Jain et al., 2012, Shah & Mistry, 2013, Venkateswarana et al. 2015, Wilcox, 1955, Yogesh & Vadodaria, 2015). The study area is famous for industries such as lock iron safe manufacturing, leather tanneries, soap industries and other chemical and manufacturing industries. More than 65 tanneries are situated in Dindigul Corporation. Tanners use a large number of chemicals during tanning process. The tannery effluents are discharged into the nearby pond and land. These effluents pollute ground water and agricultural land. The water quality parameters such as Na, K, Ca, Mg, Cl, HCO_3 and SO_4 has been analyzed for irrigation purpose in the study area.

Study area

Dindigul is a city located in south Indian state of Tamil Nadu and lies between $10^0 26'00''$ N to $10^0 16'00''$ North latitude and $77^0 55'00''$ E to $78^0 2'00''$ E longitude. Its mean sea level is 280.11 and covering a geographical area of 110.20 sq. km. Dindigul Corporation includes 10 villages. Sirumalai hill is located in the southern part of the study area. The study area is covered by crystalline metamorphic rocks of archean age belonging to the khondalite and charnockite group of rocks. The soil type is mostly black soil with red sandy soil. The Kudavanar and Kudiraiyar are the main rivers of the

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study area. The temperature ranges from a maximum of 370C to a minimum of 290C during summer and maximum of 260C to minimum 200C recorded during winter. The study area receives rainfall from northeast monsoon and southwest monsoon. The average annual rainfall is about 836mm. The relative humidity varies between 65% and 85%. The total population of the study area is 3,37,874 as per census 2011 [source: http://www.dindigul.tn.nic.in/dhb2011-12.pdf].

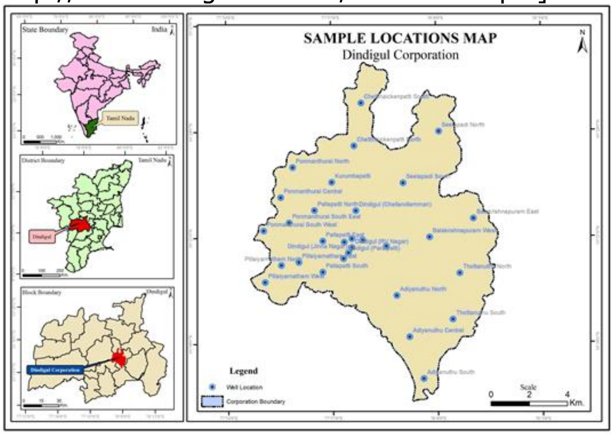

Fig. 1: Location of the study area

Material and methods

Within the study area, 30 ground water samples were collected in 1 litter polythene bottles from bore wells in August 2017. The bottles were cleaned and rinsed with sample water before sampling. The water samples were sent to the laboratory to analyze the parameters. Water quality parameters were analysed through EC, TDS, PH, SAR, RSC, SSP, PS, and Kelley's ratio for irrigation purpose. These criteria were used to estimate the ground water quality for agricultural use.

Results and discussion

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is used for evaluating the sodium hazard associated with irrigation water. The high sodium hazards lead to a decrease in infiltration and permeability of the soil, causing problems with crop production.

SAR value was calculated using the formula proposed by Richards (1952). All the values are expressed in epm Value.

$$\mathbf{SAR} = \frac{Na+}{\sqrt{Ca^{2+}+Mg2+/2}}$$

Within the study area, SAR values of the ground water samples range from 1.87 to 63.56. About 83% of ground water samples are <10, which indicates excellent category (S1), while 17% of samples within the range of 10 – 18 indicates good quality (S2) for irrigation. None of the water samples come under S3 and S4 categories.

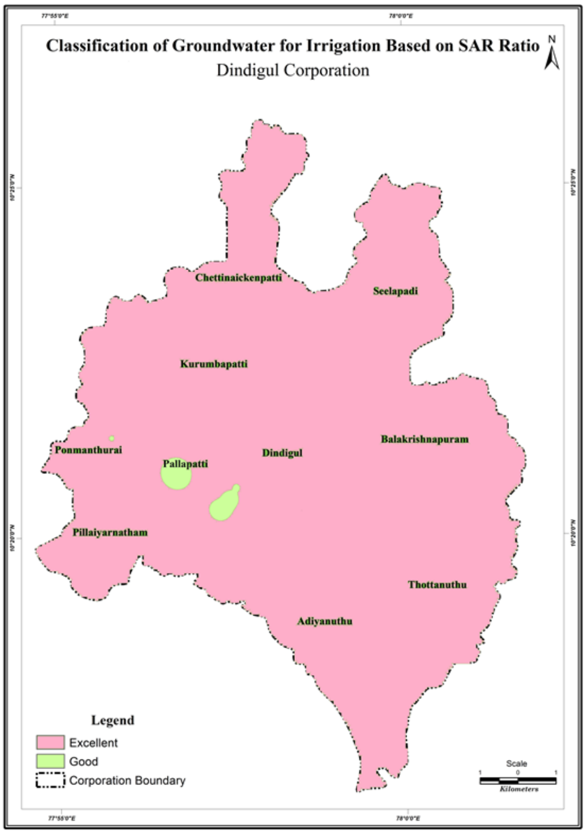

Fig. 2: Groundwater quality for irrigation based on SAR ratio

Table 1: Classification of groundwater for irrigation based on SAR

S. No	SAR in epm	Water quality	Total No of samples	Percentage of total
1	<10	Excellent	25	83
2	10-18	Good	5	17
3	18-26	Doubtful	-	-
4	>26	Unsuitable	-	-

Electric conductivity

Salinity hazard in ground water is measured by Electric conductivity. EC is generally related to the amount of dissolved solids or minerals. EC of water will be higher as dissolved solids increase. Higher EC in water creates a saline soil. Higher salt content in irrigation water affect plants growth, soil permeability. Electric conductivity varies between 1.06 and 5.06µsCm^{-1}.

Within the study area, none of the water samples are found in excellent and good category. About 43% of water samples showed EC value of permissible limit of 750-2000µsCm^{-1}. Eastern zone of the study area comes under this category. About 27% of water sample fall in the doubtful category (2000-3000µsCm^{-1}), while the remaining 30% water samples are unsuitable, with above 3000 EC value.

The underground water in the Western part of the study area is not suitable for irrigation.

Table 2: Classification of groundwater for irrigation based on EC

S. No	EC in $\mu S cm^{-1}$	Water quality	Total No of samples	Percentage of total
1	<250	Excellent	-	-
2	250-750	Good	-	-
3	750-2000	Permissible	13	43
4	2000-3000	Doubtful	8	27
5	>3000	Unsuitable	9	30

U.S.S.L classification for irrigation water

Wilcox (1955) determined U.S.S.L classification to analyze ground water quality for irrigation. U.S.S.L diagram is based on Sodium Adsorption Ratio and Electric Conductivity of water. The EC value is plotted on X axis and SAR on Y axis. The irrigation water has been divided into four classes based on salinity hazard (EC).

C_1– low saline water (0-250$\mu S cm^{-1}$)
C_2 – Medium saline water (250 -750$\mu S cm^{-1}$)
C_3 – High saline water (750-2250$\mu S cm^{-1}$)
C_4– Very high saline water (>2250$\mu S cm^{-1}$)

Based on the sodium hazard (SAR) water has been classified into four categories S_1, S_2,S_3,S_4 represent low, medium, high and very high sodium hazard respectively. According to the analysis, 14 samples fall into C3S1 category, which indicate high salinity with low sodium. Another 4 samples come under C3S2 level, indicating high salinity with medium sodium, 4 samples fall into C4S1category, which represent very high salinity with low sodium water, 6 samples come under C4S2, i.e. very high salinity with medium sodium, while 2 samples fall into C4S3, which indicate very high salinity and high sodium hazard. C4S2 and C4S3 of water sample areas are located in the western part of the study area. Most of the tanneries are found in these areas. The analysis of the ground water samples from the categories above are not suitable for irrigation. In some places from the northeast and southeastern part of the study area, saline resistant crops such as cotton, maize, millet, onion, tomato, brinjal can be cultivated.

Sodium Percentage (SP)

Sodium percent is classified based on Wilcox (1955) methodology to determine the Sodium Hazard. The high sodium concentration in ground water reduces Soil permeability. The sodium replacing adsorbed Calcium and Magnesium is a hazard as it causes damage to the soil structure. The following formula was used to measure Sodium percentage:

$$\%Na = (Na+K) / (Ca+Mg+Na+K) \times 100$$

According to Wilcox (1955), groundwater was classified based on average Sodium percent as excellent (<20), Good (20-40) permissible (40-60) and unsuitable (>60).

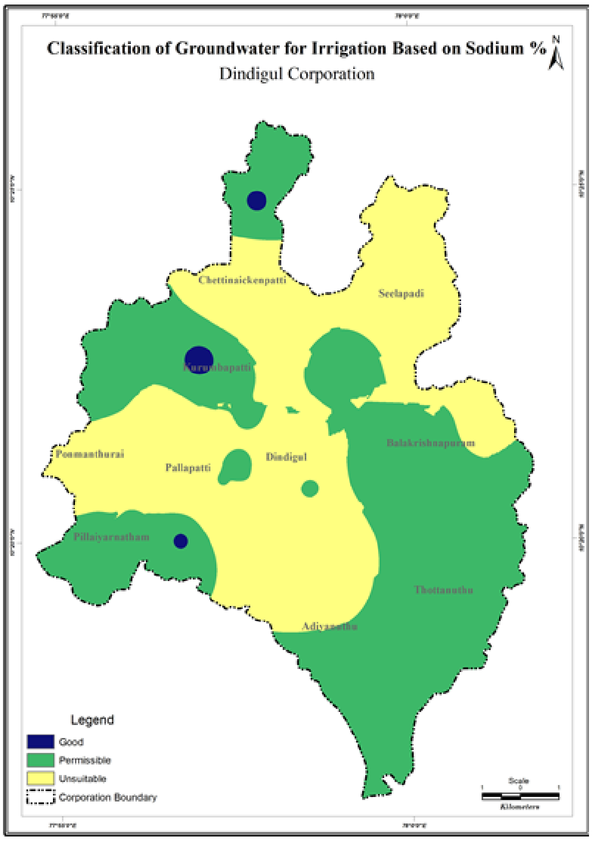

Fig. 3: Groundwater quality for irrigation based on Sodium

Within the study area, the Sodium Percentage was found in range from 33.65 to 99.05 epm. The analysis indicates that no water sample location comes under excellent category. About 10% of water samples indicate good in quality. Nearly 50% of sample locations have permissible limit. The remaining 40% of water samples come under unsuitable for irrigation water.

Potential Salinity (PS)

Doneen (1962) determined the potential Salinity for assessing the suitability of water for irrigation, arguing that the low solubility salts get precipitated in the soil and lead to successive irrigation, whereas the high concentration of soluble salts increase the salinity of the soil.

The below mentioned formula used in the estimation of potential salinity is expressed as:

$$PS = Cl + \tfrac{1}{2} SO_4$$

Within the study area, the PS of the water samples varied from 4.75 to 30.55 meq/l. None of the analyzed water samples comes under the excellent (<3) water irrigation category.

About 3% of the samples fall into good to injurious quality for irrigation (3-5). About 97% of

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ground water sample locations are injurious to unsuitable water for irrigation (>5). As it can see on the map, except for the southern part of Thottanuthu, the remaining areas are not suitable for irrigation.

Residual Sodium Carbonate (RSC)

Eaton (1950) classified Residual Sodium Carbonate for assessing water quality for irrigation. Ground water having high concentration of Carbonate and Bicarbonate ions tends to precipitate calcium and magnesium. As a result, the relative proportion of sodium increase will lead to decreasing the soil permeability. The RSC value is determined by the following formula:

$$RSC = [HCO3 + CO_3] – (Ca + Mg)$$

where, all Ionic concentration is expressed in epm. RSC values less than 1.25 are considered as safe for irrigation purpose, if the value is between 1.25 and 2.5 mg/L, the water is within the marginal range. RSC level more than 2.5 mg /L is unsuitable for irrigation purpose.

For the present study area, RSC values range between 0.05 and 30.3. All the groundwater samples fall in above 2.5 and indicate unsuitable quality for irrigation category, except the southern part of Adiyanuthu, where values are below 1.25.

Kelly's Ratio

The sodium iron concentration was measured to determine the ground water quality by Kelly's Ratio (1940).

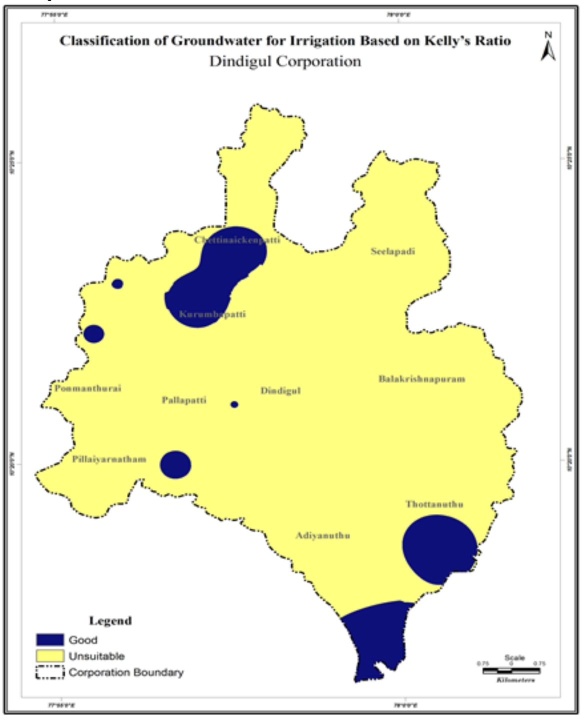

Fig. 4: Groundwater quality for irrigation based on Kelly's Ratio

The formula below mentioned is used to estimate Kelly's Ratio:

$$KR = Na / (Ca + Mg)$$

A Kelly's Ratio higher than 1 indicates excess level of Sodium in water. Within the present study area, Kelly's Ratio values varied from 0.21 to 3.83 epm. According to Kelly's Ratio, about 27% of ground water samples are less than 1, thus indicating good quality water for irrigation purpose, while 73% ground water samples are higher than 1, being unsuitable for irrigation. As the map shows, the southern part of Adiyanuthu, Thotanuthu, Chettinaikenpatti, Kurumpapatti areas have suitable water for irrigation and the remaining areas have not.

Soluble Sodium Percent (SSP)

Soluble Sodium Percent is used to measure sodium hazard. SSP is defined as the ratio of sodium to the total cations. SSP For ground water was calculated by the following formula:

$$SSP = Na / (Ca+Mg+Na) x100$$

Table 3: Classification of water quality parameters for irrigation

Parameters	Range	Water quality classes	Percentage of Sample
%NA	<20	Excellent	-
	20-40	Good	10
	40-60	Permissible	50
	>60	Unsuitable	40
PS	<3	Excellent	-
	3-5	Good to injurious	3
	>5	Unsuitable	97
RSC	<1.25	Safe	3
	1.25-2.5	Marginally suitable	-
	>2.5	Unsuitable	97
Kelly's ratio	<1	Good	27
	>1	Unsuitable	73
SSP	<50	Good	27
	>50	Bad	73

The SSP values range from 29.80 to 99.01epm. Within the study area, about 27% of water samples are less than 50, indicating good quality of water for irrigation and 73% of water sample location comes under more than 50, indicating unsuitable water for irrigation purpose.

The western part of study area such as Pillarnatham, western part of Dindigul city, Pallapatti, Ponmanthurai comes under unsuitable for irrigation.

Conclusion

The analysis reveals that most of the sample locations have high salinity and sodium concentration. There were 30 samples collected from the study area to determine water quality parameters. According to the USSL classification, all the ground water samples have high and very high saline water with medium to high sodium hazard. The western part of the study area such as Ponmanthurai, Pallapatti, Pillayarnatham, Dindigul town (Saveriarpallayam and Jinnanagar) areas are affected by very high salinity and sodium hazard, because most of the tanneries are found in these areas. Ground water within these areas is not suitable for irrigation. Within the eastern part of the study area, saline resistant crops such as cotton, maize, millet, onion, tomato, brinjal can be cultivated.

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Monitoring Drought Status Using Precipitation Factor: a Case Study of Jaisalmer Meteorological Station in Rajasthan, India

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Abstract

Drought is a climatic phenomenon induced by a deficiency in moisture due to the decrease in precipitation amount over of a region for a given time period. Thus for evaluating drought, long-time data series are necessary. In the present study on the basis of precipitation amounts registered at Jaisalmer station in Rajasthan state India, meteorological drought indices such as the Standard Index of Annual Precipitation (SIAP), Standardized Precipitation Index (SPI), Precipitation Anomaly Index (RAI) and Deciles Index (DI) have been computed in order to monitor the drought status. Then Kolmogorov-Smirnova and Shapiro-Wilk tests were applied to examine the normality of raw data. Sequential Mann–Kendall test (SQ-MK test) was applied for determining trends. The results show no statistically significant trend, but there were points of negative mutation in annual precipitation. Drought monitoring, based on the four mentioned indices, indicate SIAP index as the most appropriate for the study area as its coefficient of correlation is close to 1.

Keywords: *drought, precipitation, SIAP index, coefficient of correlation, monitoring*

Rezumat. Monitorizarea condițiilor de secetă prin utilizarea factorului precipitații. Studiu de caz: stația meteorologică Jaisalmer, Rajasthan, India

Seceta reprezintă un fenomen climatic indus de un deficit de umezeală generat de scăderea cantității de precipitații căzute într-o regiune, într-o perioadă dată. Astfel, pentru evaluarea secetei sunt necesare serii lungi de date. Pe baza cantităților de precipitații înregistrate la stația Jaisalmer din statul indian Rajasthan, pentru monitorizarea condițiilor de secetă au fost calculați indicatori ai secetei meteorologice precum Indicele Standard al Precipitațiilor Anuale (ISPA), Indicele Standardizat de Precipitații (ISP), Indicele Anomaliei de Precipitații (IAP) și Indicele Decilelor (ID). Apoi, testele Kolmogorov-Smirnova și Shapiro-Wilk au fost aplicate pentru a verifica acuratețea datelor brute. Testul secvențial Mann–Kendall (testul SQ-MK) a fost aplicat pentru determinarea tendințelor. Rezultatele nu arată o tendință statistic semnificativă, dar au existat mutații negative punctuale ale precipitațiilor anuale. Monitorizarea secetei pe baza celor patru indicatori menționați relevă că indicele ISPA e cel mai potrivit pentru arealul în studiu, deoarece coeficientul său de corelație e apropiat de valoarea 1.

Cuvinte-cheie: *secetă, precipitații, indicele ISPA, coeficient de corelare, monitorizare*

Introduction

Different areas of the earth's surface receive different amounts of precipitation. There are multiple factors like latitude, altitude, presence of humidity in the atmosphere, relief barriers, etc. which affect the precipitation amount. Precipitation variability indices used to identify droughts as a single input perform comparatively well in comparison to more complicated indices in depicting periods and intensity of droughts. The meteorological station of Jaisalmer is located at a relatively low altitude, in the heart of the Thar Desert. The absence of moisture in the atmosphere and of relief barriers to obstruct and to uplift the moist air is mainly responsible for the low amount of precipitation. Long distance to the closest large aquatic body also causes the low level of absolute humidity in this area. The amounts of annual precipitation registered at this metrological station clearly indicate high oscillation during the last 50 years and frequent drought phenomenon in this area. Therefore, the analysis of precipitation oscillation for assessing drought intensity with multiple indices is necessary. Drought is usually defined as a period with below normal rainfall and a cumulative departure from normal or expected precipitation that is a long-term average (WMO, 2006). Droughts occur in virtually all climatic zones and are mostly related to the reduction in the amount of precipitation received over an extended period of time. It is a temporary anomaly in contrast to aridity, which is a permanent feature of climate and is restricted to low rainfall areas (Wilhite et al., 2000). Different climatic elements, especially precipitation, are considered as a producer of meteorological drought, which is responsible for other types of droughts like agricultural and hydrological drought. Researchers in the field of climatology have designed multiple indices for estimating and monitoring drought. Each of these indices are based on climatic variables and are calculated using different methods (Richard, 2002). They are useful tools for drought management and determination of intensity and frequency of drought in time and space. They developed different indices to quantify meteorological droughts. The indices used include Deciles Index (DI), Percent of Normal (PN), Standard Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Standardized Water-level Index (SWI), Effective Drought Index (EDI), Normalized Difference Vegetation Index (NDVI), Crop Moisture Index (CMI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI). Hayes et. al. (1999) used SPI to monitor 1996 drought in the United States of America. They showed that SPI can detect the start of the drought, its spatial extension and temporal progression. They also showed that the onset of the drought could have been detected one month in advance of the Palmer drought severity index (PSDI). In India, there have been made only several studies related to drought using drought indices based on rainfall data. These studies mainly dealt with droughts during the southwest monsoon season. Pai et. al (2011) examined drought climatology over India for the southwest monsoon season (June–September) using two drought indices PNP and SPI for rainfall data between1901 and 2003. Identification of all India (nationwide) drought incidences using both PNP and SPI yielded nearly similar results. This study shows that SPI is a better drought index than PNP for district level drought monitoring and also suitable for examining break and active events in the southwest monsoon rainfall over India. Naresh Kumar et al. (2012) analysed daily rainfall data over India from June to September for the years 1951–2007 to build monthly time series of SPI. The results indicated that the area under moderate drought frequency increased in the most recent decade. Singh and Ballabh Pant (2014) in the study of precipitation indices for drought intensity at New Delhi, India used PAI, DPI, SPI and SIAP. The results showed that there was a very high rainfall variability and subsequent drought intensity. The results obtained from rainfall analysis pertaining to SIAP showed that there were 14 extremely dry, 19 normal, 4 wet, and 10 extremely wet years at New Delhi. Modi and Roy (2016) in a research on drought management for sustainable development in Chhattisgarh state used the IMD index. The result showed that the state experienced a high number of mild droughts and few moderate droughts. However, no severe drought was experienced. Murthy et. al. (2016) used CPC rainfall time series of 12 years (2001–2012) during southwest monsoon in India at 10 km × 10 km pixel for the meteorological drought analysis. Meteorological drought map was prepared separately based on IMD criteria of rainfall deviations. The result indicated that a combination of rainfall and rainy days brings additional information on drought intensity. Furthermore, the high CV of 40 % in the western parts of the country i. e. Rajasthan and Gujarat indicated that these areas are more drought prone regions.

The study area

Jaisalmer district is located within a rectangle lying between 26° 04′ to 28° 23′ North latitude and 69° 20′ to 72° 42′ east longitude (Fig. 1). It is the largest district of Rajasthan and one of the largest in the country. The width (East-West) of the district is 270 km and the length (North-South) is 186 km. Jaisalmer District, part of the Great Indian Thar Desert, is sandy, dry and scorched. The terrain around a radius of about 60 km is stony and rocky. The area is barren, undulating with its famous sand dunes and slopes towards the Indus valley and the Rann of Kutch. Geographically this district covers 38, 401 sq. km. This district has a very dry climate with very hot summer; a cold winter and sparse rains. The variation in temperature from morning to noon and the late midnight is a sudden phenomenon.

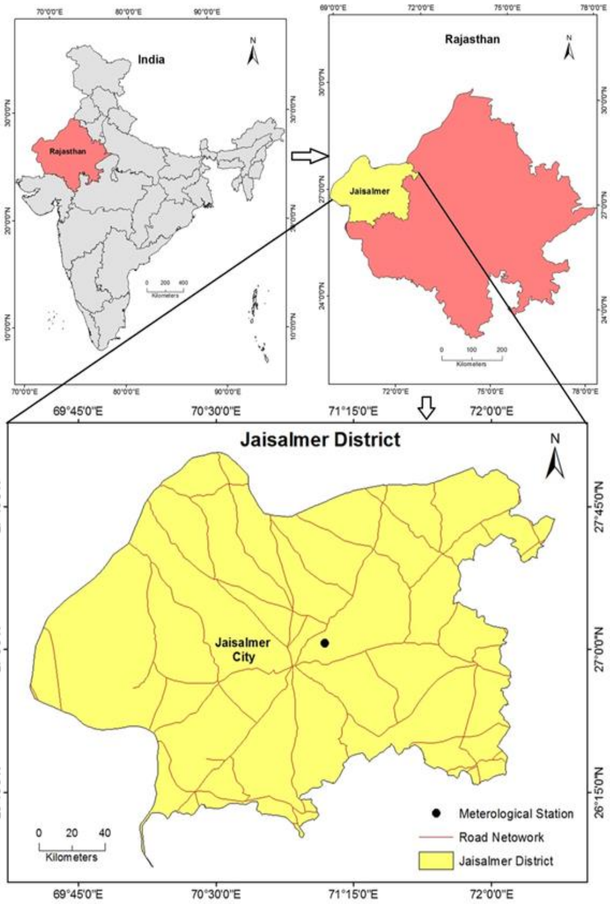

Fig. 1: Location of Jaisalmer meteorological station

Methods

Rainfall data used in the present study have been taken from India Water Portal Safe Sustainable Water for the period of 50 years from 1953 to 2002. Precipitation data were analysed and relevant maps were prepared using EXCEL and SPSS softwares. There were calculated different coefficients, such as the coefficient of variation, skewness, kurtosis, Runs

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Test and normality test were also computed in support and better analysis and explanation of the reserch problems. Mann–Kendall test was used to assess the statistical significance of the determined trends. To achieve the main objective of the present research paper on monitoring droughts using precipitation factor, four indices of meteorological drought i. e. SIAP, SPI, RAI and DI have been defined, computed (DrinC software) and analysed.

SIAP index: The best method to convert raw data of precipitation to relative values is to subtract the mean precipitation from precipitation of the particular year and divide by the standard deviation to obtain the value standard index of annual precipitation (SIAP). Mathematically it can be expressed as:

SIAP = (P_i —$\bar{P}$) / PSD where P_i = annual precipitation in i^{th} year(mm); $\bar{P}$ = average precipitation; and PSD = standard deviation observed for precipitation during the study period. The trend of drought and wet years can be ascertained on the basis of table 1:

Table 1: Drought classification criteria on the basis of SIAP index and value

Classification	SIAP value
Extremely wet	≥ 0. 84
Wet	0. 52 to 0. 84
Normal	- 0. 52 to 0. 52
Drought	- 0. 84 to - 0. 52
Extreme drought	≤ - 0. 84

Source: Aparna and Basil, 2013

SPI index: The SPI was defined as the number of standard deviations that the observed cumulative rainfall at a given time scale would deviate from the long-term mean for that same time scale over the entire length of the record (Mckee et al., 1993). As a single numeric value, SPI can be compared across regions with markedly different climates. Since the cumulative precipitation may not be normally distributed, the data has been transformed approximately to the normal domain to standardize the drought index. The time scale of SPI is also flexible, which is an attractive feature because it is possible to experience wet conditions at one time scale but dry conditions at another simultaneously (Mckee et al., 1993). It was shown that the use of SPI at longer time steps was not advisable as the sample size reduces even with originally long-term data sets. Positive SPI values indicate greater than mean precipitation and negative values indicate less than mean precipitation. The SPI may be used for monitoring both dry and wet conditions. SPI overcomes the discrepancies resulting from using a non-standardized distribution by transforming the distribution of the precipitation record to a normal distribution. For this, the precipitation record is first fitted to a gamma distribution then transformed into a normal distribution using an equal-probability transformation. SPI index can be obtained by using the following equation:

$$SPI = \frac{x_i - \bar{x}}{s_\chi}$$

where x_i is precipitation in each scale, $\bar{x}$ and s_χ are average and standard deviation of precipitation respectively in time scale. Drought classification according to SPI is rendered in table 2.

Table 2: Drought classification using SPI value

SPI value	Class
SPI >2	Extremely Wet
1. 5 to 1. 99	Severely Wet
1 to 1. 49	Moderately Wet
- 0. 99 to 0. 99	Near Normal
-1. 0 to -1. 49	Moderately Dry
- 1. 5 to -1. 99	Severely Dry
SPI < -2	Extremely Dry

Source: Hayes et al., 1999, p. 431

RAI index: Precipitation Anomaly Index (RAI) has been developed by Van Rooy (1965). It is an index used to explain inconsistency in annual precipitation and has proved itself to be a very effective measure in comparison to other complex indices. RAI is used to describe annual rainfall variability and the calculated value may show both positive and negative anomalies (Table 3).

Table 3: Drought classification on the basis of RAI value

RAI > 4. 00	Extremely wet
3. 01≤ RAI ≤ 4. 00	Considerably wet
2. 01 ≤ RAI ≤ 3. 00	Wet
1. 01 ≤ RAI ≤ 2. 00	Slightly wet
- 1. 00 ≤ RAI ≤ 1. 00	Close to normal condition
- 2. 00 ≤ RAI ≤ - 1. 01	Slightly dry
-3. 00 ≤ RAI ≤ - 2. 01	Dry
- 4. 00≤ RAI ≤ - 3. 01	Considerably dry
RAI < - 4. 00	Extremely dry

Source: Van Rooy, 1965

RAI is computed using the following equation:

$$RAI = \pm 3 \times \frac{(YP - AP)}{(A10 - AP)}$$

Where YP=actual rainfall for individual year, AP=average rainfall, A10=extreme rainfall values (highest and lowest) observed during the study period.

DI index: Deciles method has been utilized by Gibbs and Maher (1967) in Australia as an aerological index for monitoring drought. The values of precipitation should be normally distributed. Yearly precipitation totals from a long-term record are first ranked from the highest to the lowest to construct a cumulative frequency distribution. The distribution is then split into 10 parts (tenths of distribution or deciles) on the basis of equal probabilities (Gibbs and Maher 1967). The first decile is the precipitation value that does not exceed by the lowest 10% of all the precipitation values in a record. The second decile is between 10 to 20% of all precipitation values in a record. The fifth or "middle" decile is the amount of precipitation not greater than 50 percent of total precipitation in a record. These deciles continue until the rainfall amount identified by the tenth decile is the largest precipitation amount within the long-term record (Table 4). The severity of drought can be assessed by determining deciles domain using the following equation:

$$m_i = i \times \frac{n+1}{10}$$

Where m_i : i^{th} decile, i: decile number and n: number of precipitation data (Alijani et al., 2015).

Table 4: Drought categories and value of DI index

Deciles 1–2: lowest 20%	Much below normal
Deciles 3–4: next lowest 20%	Below normal
Deciles 5–6: middle 20%	Near normal
Deciles 7–8: next highest 20%	Above normal
Deciles 9–10: highest 20%	Much above normal

Source: Rahmat et al., 2015

Results and discussions

Data monitoring

The extreme values i. e. maximum and minimum annual precipitation at Jaisalmer station during the analysed period are 432. 84 and 44. 64 mm in the year 1969 and 1994 respectively. The oscillation range of precipitation for this station is 388. 20mm. The multiannual mean precipitation amount is 186. 67mm. The coefficient of variation (CV) is the ratio of the standard deviation to the mean expressed in percentage. The higher coefficient of variation value, shows greater departure from mean and vice versa. Coefficient of variation was computed annually for analysed period. During the whole period under study only 9 years, 18% of the total years had the coefficient of variation less than140%. On the other hand, the remaining 82% years had the coefficient of variation greater than140%. However, overall, the coefficient of variation of precipitation is 49. 03%. As there are 12 years with a standard deviation greater than 35 and also a lot of years with more than 30. Thus, it is illustrative of high scattering of average precipitation data. In order to determine the normality of distribution data, skewness coefficient using the third torque, has been computed annually. In fact, skewness is benchmark of existence or lack of symmetry in distribution data. For a perfect and symmetrical distribution, skewness is zero and for an asymmetric distribution towards higher values than the mean skewness is positive, thus distribution is crooked to right direction. For an asymmetric distribution towards lower values than the mean, skewness is negative and distribution is crooked to left direction. If the skewness is between -1 and – 0. 5 or between 0. 5 and 1, the data are moderately skewed. Obtained skewness coefficient using SPSS software indicated that the distribution of annual precipitation during analysed period is asymmetrical towards positive amounts. The skewness coefficient for the whole period is 0. 814 indicating that the precipitation data is moderately skewed. Kurtosis coefficient is explanatory of altitude of a data distribution. It is assessed by the fourth torque. In other words, kurtosis is benchmark of curve height at the point of maximum value. Kurtosis value for normal distribution is 3. In case of positive kurtosis, peak of distribution is higher than the normal distribution, while negative kurtosis altitude of peak of distribution is lower in relation to normal distribution. In many years the kurtosis value is higher than 3 for precipitation distribution, i. e. upper than the normal curve. For the whole period kurtosis value is 0. 407. This indicates that, in many years, the data distribution is lower than the normal curve. For determining the randomness of annual precipitation, Runs Test in SPSS at 95% confidence level was performed. Its result should be greater than 0. 05. On the basis of this result, null hypothesis is accepted, the data can be considered as random. The amount obtained so far Asymp. Sig. (2-tailed) is 0. 766. It indicates a significant level of more than 0. 05, therefore, the annual precipitation data are random. For testing normality of annual precipitation, Kolmogorov-Smirnova test was used in SPSS software. The obtained amount of Asymp. Sig. (2-tailed) of this test is. 036. The significance level of this test is 0. 05, therefore the data have a normal distribution. Amount of P-value at significant level 0. 01 by Shapiro-Wilk test was obtained 0. 930 thus again H_0 is accepted. Thus data at this significant level have had normal distribution. In order to determine the type of trend and the mutation points in annual precipitation at Jaisalmer station graphic chart of Sequential Mann–Kendall test (SQ-MK) was used. The Sequential values of U (ti) are found from the first to last data point and Sequential values U′(ti) are computed backward starting from end to the first data point. Thus U(ti) is the sequential trend value, and U′(ti) the sequential value of occurrence time of mutation points (Fig. 3). Sequential Mann–Kendall test also confirmed the existence of muta-

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tion points when sequential value of U (ti) and U′ (ti) disconnect together in critical range of −1. 96 to +1. 96. The Sequential Mann–Kendall test result does not reject the assumption zero (H_0) indicating the annual precipitation are random and there are positive and negative trend, no significant trend in it. However, there are points of negative mutation in annual precipitation in the critical range of −1. 96 to +1. 96 in the years of 1954, 1964, 1978, 1986, 1996(Fig3). Also there was a decreasing trend but no significant trend, between year of 1962 to 1973 in annual precipitation of Jaisalmer station (Fig. 3). Considering normality of annual precipitation at Jaisalmer station its linear trend was obtained and plotted on the graph. Moving average trend was superimposed over it (Fig. 4). Linear trend analysis showed a declining trend with slope amounting to -0. 37 during the analysed period. On the basis of the line of moving average where major parts of it are located below the average line, it can be concluded that there are more drought years than wet years.

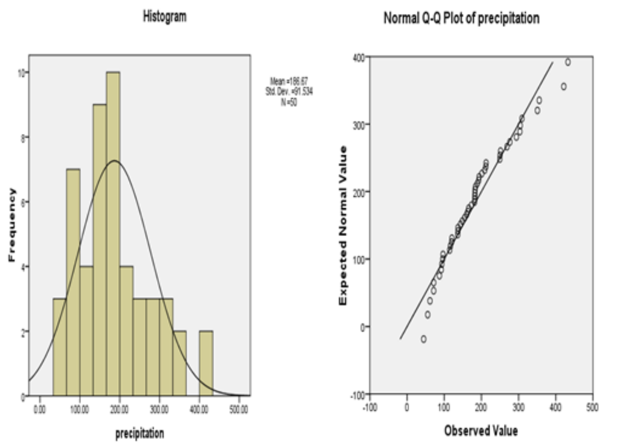

Fig. 2: Normal curve and expected normal of annual precipitation at Jaisalmer station

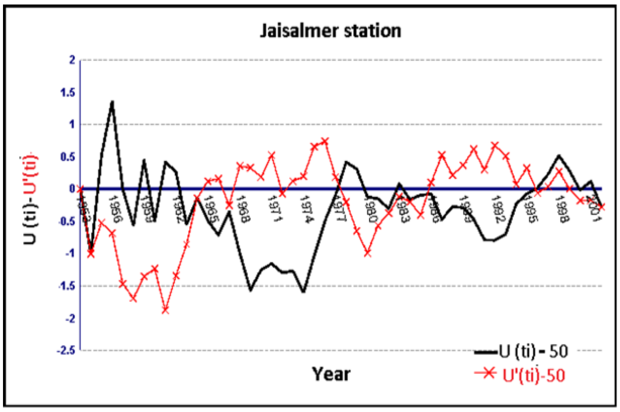

Fig. 3: Mutation points of the annual precipitation by Sequential Mann–Kendall test (SQ-MK)

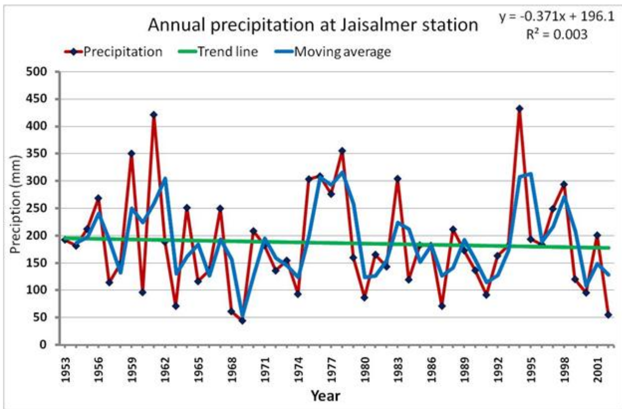

Fig. 4: Moving average and linear trend of annual precipitation at Jaisalmer station

Results

The aim of the present paper was to monitor drought at Jaisalmer meteorological station on the basis of SIAP, SPI, RAI and DI indices. Two of the indices DI and RAI show that 20 and 19 years 40% and 38% of the analysed years, are drought years. All classes of the DI index are much larger than that of the SPI. Conversely, this fact points to a larger sensitivity of DI to changes in precipitation compared to SPI (Gholami et al., 2011).

The indices SIAP and SPI display 17 and 14 years as drought years. In other words the two drought indices DI and RAI show drier conditions while SPI index shows only 14 years as dry, 34 normal years and 2 moderately wet out of the total 50 years. Therefore, SPI index shows wetter conditions at Jaisalmer station relative to other indices. The SPI index also shows periodical droughts, where, negative amount of SPI index begins and continues in a continuous range with negative amount. This duration is classified as periodical droughts. On the basis of SPI index, six periodical droughts, i.e. between the years1953 up to 1955, 1957 up to 1958, 1968 up to 1974, 1979 up to 1982, 1984 up to 1993 and 1999 up to 2002 and a wet period from 1975 up to 1978 were observed. The longest period of drought is between 1984 up to 1993. The longest wet period (4 years) according to SPI index is between 1975 up to 1978. When SPI index is -1, it indicates a more severe drought. SPI index shows 14 years as drought years at Jaisalmer station.

The coefficient of correlation between the values of indices and the registered precipitation amounts was calculated using Karl Pearson 's method. In case of SIAP index it is a perfect and direct correlation between its values and the precipitation amounts. In other words, as precipitation amounts increase or decrease SIAP index also increases or decreases.

The RAI index has a correlation coefficient of 0.991, while SPI and DI indices have correlation coefficients of 0.974 and 0.953 respectively. In order to assess the proximity of the obtained results of drought indices with each other, Pearson correlation coefficient between them was computed. The result shows that the highest positive correlation is between SPI and RAI, 0.994. This means that the obtained results in case of these indices are quite close (Fig 5). Other indices like SIAP-RAI, SPI-SIAP, SPI-DI, RAI-DI, DI-SIAP have correlation coefficients of 0.991, 0.974, 0.973, 0.968, and 0.953 respectively. Figure 5 also indicates that after SPI-RAI the amount of SIAP index is near to them. Furthermore figure 6 shows that in case of DI, 9 years are more than 300, 10 years less than 100 and 31 years between 100 and 300. Thus one of advantage of using DI index is that it indicates drought intensity at annual scale.

Table 5: Analysis of precipitation status by diverse indices at Jaisalmer station

Status of precipitation in Jaisalmer station	Indices			
	SIAP	SPI	RAI	DI
Normal	20 years	---	---	---
Extreme drought	8 years	---	---	---
Drought	9 years	---	---	---
Extremely wet	8 years	---	2 years	---
Wet	5 years	---	4 years	---
Near normal	---	34 years	---	---
Extremely dry	---	3 years	---	---
Moderately dry	---	6 years	---	---
Moderately wet	---	2 years	---	---
Severely dry	---	5 years	---	---
Dry	---	---	5 years	---
Close to normal condition	---	---	18 years	---
Slightly wet	---	---	5 years	---
Slightly dry	---	---	9 years	---
Considerably wet	---	---	2 years	---
Considerably dry	---	---	5 years	---
Much below normal	---	---	---	10 years
Below normal	---	---	---	10 years
Near normal	---	---	---	11 years
Above normal	---	---	---	10 years
Much above normal	---	---	---	9 years

Source: Computed by author

Table 6: Comparison of precipitation monitoring by different indices

Index	Percent of drought year	Percent of normal year or near normal	Percent of wet year
SIAP	34%	40%	26%
SPI	28%	68%	4%
RAI	38%	36%	26%
DI	40%	22%	38%

Source: Computed by author

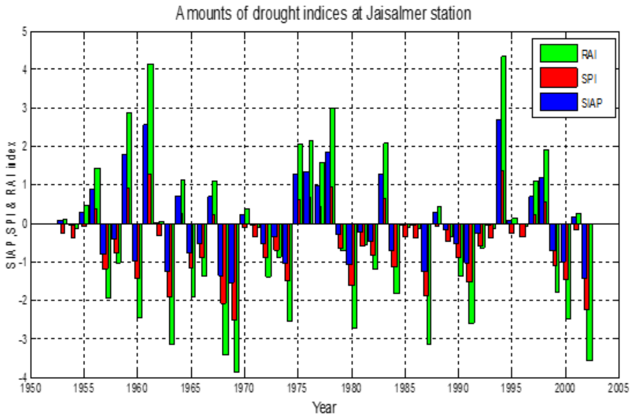

Fig. 5: Temporal variation of SIAP, SPI and RAI, Jaisalmer station

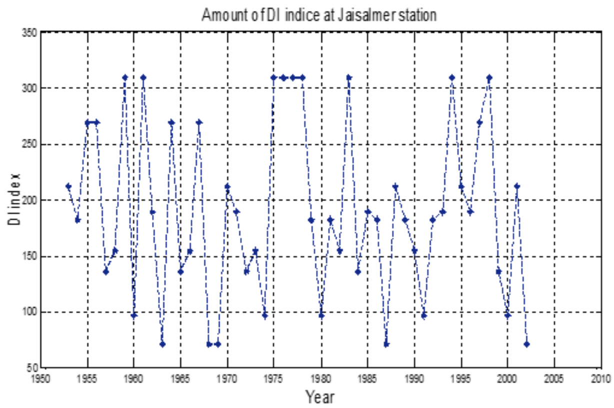

Fig. 6: Temporal variation of DI index, Jaisalmer station

Conclusions

The existence of 9 years, 18 % of the period, with a coefficient of variation less than 140% and of 41 years, 82% of the period, with a coefficient of variation greater than 140%, is self-explanatory of high irregularities in precipitation amounts. Simultaneously, the coefficient of variation for the whole period of 49.03% is indicative of the dominance of dry conditions at Jaisalmer station. The DI index, showing 40% and 38% of the total years as dry and wet years respectively, is the most sensitive in monitoring drought status using only the precipitation factor at Jaisalmer station. However, the correlation coefficient between its values and the registered amounts of precipitation is 0.953 indicates no desirable results. SIAP index, as it emphasizes a correlation coefficient equal to 1 is the best indicator of drought status at Jaisalmer station. However, the results indicate that SIAP, SPI and RAI are in a close range. RAI index is the best indicator of the intensity of dry and wet years, which amounts between -3.883 and 4.339 for the years 1969 and 1994 respectively. Thus this index amongst the three remaining indices has good ability of showing the intensity of drought and wet years at Jaisalmer station. SPI index indicates the greatest number of normal or close to normal years, 68% (34 years out of 50 years), and also the lowest number of years with wet condition.

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A web-map of the landscapes of Vitosha Mountain and the development of landscape science in Bulgaria

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Abstract

On the first hand, the purpose of this article is to present the map and classification of the landscapes of Vitosha Mountain. On the other hand, it aims to present this map as an example and illustration in the context of traditionally applied approaches in Bulgaria in defining the landscape, as well as in researching and classifying the landscapes. There is also a brief overview of the development of landscape science in Bulgaria.
The choice of the territory in study relates to the fact that Vitosha Mountain is a protected area, i.e. a Nature park declared in 1934, now part of the NATURA 2000 network.
The Vitosha Landscape Map is developed by using GIS tools and it is implemented as a web-map, which makes it much easier to access, examine and work with it, as compared to static maps.

Keywords: *Vitosha Mountain, landscapes, GIS, web-mapping*

Rezumat. O hartă web a peisajelor Muntelui Vitosha și dezvoltarea științei peisajului în Bulgaria

În primul rând, scopul articolului este acela de a prezenta clasificarea peisajelor și harta acestora la nivelul Muntelui Vitosha. Pe de altă parte, lucrarea furnizează harta ca exemplu și ilustrare în contextul abordărilor tradiționale utilizate în Bulgaria cu privire la definirea peisajului, precum și în cercetarea și clasificarea peisajelor. În articol se realizează și o succintă prezentare a dezvoltării științei peisajului în Bulgaria.
Alegerea arealului de studiu este legată de faptul că Muntele Vitosha reprezintă o arie protejată, fiind declarat Parc natural în 1934, iar în prezent este parte a rețelei Natura 2000.
Harta peisajelor Muntelui Vitosha este realizată prin utilizarea instrumentelor GIS și este implementată ca o hartă web, ceea ce ușurează mult accesul, examinarea și lucrul cu aceasta, în comparație cu hărțile statice.

Cuvinte-cheie: *Muntele Vitosha, peisaje, SIG, web-mapping*

Introduction

In the context of the European Landscape Convention – ELC (ratified in 2004 by the Bulgarian Parliament) it is crucial to increase cooperation in landscape science between all European countries, because ELC emphasizes that landscape "identification and assessment procedures shall be guided by the exchanges of experience and methodology, organised between the Parties at European level". Landscape science in Bulgaria has a long tradition. It covers numerous branches like landscape mapping, landscape evaluation, landscape geochemistry etc. Unfortunately, as most of the publications in this field are issued in Bulgarian language, they are not well known to the international scientific community in the area of landscape science and landscape ecology. In an attempt to fill this gap, in the present article we will present a short introduction to the development of landscape science in Bulgaria. Then, we will introduce a web-map of the landscapes in Vitosha Mountain (South-West Bulgaria), as an example of this tradition. This web-map application is made by using free GIS tools in QGIS Cloud service. It contains two separate layers, the first one being that of the potential landscapes (or primary landscape structure) and second one being that of the anthropogenic landscape changes (or secondary landscape structure). All attributes of the layers are bilingually expressed (in Bulgarian and English), which, in combination with the easy access to the web-map, makes it suitable to present some of the landscape concepts used in Bulgaria to a broader scientific audience.

A short history of the landscape science in Bulgaria

The development of the landscape science in Bulgaria started in the first half of the 20th century in the Sofia University, with the names of Prof. Jeko Radev and Prof. Dimitar Yaranov, who first used the term "landscape" in their scientific works. In 1934, Prof. Ivan Batakliev published "Landscape differentiation of Bulgaria", the first scientific paper dedicated especially to landscape science issues. In 1943, Ignat Penkov published a broad study with the title "Cultural landscapes". Most of them follow the German tradition in landscape science. After the WWII, D. Yaranov and I. Batakliev were dismissed from the Sofia University and the development of landscape science was discontinued for nearly 25 years. In 1970, I. Ivanov, D. Dimitrov and P. Penchev argued the necessity of Bulgarian physical geography to turn again to the study of landscape problems. In 1972, the Department of Landscape Science (now Landscape Science and Environmental Protection) was established in the Faculty of Geology and Geography of the Sofia University. Until the end of the

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eighties, many young geographers were trained in the field of landscape science in the former Soviet Union, where they acquired Ph.D. For several decades, hundreds of scientific publications were issued, covering almost all branches in the field of landscape science, such as landscape classification and landscape mapping, landscape geophysics, landscape geochemistry, and landscape evaluation (Velchev et al., 2011).

To the end of the eighties, landscape science in Bulgaria (Petrov, 1990) was strongly influenced by the scientific traditions and concepts established in the former Soviet Union and in other Eastern and Central Europe countries. Afterwards, broader scientific concepts, theories and methods from the field of landscape ecology started to penetrate the Bulgarian landscape science. The contemporary challenge of Bulgarian landscape science is to apply these concepts developed in different scientific schools, preserving the best of the old tradition and accepting all the best from the landscape ecology.

Table 1 Comparison of the two basic landscape classifications in Bulgaria

Landscape level	Petrov, 1979		Velchev et al., 1992	
	Taxonomic unit	Criteria	Taxonomic unit	Criteria
Level 1	Class	Physical conditions of the surface – territory or water surface. Macro-geomorphologic features, determining the character of zonation (plains or mountains).	Class	Relief and its geologic content (plains or mountains).
Level 2	Type	Typical features of zonation; vegetation and soil type.	Type	Hydroclimatic conditions; vegetation types and their relation with climate conditions.
Level 3	Subtype	Features of zonation inside the type; vegetation and soil subtype.	Subtype	Secondary features of zonation and bioclimatic conditions.
Level 4	Group	Geologic and geomorphologic features – mesorelief; base rock formation (parent material); phytocoenosis and soil.	Genus	Relief type and geological structures; vegetation and soil.
Level 5	Species	The most relative homogeneity of the environmental features.	Species	Geologic and geomorphologic homogeneity; soil-vegetation cover; microclimate conditions.

The view of landscape and the landscape classifications in Bulgaria

The view of landscape in Bulgarian science is mainly based on the works of the Russian scientists and geographers like V. V. Dokuchaev, L. S. Berg, A. A. Grigoriev, S. V. Kalesnik, N. A. Solntsev, A. G. Isachenko, N. A. Gvozdetskii, F. N. Milkov, D. L. Armand, V. A. Nikolaev, and V. B. Sochava. In this context, a common definition of landscape accepts that it is "a natural formation in exact stage and operating in time and space within the environmental system; it holds some natural resources and it is affected more or less by the human activity" (Velchev et al., 2011). In contrast with one of the broad accepted views in landscape ecology, where "a landscape is an area that is spatially heterogeneous in at least one factor of interest" (Turner et al., 2001), this perspective postulates a more holistic approach, i.e. landscape is only a spatial whole consisting of all environmental components: rocks and geologic structures, geomorphologic features, air masses and its climate, water masses, soils, vegetation cover, animals, human activity reshaping the natural environment (Petrov, 1990; Velchev et al., 2011).

On the national level, there are two basic landscape classifications accompanied by landscape maps for Bulgaria. The first one is based on N. A. Gvozdetskii's landscape classification and it was accompanied by a landscape map at scale 1:400,000 (Petrov, 1979). The second one is based on N. L. Berouchashvili's landscape classification and it was accompanied by a landscape map at scale 1:500,000 (Velchev et al., 1992). Table 1 displays the taxonomic units and the differentiation criteria.

Besides these two basic classifications, several dozens of variants and modified versions of them, as well as a few generally different landscape classifications were used for landscape mapping only for a part of the country and they were not applied at national level.

Short description of the study area

Vitosha Mountain is located in South-West Bulgaria, near the capital Sofia. Its total area is 27,485 ha and the highest peak is Cherni Vrah (Black Peak), with 2,290 m a.s.l. The mean altitude of the mountain is nearly 1,400 m a.s.l. The mountain is the first Bulgarian National Park and the first in the Balkan Peninsula, being declared in 1934. Since 1998, Vitosha is a Nature Park, with a total area of 27,079 ha. It includes two reserves. "Bistrishko Branishte" (1061 ha) is a forest reserve with mainly spruce forests. "Torfeno Branishte" (784 ha) is a peat-bog reserve located in the sub-alpine mountain belt. Vitosha Mountain preserves a valuable natural heritage with great biological diversity and it has important ecological functions to the adjacent country capital Sofia.

Vitosha Mountain landscape classification

For Vitosha Mountain landscape, we used a modified classification generally based on the second one presented above (Velchev at al., 1992), but combining elements from both. This landscape classification is describing the potential landscapes (primary landscape structure) without taking into account the human impact on the landscapes. Therefore, this map has some hypothetical content especially concerning the attempt to reconstruct the potential vegetation cover, which is mostly affected by human impact.

This classification of the potential landscapes has six levels. Each level is described below, together with the corresponding criteria and with a list of the correlative landscape units existing in Vitosha Mountain.

Level one (Class) with differentiation criteria: presence or absence of altitudinal zones (plains or mountains).

- Mountain landscapes (with altitudinal zonation)

Level two (Type) with differentiation criteria: climate type.

- Warm-temperate semi-humid
- Temperate humid
- Cold-temperate humid
- Cold humid

Level three (Subtype) with differentiation criteria: vegetation type.

- Low mountain forests in oak-hornbeam belt
- Mid mountain forests in beech belt
- Mid mountain forests in coniferous belt (mainly spruce)
- High mountain subalpine meadows and shrubs
- High mountain subalpine meadows and shrubs and intrazonal sphagnum vegetation
- Intrazonal riparian vegetation
- Bare rocks with sparse mainly rock vegetation

Level four (Group) with differentiation criteria: topological features of the relief.

- Ridges with denudation and slopes under 4 degrees
- Slopes with erosion and denudation
- Slopes with erosion, denudation and karst
- Hydromorphic and sub-hydromorphic with erosion and accumulation (river-bed/river banks)
- Hydromorphic and sub-hydromorphic with upland accumulation (peat-bogs)

Level five (Genus) with differentiation criteria: rock formation and type.

- Alluvial unconsolidated sediments
- Unconsolidated and semi-consolidated sedimentary rocks
- Non-calcareous concrete sedimentary rocks
- Calcareous concrete sedimentary rocks
- Intrusive rocks
- Volcanic rocks (andesite)
- Metamorphic rocks

Level six (Species) with differentiation criteria: soil type.

- Brown-forest soils
- Brown-forest soils and rendzinas
- Dark-coloured and brown-forest soils
- Mountain-meadow soils
- Peat soils and peat-bogs
- Alluvial soils
- Bare rocks and lithosols

To reveal the contemporary state of the landscapes and the anthropogenic changes (secondary landscape structure), we used a classification based on several works of A. Velchev, N. Todorov and R. Penin (Todorov, 1997). The main advantage of this classification is that it describes five ranks (stages) of anthropogenic modifications and their criteria:

1. Unaffected landscapes (conditionally unaffected) – with climax vegetation and without visible traces of human disturbance; only slight changes of the geochemical background is possible due to contamination transport by air flows from remote places.
2. Landscapes with slight anthropogenic impact – with secondary vegetation, but identical in species composition with the climax vegetation, with possible appearance of grass vegetation within forested areas due to less dense tree cover; slow soil erosion is also possible.
3. Landscapes with moderate anthropogenic impact – with significant lower phytomass due to changes, i.e. to the replacement of climax vegetation with vegetation with less biomass (e.g. forests with scrubs); other features are the lower litter horizon and the possible erosion of the humus soil horizon.
4. Landscapes with strong anthropogenic impact – with strong change of the vertical structure, complete destruction of the natural vegetation and replacing with vegetation with very low biomass (e.g. forests with meadows); tree plantation with trees without ecological correspondence with the natural (e.g. coniferous in the vegetation belt of deciduous); agriculture and arable land with active soil erosion and melioration.
5. Anthropogenic landscapes – without vegetation cover and often without soil cover, changes

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could affect also topographic surface and base rocks (e.g. settlements, roads and mining areas).

For the purpose of Vitosha Mountain landscape mapping, these five ranks were reduced to three by combining the first with the second and the third with the fourth, in the attempt to make the mapping units more objective and easily to outline by the available input spatial data. This classification of landscape changes by human-induced factors, with 3 ranks and 13 types is presented below.

Unaffected landscapes and landscapes with slight anthropogenic impact:

- bare rocks
- broad-leaved forest
- coniferous forest.

Landscapes with moderate and strong anthropogenic impact:

- meadow and shrub lands
- planted coniferous forest
- agriculture and arable lands.

Anthropogenic landscapes:

- ancient dump site (ore deposit)
- stone-pit
- lift
- road
- buildings and single yards
- settlement
- artificial lake or dam.

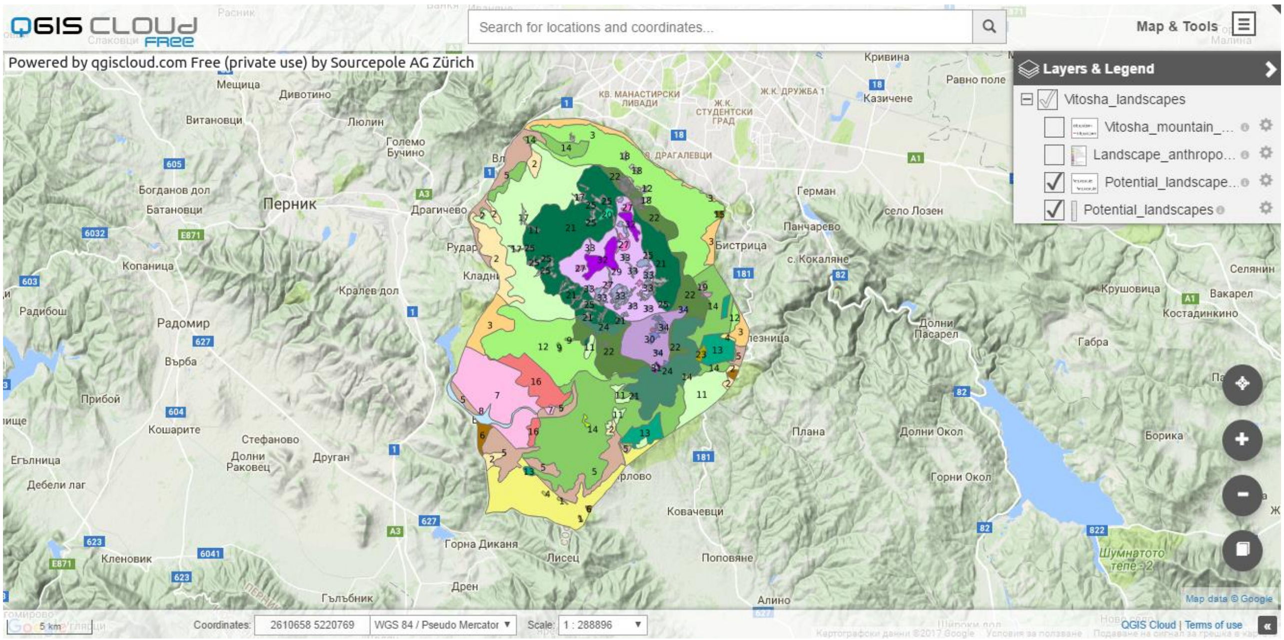

Fig. 1: Screenshot of the web-map application of the landscapes in the Vitosha Mountain with base view of the potential landscapes

Method

Various input data in digital format were used to perform landscape mapping for the Vitosha Mountain: Vitosha DEM, generated from EU-DEM with 25 m raster resolution (European Environmental Agency), the geologic map (vector layer, scale 1:100,000), forest inventory maps (vector layers, scale 1:5,000, from the Administration of "Vitosha" Nature Park), aerial photography (orthophoto) - images for 2006 year (raster data from the Bulgarian Ministry of Regional Development), and field investigations from transects (descriptions of selected sites or so called "landscape points").

The data was processed with GIS software and the two layers are the final outputs. The first data layer corresponds to the potential landscapes of Vitosha Mountain, its reference scale being 1:50,000 and its minimum mapping unit 4 ha. The second layer corresponds to the landscape anthropogenic modifications, its reference scale being 1:5,000 and its minimum mapping unit 0.02 ha. Finally, by using the open-source QGIS, a web-map application was created in QGIS Cloud service, with the following URL: http://qgiscloud.com/jdgis/Vitosha_landscapes.

Discussion

The first layer, i.e. that of the potential landscapes, contains 35 potential landscape units (on level 6 – "landscape species") and 158 polygons (fig. 1). The second layer, i.e. that of the landscape anthropogenic modifications, contains 13 landscape units and 3,698 polygons (fig. 2).

The landscape structure characteristic of Vitosha Mountain shows certain variety. It is represented both by landscapes with zonal character, as well as with azonal one – karst, hydromorphic (e.g. peatbogs) and rocky landscapes (bare rocks).

The altitude landscape belts are represented by a full height landscape spectrum, including subtypes of low mountain landscapes with oak-hornbeam forests, middle mountain landscapes with beech forests, mid-mountain landscapes with coniferous forests and sub-alpine landscapes.

Human activity has taken place for centuries in Vitosha Mountain and it has led to several types of impacts on landscapes. The human-induced impact during the Ottoman period was the greatest. Within this period, agricultural (grazing) and industrial (iron and gold mining) activities contributed most to the formation of the modern landscapes of Vitosha Mountain (Deliradev, 1926; Georgiev, 1978; Avdev, 2005). After 1934, there has been a radical change in the functional purposes on the territory of Vitosha, the economic functions moving towards conservation and recreation.

The potential landscape structure has been significantly modified because of the intense anthropogenic impact in the past. As a result, it is best preserved mostly in the northern part of the mountain (fig 2). In the southern part of the mountain, landscapes with natural coniferous forests are totally replaced by meadows and shrubs. The total area of unaffected landscapes and of landscapes with slight anthropogenic impact covered with forest amounted to 11,456 ha or 41% of the total area of Vitosha Mountain (of which about 9,983 ha - 36% are deciduous forests and about 1,473 ha - 5% are coniferous forests). The total area of landscapes with moderate and strong anthropogenic impact, with secondary meadows and shrubs that occupied the place of forest landscapes amounts to 6,688 ha (24%). The total area of planted coniferous forests in Vitosha Mountain amounts to 4,318 ha (15.7%).

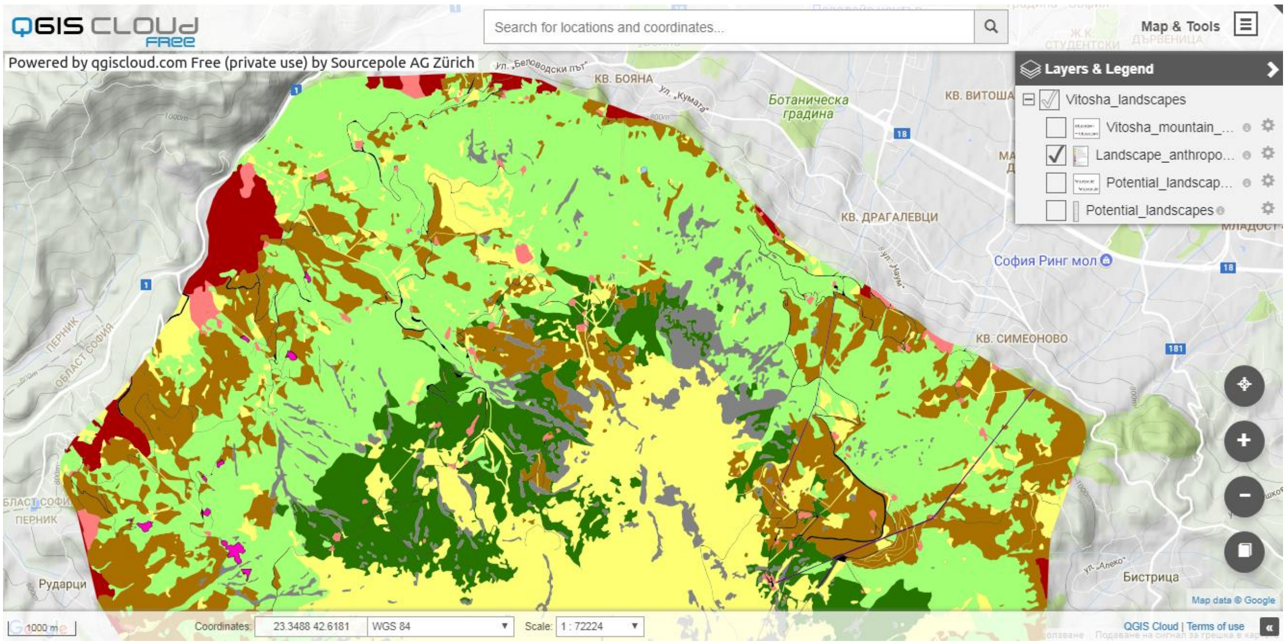

Fig. 2: Screenshot of the web-map application of the landscapes in the Vitosha Mountain, with a view of the landscape anthropogenisation map (fragment for the Northern part of the mountain)

Conclusion

There are several benefits of the built-in web-map. On the one hand, it provides an opportunity to explore interactively and in more detail the structure of the Vitosha landscapes, both of the potential landscapes (primary structure) and of the anthropogenic modifications (secondary structure). On the other hand, it provides an opportunity to get to know the concepts related to landscape classification and mapping that are employed in Bulgaria, although different approaches to exploring the landscapes are used in our country.

Finally, it can be noted that there is some proximity in approaches and convergence in landscape exploration through a typological approach in different landscape schools (Wascher, 2005). This facilitates the exchange of such ideas and approaches and it is the basis for future closer cooperation in carrying out international studies in the field of landscape science and landscape ecology.

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The impact of the urban expansion on the Jiu floodplain. Case study –Craiova, Romania

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Abstract

The urban expansion of any settlement implies changing natural environment and gradually transforming it into an anthropogenic one to assure the needs of the community. A first step in urban planning is to identify the changes that have been made, and this study reconstructs the anthropogenic changes induced to the Jiu floodplain in the last 150 years, through multi-temporal spatial comparisons, geomorphological characteristics and anthropological and environmental transformation indicators. The processing of historical cartographic materials and current satellite imagery highlights the dynamics of the wetlands and the built-up area in the Jiu floodplain between 1864 and 2017. The urban expansion required flood protection works that were carried out along the canals and lakes resulting from the drainage of the ponds and marshlands. On the course of the Jiu hydro-technical works of straightening, embankment and regularization were achieved, which led to the transformation of the course from a highly meandered one as it was in the second half of the 19th century into a sinuous one in 2017. The study is a useful tool in urban planning, by centralizing the changes in the floodplain, the anthropogenic works carried out and the changes of the Jiu course within the analyzed sector.

Keywords: *Jiu Floodplain, Craiova, Urban Expansion, Sinuosity Index, Urban Geomorphology*

Rezumat. Impactul expansiunii urbane asupra Luncii Jiului. Studiu de caz – Municipiul Craiova, România

Expansiunea urbană a oricărei așezări presupune modificarea mediului natural și transformarea treptată a acestuia într-unul antropic, care să asigure necesitățile comunității. Un prim pas în planificarea urbană îl constituie identificarea schimbărilor produse, iar acest studiu reconstituie modificările antropice induse luncii Jiului în ultimii 150 de ani, prin intermediul comparațiilor spațiale multi temporale, a caracteristicilor geomorfologice și a indicatorilor de antropizare și transformare a mediului. Prin procesarea materialelor cartografice istorice si a imaginilor satelitare actuale se evidențiază dinamica zonelor umede si a ariei construite din lunca Jiului in perioada 1864 – 2017. Extinderea teritoriul urban a impus lucrări de protecție împotriva inundațiilor, ce au fost realizate de-a lungul canalelor și lacurilor rezultate din desecarea bălților si zonelor mlăștinoase. Pe cursul Jiului au fost executate lucrări hidrotehnice de îndreptare, îndiguire și regularizare, ceea ce a dus la transformarea cursului dintr-unul puternic meandrat cum era în a doua jumătate a secolului al XIX-lea, într-unul sinuos în anul 2017. Studiul se constituie într-un instrument util in planificarea urbană, prin centralizarea modificărilor survenite în luncă, a lucrărilor antropice realizate si a schimbărilor cursului Jiului in sectorul analizat.

Cuvinte-cheie: *Lunca Jiului, Craiova, expansiune urbană, indice de sinuozitate, geomorfologie urbană*

Introduction

The most suitable areas for the establishment of human settlements have always been the riparian territories, and the location of the old settlement on the territory of which Craiova now stands is no exception, having been consolidated on the left bank of the Jiu River. The extension of a settlement in the floodplain of a river benefits, on the one hand, from the proximity to a water source that can be used for agriculture, industry or directly for human needs, but, on the other hand, it involves exposure to the risk of destruction of property or human casualties in case of floods or other consequences of the not properly maintained wet zones.

Within the urban environment, man is the landscape creator of what Coates (1976) called ”cityscape” and urban geomorphology is the study of man as a physical process of change whereby he metamorphoses a more natural terrain to an anthropogene cityscape (Coates, 1976). On the other hand, the urban geomorphology is described by Cooke as the research of constraints in urban expansion. (Goudie, 2004) defined urban geomorphology in terms of restrictions on urban expansion, constraints represented by landscapes, evolution of geomorphological processes, soil types, water resources or natural hazards, but also through the impact of urban constructions on vegetation, soil, versants and rivers.

The urban expansion in the Jiu floodplain and the consequences of the human-natural interaction will be detailed in the area located in the south-western part of Romania, at the contact of the Getic Piedmont and the Oltenia Plain, on the territory belonging to the town of Craiova.

The study area

Craiova municipality is located in Oltenia Region (Fig.1), has an area of 81.96 km², which covers the floodplain and terraces on the left bank of the Jiu, creating an altitude difference of 130 m between the

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Eastern extremity of the town where the height of 199 m is reached and the South-West of the settlement, within the Jiu floodplain, where the minimum altitude is 69 m. The geomorphology of the contact area between the Getic Piemont and the Oltenia Plain favored the development of the settlement on the left bank of the Jiu, on the terraces with a sloping reduced to a maximum of 11°, compared to the right slope of the river, abrupt, with a declivity of 10° - 33° (Alba, Mititelu-Ionus, & Boengiu, 2017).

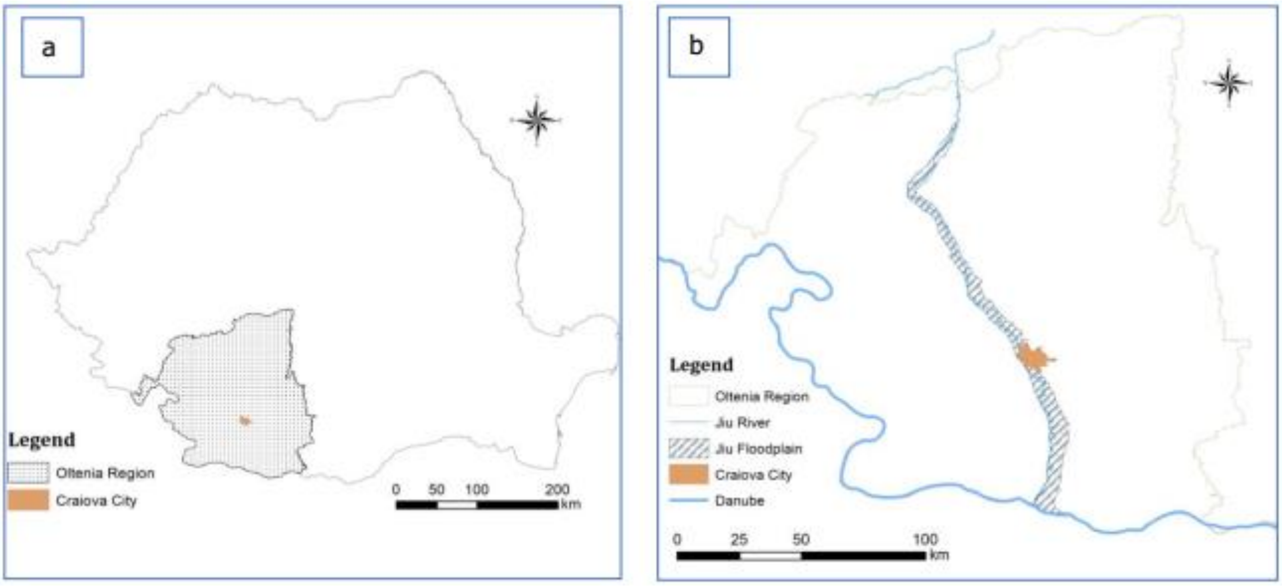

Fig. 1: Location of Craiova in Romanian (a) and Oltenia Region (b)

From a geostructural point of view, the geological unit that also includes Craiova area is the Valahia Platform, the stratigraphy of which involves the existence of two floors: a foundation one - the Cadonmian socle and the upper sedimentary cover (Mutihac & Mutihac, 2010). The tectonics of sedimentary cover of the Valahia Platform sketched a system of faults and blocks that had a differentiated vertical displacement. Some blocks, including the Craiova Depression, were characterized by a more pronounced subsidence becoming graben, functioning as depression sedimentation areas (Mutihac & Mutihac, 2010). The sedimentary cover of the Valahia Platform is approximately 10,000 m thick (Stroe, 2003), but with a non-uniform thickness due to the vertical movement of the blocks, reaching in some points 23,000 m (Ionești, 1994).

The Jiu River, which has created the proper landscape for the settlement through floodplain and terraces, has a length of 339 km, 52 tributaries, an average talweg slope of 5% and a sinuosity index of 1.85. The multi-annual average discharge in the study area, at Podari hydrometer station, is 85.6 m^3/s. At the exit of the Jiu from the Getic Piedmont, on the territory of Craiova, the Jiu floodplain has an asymmetric aspect and is situated between 69 m downstream and 101 m upstream. The lithological composition of this floodplain sector includes two different structures, the lower one, the channel alluvium, made up of coarse sands, gravel and blocks, and the upper one - floodplain alluvium formed of sands, dusty clay, sands and mud seam (Savin, 1990).

From an administrative point of view, the town of Craiova includes 9 settlements (Craiova town proper and 8 communes), it has 110,207 dwellings, 305,945 people and from the total surface of 81.96 km^2, 70.63km^2 is within the built-up areas. In 2008, Craiova was granted the statute of urban growth pole, which became the center of Craiova Metropolitan Area and represents a polarizing area for Oltenia Region (South-West of Romania).

Material and methods

The reconstruction of the changes, including wetlands and swamps dynamics and the expansion of the built-up areas in the Jiu floodplain, was made by analyzing historical documents and cartographic materials that also include the settlement, by comparing the multi-temporal spatial maps with the actual ones, confirmed by field checks. The list of cartographic materials used is found in Table 1.

Changes in the channel of the Jiu River are highlighted by the dynamics of the sinuosity index values, calculated as the ratio between the real length of the drainage channel and the straight-line length between the extreme points of the sector, from 1864, 1910, 1944, 1974, 1992, 2017.

Table 1: The cartographic materials used for the reconstruction of urban expansion

Map	Source	Publishing date / date of satellite take-over
The Map of Craiova in the 15th century	(A. Georgescu, 1936)	1936
The Map of Craiova in the 18th century	(A. Georgescu, 1936)	1936
Planul Caselor Bănești din Craiova in 1780	(Buce-Răduț, 2011)	2011
Specht Map 1791	http://www.limes-transalutanus.ro	2014
The Second Military Survey 1856 - 1859	http://mapire.eu/en/map/secondsurvey	2014
Charta României Meridionale 1864	http://www.charta1864.ro/charta.html	1864
The Plan of Craiova in 1888	(Buce-Răduț, 2011)	2011
The plan draw of Craiova in 1905	(Buce-Răduț, 2011)	2011
Planurile Directoare de Tragere – file 3042, 1903 – 1925	http://www.geo-spatial.org	2011
The "Austrian" Maps 1910	http://www.geo-spatial.org	2006
The "British" Maps 1944	http://www.limes-transalutanus.ro	2014
Topographic Map of Romania 1:25000	Direcția Topografică Militară	1974
The "Russian" Maps 1976	http://www.geo-spatial.org	2012
Landsat 5, TM (50 m)	USGS	01.aug.1992
Digital Globe / CNES / Astrium	Google Earth PRO	01.feb.2017
Ortophoto	ESRI	10.dec.2017

The highlighting of the urban expansion impact on the Jiu floodplain is also achieved by presenting the dynamic of the environmental transformation index (*Itre*) as a result of the ratio of the natural and the anthropogenic surfaces. *Environmental transformation index (Itre),* used by the Polish researchers Maruszcsak and Pietrzak in 1988 to assess the human impact in the Subcarpathians and the Hills of Poland, was applied, with adaptations according to the type of surfaces, in hilly and plain areas in Romania (Ianaș, 2013; Ionuș, Licurici, Boengiu, & Simulescu, 2011; Mititelu-Ionuș & Avram, 2016; Prăvălie, 2012; Zarea & Ionuș, 2012). In order to reveal the natural / anthropogenic ratio, the calculation formula used, depending on the involved areas, variables such as forest, floodplain or aquatic area, relative to the built or used agricultural area. For the analyzed floodplain sector in this study, we considered the wet surface (S.w.)/ built surface area (S.b.) to be representative of the *Itre*'s multi-temporal calculation.

The development of the settlement on the bank of the Jiu

The current territory of Craiova is considered to be either overlapping the former Pelendava settlement (Vulpe, 1979), or as established in the vicinity of the Geto-Dacian settlement (A. Georgescu, 1936). Pelendava, also known as Pelendova, appears for the first time in Tabula Peutingeriana, a map of the Roman Empire, made around 225 or in the years 251-271, whose copies from the 11 - 12th centuries have been preserved until today (T. Georgescu, Barbacioru, & Florea, 1977; *Izvoare privind istoria Romîniei*, 1964). The location of Pelendava on the bank of the Jiu also defined its toponymy, which includes the "peled" meaning *wet* or *flowing* (Pospai, 2003; Toropu, 1979). Evidence confirming the permanence of the dwelling around, but also on the current territory of Craiova were associated with all the historical periods starting with the Neolithic - about 6000-2500 BC. (T. Georgescu et al., 1977).

The first documentary use of the name of Craiova appears in a document dated July 1, 1475, and as "the town of Craiova" on July 25, 1582, but the archaeological evidence reveals at Craiova the existence of a settlement of economic and administrative importance which had evolved beyond a rural stage, long before the 14th century, being an important point on the commercial road connecting Transylvania to the Danube (T. Georgescu et al., 1977). At the end of the 15th century, the settlement was presented as a borough, developed in the current area of the Old Town Square, towards which several commercial

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roads converged. From a geomorphologic point of view, the core of the settlement expansion was on the first terrace of the Jiu (85-110 m altitude Fig. 2).

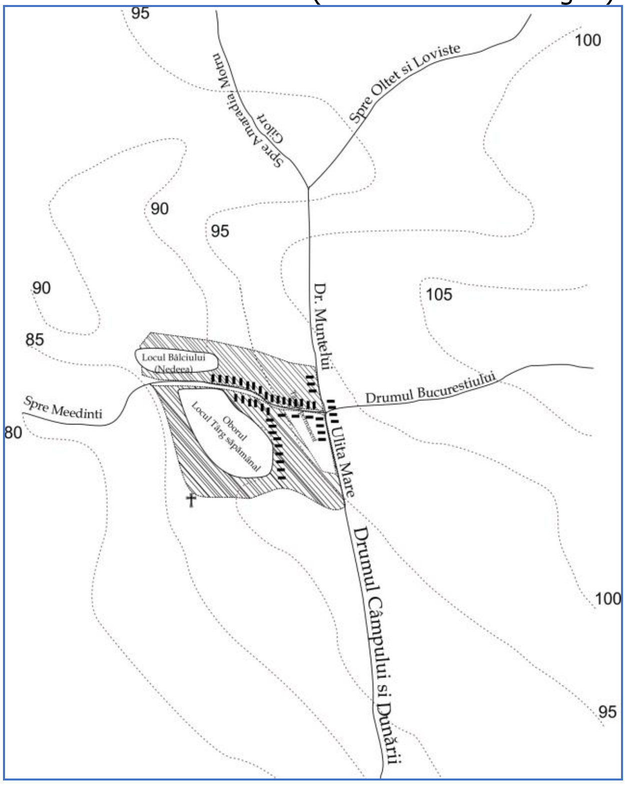

Fig. 2: The map of Craiova in 15th century

On the map achieved during the period September 1790 - May 1791, under the coordination of the Austrian officer Specht, which is considered the "first plan of the town" (Croitoru, 2012), Craiova appears as having a tentacular development on the terraces of Jiu, but not in the floodplain, where marshlands and ponds predominate (Fig. 3).

The end of the 17th century marked the delineation of the streets, the place of the fair, and in the 18th century the tentacular expansion of the city occurred along the main streets, on the entire Jiu terraces system (Nicolaescu et al., 1997). The city's first systematization plan dates from 1855, when the city center was established, the streets and the houses numbered. That same year, part of the streets of Craiova began to be illuminated with lamps (Nicolaescu et al., 1997).

On the first detailed map of Valahia (1: 57600), published in 1864 and based on Szathmári Pop Károly's lithography of *The Second Military Survey*, drawn by Austrians in 1855-1858, it is marked the beginning of the city's territorial expansion in the Jiu floodplain and the reduction of the areas occupied by ponds and marshes. Although the title of the map is *Charta României Meridionale*, it is widely known as the Szathmári *Map* (Fig.3).

The territorial expansion of the city continued under the power of economic and social progress and during the 1875-1906 period, Craiova deeply transformed, culminating with the "public works campaign", initiated in 1891 under the administration of Mayor Ulysse Boldescu (Ciobotea et al., 1999). The increase in the number of inhabitants due to the migration of the villagers from neighboring villages and of foreigners from Central and Western Europe led to the permanent expansion of the town limits, so that in 1899, in the Jiu floodplain, the radius of the town increased by 280 m on the Breasta Barrier (Cernele), 500 m on the Bucovăţ Barrier and 200 m on the Calafat Barrier (Balta Verde - Mofleni), compared to the limits from 1855 (Nicolaescu et al., 1997).

The presence of ponds and swamps in the southwestern part of the town has always been a source of insalubrity, infections and epidemics, which has made their drainage a mandatory assignement for the local administration. The first important work was the upheaval of all swamps from the Jiu floodplain between Balta Cornițoiu, Balta Verde, Fântâna Popova and the slope near the Bibescu Garden, according to the plans developed by G. Savopol in 1887 (Nicolaescu et al., 1997).

Although in 1904 a "neutral", peripheral area was established to separate the town from the neighboring villages, the realization of the collector canal (1896) created favorable conditions for the extension of the dwellings beyond the neutral zone, in the Jiu floodplain - on the Bresta Barrier, which led to a new resizing of the town (Nicolaescu et al., 1997).

Until the beginning of WWI, a series of anthropogenic works materialized in the floodplain sector of Craiova: the creation of the collector canal, the drainage of the southwestern swamps, the shaping of new boulevards on the site of the former streams, the designing of some discharge canals towards the main collector canal that crosses the floodplain longitudinally, the appearance of new constructions in the Eastern part of the collector canal.

In the interwar period, the urban renewal works, the city water supply, the sewerage, the pavement and the maintenance of green and recreation areas continued, including the designing of the Mofleni Park (14 ha) located within the Jiu floodplain.

In the second half of the 20th century, the image of Craiova and the floodplain sector it occupied was radically changed due to the works that aimed the streams planning, the regularization and the embankment of Jiu (the dyke from the right bank was built between 1978-1980 and the one on the left bank between 1981-1984), increasing the capacity of the collecting canal to keep up with the industrial development of the town, the improvement of pluvial water collection (Avram, Barbu, Ciobotea, & Osiac, 2005).

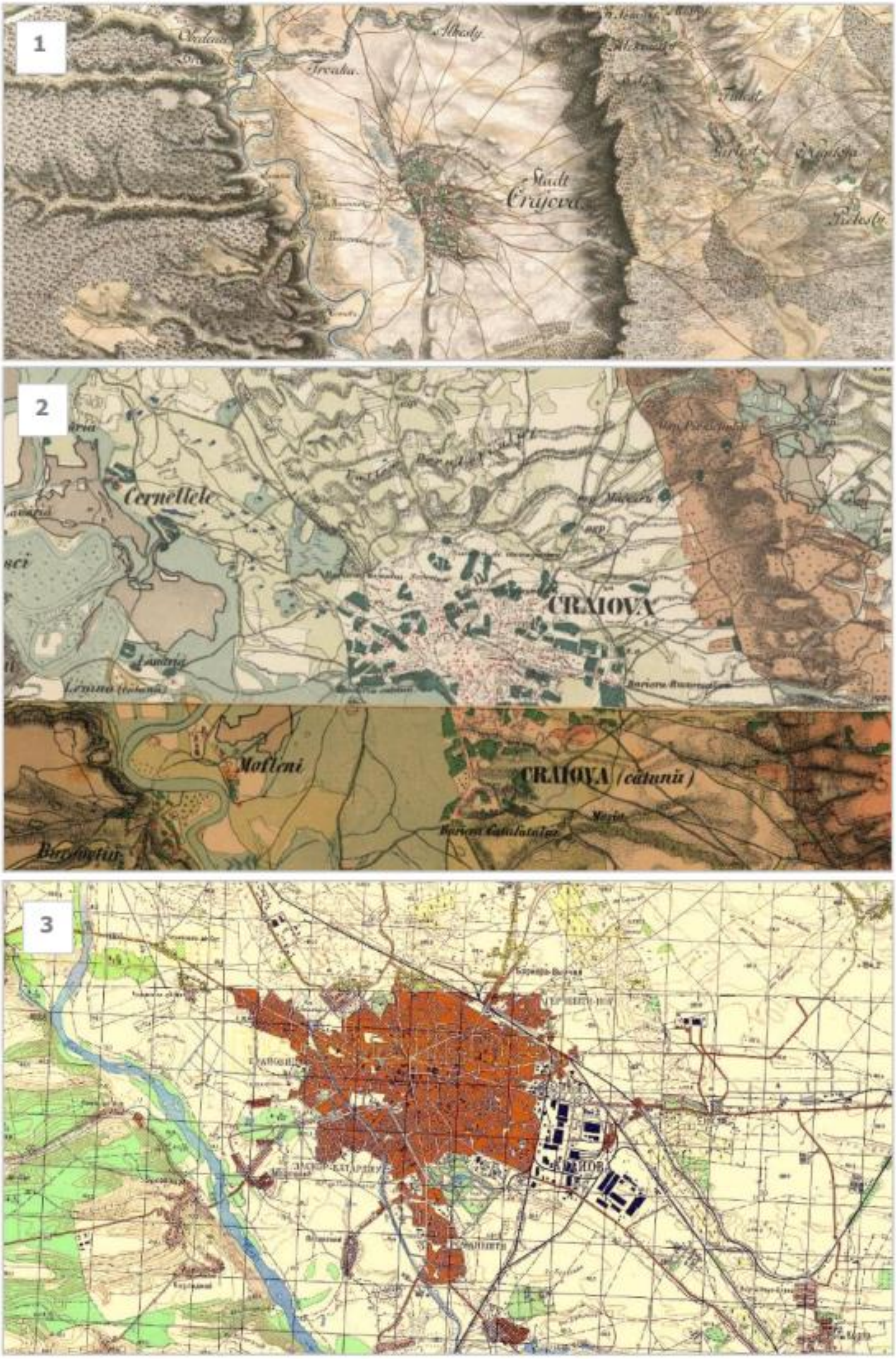

Fig. 3: The Dynamics of territorial expansion of Craiova

1 (1791) Tentacular development on terraces, Specht`s Map / Source: http://www.limes-transalutanus.ro
2 (1864) The beginning of expansion in floodplain, "Charta României Meridionale" /
Source: http://www.charta1864.ro/charta.html
3 (1976) The City of Craiova on "Russian Maps" / Source: http://www.geo-spatial.org

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Results

In its geological evolution, the Jiu presented a permanent movement of the course to the West, and one of the consequences of this movement was the formation and maintenance of marshes and ponds on the site of old courses.

The floodplain sector, which overlaps the present administrative territory of Craiova municipality, has an area of 39.79 km², a surface we have reported during the morphometric analysis and will be referred to as "the surface of the floodplain".

The visual dynamics of wetlands in the floodplain sector, represented by marshes and ponds a small part of which were later maintained as lakes intended for taking-over of pluvial waters or recreation, is synthesized in Fig. 4, having being rendered in the ArcGIS application based on historical maps: *Charta României Meridionale/ Chart of the Meridional Romania* published in 1864, British Map from 1944, Military Topographic Map, 1st edition, from 1974 Landsat Satellite Maps (1992), Google Earth (2017) and ortophoto 2017.

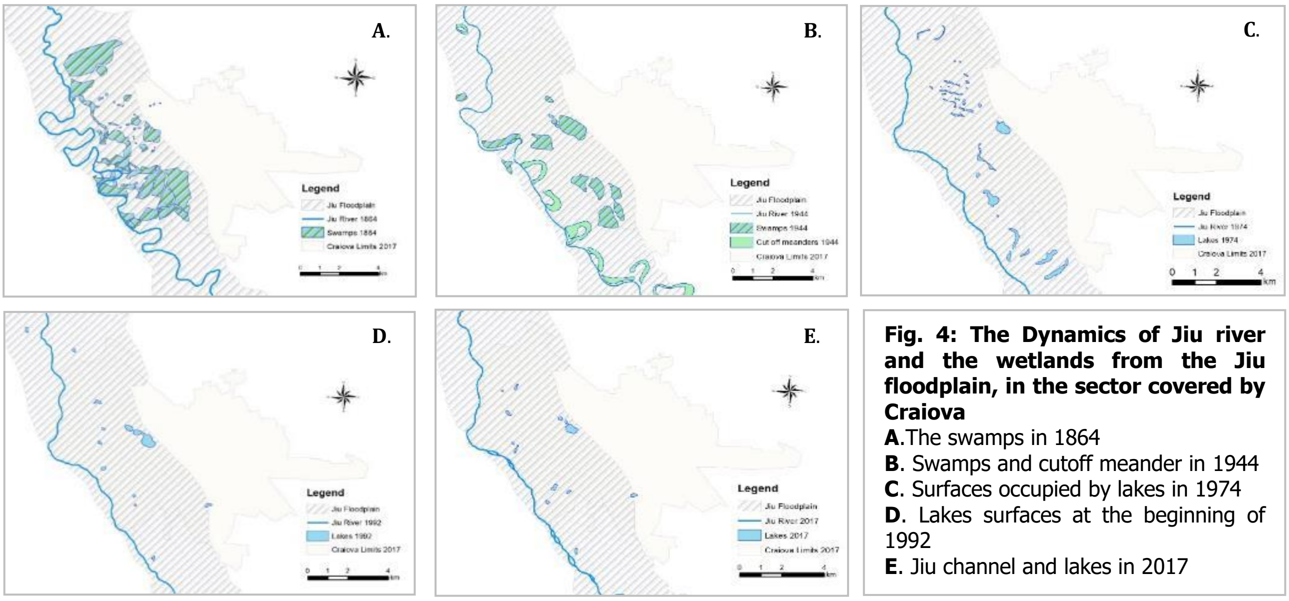

Fig. 4: The Dynamics of Jiu river and the wetlands from the Jiu floodplain, in the sector covered by Craiova
A.The swamps in 1864
B. Swamps and cutoff meander in 1944
C. Surfaces occupied by lakes in 1974
D. Lakes surfaces at the beginning of 1992
E. Jiu channel and lakes in 2017

In the second part of the 19th century, more than 28% of the floodplain surface was occupied by swamps – 11.37 km². Besides the impediment for development, they represented a source of insalubrity and maladies, their sewerage, drainage and systematization being a must. As a result of the public works launched by the authorities in 1891 and carried on constantly (except for the periods of the two World Wars), the decrease in wetlands occurred in an accelerated manner between 1900 and 1974 (Fig. 5).

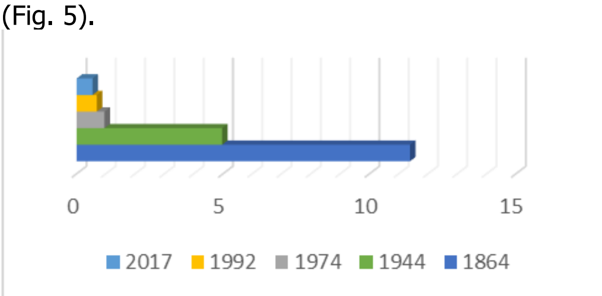

Fig. 5: The Dynamics of wetlands within the Jiu floodplain in period 1864-2017 (km²)

If in the 1860s the swamps covered about 28% of the floodplain, in 1974 they represented only 2.37%, and in 2017 the surface of the lakes in the floodplain totaled only 0.53 km², covering 1.35%.

A simulation of the cover of the current built area with the wet surfaces of the mid-19th century that dominated the Jiu floodplain is shown in Fig. 6.

The presence of the swamps covering the southwestern part of the town is easily observable.

Beginning with 1887 with the upheaval of all swamps from the Jiu floodplain, the drainage works included the creation of a channel system at surface or underground, wherethe water pond was pumped in, with discharge directly into the Jiu or in the Collector Channel (resulted by transformation of the Craiovița Stream, with a length of 11.2 km in order to take over the rainwater, industrial and domestic waters of the town).

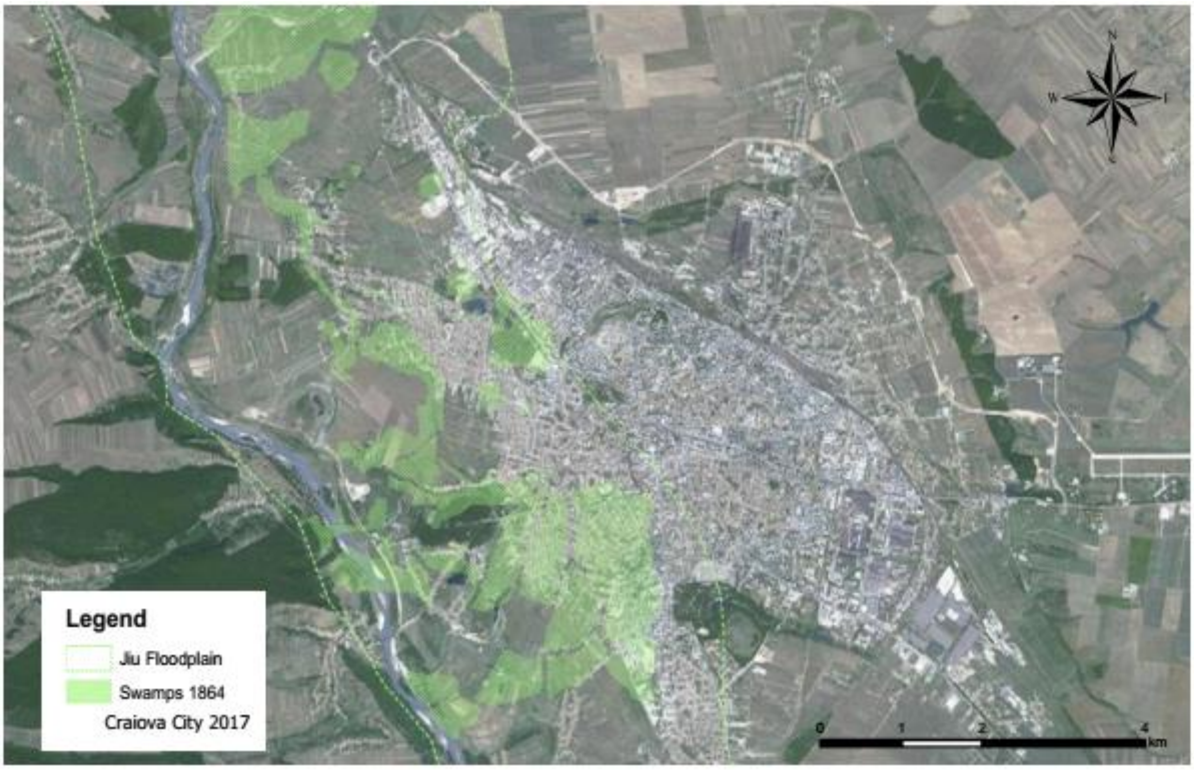

Fig. 6: The overlap of the swamps of 1864 on the current territory occupied by the city

The mitigation of the risk of pond reappearance and protection of the land, buildings and water supply fronts of the town, was achieved by the complete embankment of the left bank of the Jiu and also by the creation of the protective dyke around Lake Craioviţa, which was the source of Craiovița stream, and has the role of collecting rainwater from the surroundings. The banks of Amaradia near the confluence with Jiu, as well as the Collector Channel in the upstream sector, were embankment. The anthropogenic works that permitted urban extension in the Jiu floodplain were reconstituted on the map in Fig. 7.

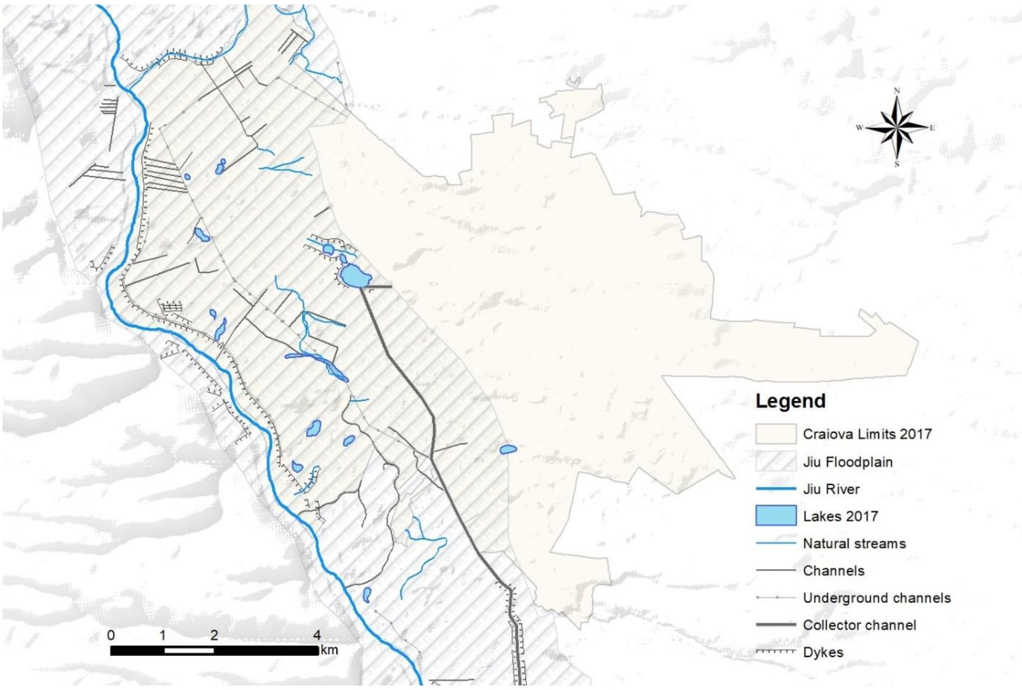

Fig. 7: The anthropogenic works realized for the swamps drainage in Jiu floodplain

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Starting with 1864 from a built-up area of 3.21 km² representing 8.08% of the surface of the floodplain and a swampy surface of 11.37 km², covering more than 28% of the floodplain, the inhospitable land of the floodplain was conquered step by step through the drainage of the ponds, the sewage of the streams and the extension of infrastructure and constructions. The expansion of the built area in the Jiu floodplain was directly proportional to the massive reduction of wetlands surfaces, while at the same time increasing the degree of safety by performing the flood protection works of the floodplain water courses. The city systematization started in 1855, including the construction of a Collector Channel in 1896, and allowed the expansion of dwellings along the roads in the East of the town, in the Jiu floodplain, and the further intensification of urbanization has increased the proportion of the built area to over 30% in the 1970s, to the detriment of wetlands that decreased to about 2% of the surface of the floodplain. The complete embankment of the Jiu banks during the period 1978-1984 favored the constant expansion of urban constructions, reaching 37% in 1992 and approximately 50% in 2017 (Fig. 8).

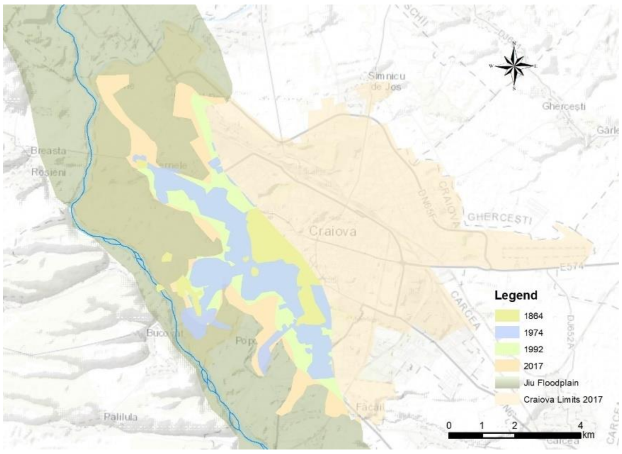

Fig. 8: The Dynamics of built surfaces in Jiu floodplain in period 1864 – 2017

On the former marsh land of the Jiu floodplain were built over the past 150 years many public utilities: the Lunca Jiului Park (now Tineret), the Mofleni Ecological Warehouse, Ion Oblemenco Stadium and the Polivalent Hall (Fig.9), the Botanical Garden, the Faculty of Agronomy, the Faculty of Physical Education and Sport, the County Hospital, the Army House, the Art High School, the House of Culture, hotels, as well as private buildings and dwellings.

Fig. 9: A - 1967. Geanoglu Swamp in drainage process - view towards center. Source: Omnia Library Craiova
B - The place of former Geanoglu Swamp in Dec. 2017 – view towards City Center. Source: C.D. Albă

The area of the broadleaf forest previously existent on the bank of the Jiu, in the southwestern part of the town, was put to use by its transformation, initially into a natural park, and from 1935 to 1936 in the Lunca Jiului Park.

To highlight the transformation made in the Jiu floodplain, the Environmental transformation index *(Itre)* was calculated for the last 150 years. *Itre*'s calculation formula has been adapted to the use of land from the Jiu floodplain, considering that the dominant areas in this case are relevant: wetlands representing natural areas and the built area representing anthropogenic surfaces. *Itre* dynamics, relevant to the expression of changes in the floodplain through urban expansion, is represented in Fig. 10.

$$I_{tre}=\frac{S_n}{S_a}=\frac{S_w}{S_b}$$

I_{tre} = Environmental transformation index;

S_n = Natural surface / S_a = Anthropogenic Surface;

S_w= Wetlands / S_b = Built surface

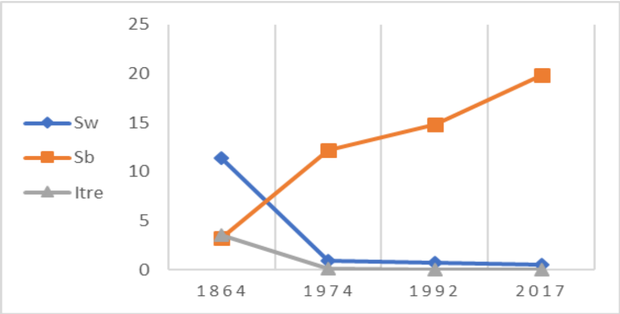

Fig. 10: Environmental transformation index (*Itre*) 1864 - 2017

The *Itre* value is much higher as the natural surface dominates the landscape. For the year 1864 the *Itre* value was 3.53, in 1974 went down at 0.07 and in 2017 this value dropped at 0.02. The much subunitary value of the past 50 years highlights the dominant anthropogenic landscape and the drastic reduction of natural surfaces.

In order to characterize the Jiu channel transformations over the last 150 years, the sinuosity index was calculated, representing the deviation of the course from a straight line and its value is expressed by the ratio between the actual length of the channel between two points and the straight line distance between the respective points (Aswathy, Vijith, & Satheesh, 2008). Depending on the static and dynamic characteristics of the course, Leopold and Wolman (1957) identified three river categories divided by the value of the sinuosity index value: straight rivers with an index of less than 1.1, sinuous rivers characterized by values of the sinuosity index ranging from 1.1 to 1.5 and meandering rivers with values higher than 1.5 (Dey, 2014).

At the exit of the Getic Piedmont and entrance into the plain area, the geomorphology of the area favored the course meandering before the anthropogenic intervention. In this sector, the Jiu River also presented a permanent movement to the West, forming the terraces and the floodplain and also several generations of meanders.

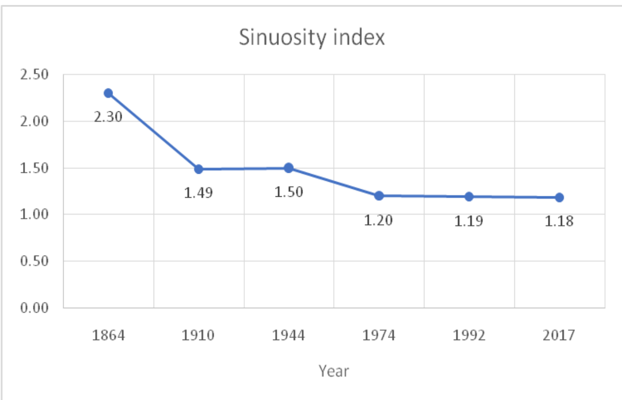

Fig. 11: The Sinuosity index of the Jiu River between 1864 – 2017

Until the first hydro-technical works on the course, the Jiu river presented on the analyzed sector a value of the sinuosity index of 2.3, being included in the category of highly meandered river (Fig. 11).

Since the first hydrotechnical works, performed at the beginning of the 20th century there has been a radical decrease of the index of sinuosity, which has an approximate value of 1.5 thus determining the inclusion of the river in the sinuous category around 1910. As a result of special hydrological events produced in 1953 and an exceptional flood in October 1972 with a flow of 2000 m³/s at the Podari hydrometric station, the regularization and straightening of the course continued and the index of sinuosity has a further diminished value in 1974. New floods occurred in 1977, which led to the planning of the complete embankment of both banks of Jiu, works that were carried out between 1978 and 1984.

The protection offered by the consolidation of the left bank and the regularization works favored the expansion of the constructions in the floodplain area, eliminating the risks of flooding for fields and constructions.

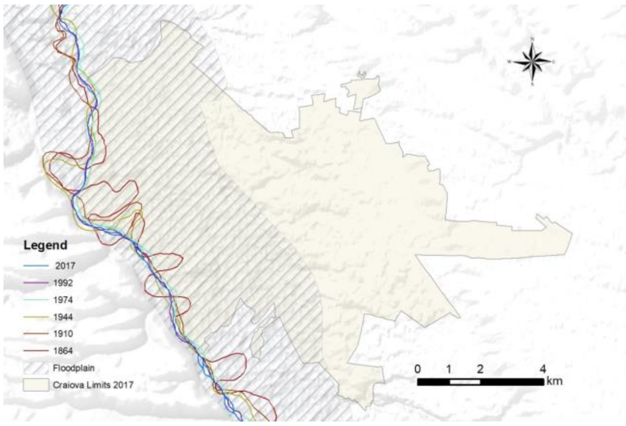

Fig. 12: The Jiu River between 1864 - 2017

Course changes recorded between 1864 and 2017 are presented in Fig. 12 where a relative stability of the course over the last 50 years can be observed.

Conclusions

Over the past 150 years the Jiu floodplain has undergone some complex morphological changes that have led to the replacement of the marshes and ponds that characterized it until the middle of the 19th century with land suitable for urban constructions. Until the beginning of the 20th century, the geomorphology of the floodplain constituted an impediment in the extension of the settlement. The human intervention began with the city's first plan of systematization in 1855 and materialized through the drainage and channeling of the floodplain, the mudding removing and embankment of Jiu and other water bodies with a potential flood risk, allowed constant urban expansion in the floodplain sector. The metamorphosis of marshy areas that favored insalubrity was achieved by creating a canals system, by building new roads, public infrastructure elements and private facilities.

We believe that the reconstruction of past conditions and the dynamics of changes in a radically transformed urban sector such as the floodplain sector of Craiova, as well as the visual exposure of anthropogenic works and changes in the field are a useful tool for good urban planning.

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The development of education in the rural areas in the post economic crisis period. Case Study: Argeș county, Romania

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Abstract

Education is the main pillar of any society, both worldwide and in Romania. The paper analyzes the evolution of the educational system in the rural areas from the county of Argeș during the crisis period and also after the financial crisis. The study has been based on statistical evidence data and also on the data provided by the Ministry of Regional Development, European Funds and Public Administration. The analysis has been applied on 95 communes, which form rural area in the county of Argeș. In addition to the educational variables, the study also took into account social and economic indicators in order to obtain a greater veracity over the analysis. In the methodological approach the article uses the principal components analysis and the hierarchical ascendant classification analysis, taking into consideration the year of 2010 and the year of 2016. The analysis points to the fact that the villages close to Pitesti stands out, as these are more developed. They are followed closely by the category represented by the villages with an aging population, from where the majority of the young workforce has emigrated. Another category is represented by the villages which have their economy based on the primary sector, and the last category is the one containing the villages with a disadvantaged ethnic population.

Keywords: *education in the rural areas, school population, principal component analysis, hierarchical ascendant classification, Argeș county*

Rezumat. Dezvoltarea educației în perioada post-criză economică în zonele rurale. Studiu de caz: județul Argeș, România

Educația, atât în lume cât și în România, reprezintă pilonul de bază al oricărei societăți. În acest articol se evidențiază modul de evoluție al sistemului educativ în zonele rurale din cadrul județului Argeș în perioada de criză și post criză financiară. Studiul s-a bazat pe date de evidență statistică, dar și din datele Ministerului Dezvoltării Regionale, Administrației Publice și Fondurilor Europene. Analiza se aplică la nivelul a 95 de unități rurale de la nivelul județului Argeș. Pe lângă variabilele educaționale, s-au luat în considerare și indicatori sociali și economici pentru a oferi o mai mare veridicitate anlizei. În demersul metodologic articolul recurge la analiza în componente principale și clasificării ierarhice ascendentă fiind analizată la nivelul anului 2010 și 2016. În cadrul rezultatelor obținute se remarcă tipologia specifică educației din comunele din proximitatea municipiului Pitești cu o dezvoltatare ridicată, urmată de categoria comunelor cu o populație foarte îmbătrânită de unde a migrat majoritatea forței de muncă tinere. O altă categorie este reprezentată de comunele în care predomină sectorul primar, iar o ultimă categorie este cea a comunelor cu populație etnică dezavantajată.

Cuvinte-cheie: *educația în zonele rurale, populația școlară, Analiza în Componente Principale, Clasificarea Ierarhică Ascendentă, județul Argeș*

Introduction

The central theme of this paper shows the main challenges we encounter and which the educational system is confronting with in the rural areas. Thereby, through keeping education at the high quality level, the society can answer fast to the sudden modifications in the local development (Smit & Wandel, 2006). Education, a constructive factor in any society (Borys, 2010), has in mind finding a solution to major problems, being considered the most sustainable method of dealing with the current challenges, among which the impact the society has over the environment is the most important one (Bühler et al., 2013; Mugi-Ngenga et al. 2016).

Out of the most challenging issues societies in the Eastern European countries are facing, education stands out through a drastic decrease in the school population (Pickup & White, 2003) and in the GDP share attributed to education. The foundation of these problems is representative for transition economies, which have known an ideological change, because, together with the economic decline, they have faced serious issues from a social point of view as well. The rural areas are more susceptible to changes in the socio-economic structure. There have been excessive migrations of the workforce to European countries, phenomena which has been amplified by the economic crisis in 2008 that has led the young population wanting to migrate to urban areas (Gatarić et al., 2016). At the same time, the educational system in the rural areas has had some downward dynamics in what is related to the quality of education, aspect underlined by the number of the teaching staff or by the school population.

The main idea in this article is the necessity to observe the challenges the rural areas were facing in the post-crisis period. These challenges concern both educational components and socio-economic aspects, aimed at society's development (Lukic et al., 2016).

Methodology and methods

In our study we used advanced statistical methods as principal component analysis (P.C.A.) and hierarchical ascendant classification (H.A.C.) (Henning et al., 2011; Șerban & Ianoș, 2014) in order to organize the rural villages in the county of Argeș and in order to analyze the specificities of the main components resulted from the educational system when correlated with socio-economical aspects.

For the statistical analysis of the educational system, we used four indicators: school population, school laboratories, teaching staff, classrooms; apart from that, we can add two economic indicators: expenses for education in the local budget and the number of employees, but also two social indicators: the number of households and the number of unemployed persons.

Through our analysis, we have identified the degree of correlation between the indicators taken into consideration and also casualty issues which prove the functional mode of the socio-educational system. The methods that have been used were analyzed with the aid of Philcarto.

As mentioned above, the analysis comprises two different stages after the 2008 crisis period, 2010 and 2016 (except the number of employees - 2015). The period is determined by data availability. At the same time, the problem of education needs was analyzed across the entire post-socialist period (Stanilov, 2007), when the Romanian socio-economic system is evolving (Șerban & Ianoș, 2014). In this regard, we have used the percentage of the school population from the total population in the entire period of time between 1991-2016 in the county of Argeș.

Results

The analysis of the entire post-socialist period indicated the existence of three great significant periods in the evolution of the school population (Figure 1): the first one is comprised between 1992-2000 and it has been dominated by school population values of about 20%, which was due to the birth stimulating politics imposed by Nicolae Ceaușescu. The second one (2000-2008) overlaps the period of economic growth, but also a certain regress for the school population mainly due to the opening borders to the European Union and to the demographic "gap" in the 1990's (Nancu et al., 2011). The third one (2008-2016) coincides with the financial crisis period, continuing through a mass exodus of the young population, who chose to leave to foreign countries (Oberhauser, 2016).

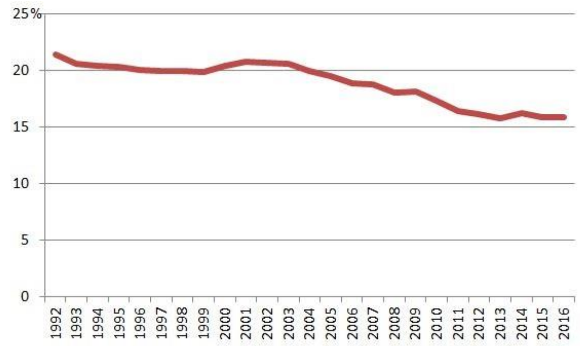

Fig. 1: The evolution of the school population share between 1992-2016 in county of Argeș

Based on the dynamics of the share of population aged between 20-39 years old in the county of Argeș, between 1992 and 2016, but also based on the rural population with the same characteristics, we will be able to prove some interesting facts. One can notice (Figure 2) that the dynamics of the rural population aged between 20-39 years old is divided by two different trends: the first one (1992-2007) shows an ascending trend, while after 2007 it fell below 30%. The reasons for these phenomena can be explained through a high migration rate of the young population to the urban areas to cities with better economies (e.g. Bucharest, Brașov or Sibiu), and also through the specifics of the age categories we encounter in the rural areas from the vicinity of the major towns in the county (Miletić et al., 2011).

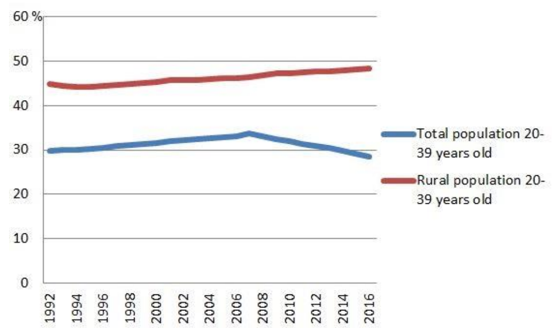

Fig. 2: The evolution of the population ratio with ages between 20-39 and the evolution of the rural population with ages between 20-39 in the period between 1992-2016, in the county of Argeș

Source: National Institute of Statistics

Continuing the analysis on the same path, by comparing the total gross variables for the indicators that were used in the principal component analysis and in the hierarchical ascendant classification for the time between 2010 and 2016, the following percentage values are highlighted: a drop of -14.93% in the school population, a drop of -5.32% in the number of labs, a drop of -18.10% in the teaching staff, and an increase of 38.71% of the local budget expenses in education. We can state that the main problems in the two years which have been analyzed are represented by the decline in the number of the school population and of the teaching staff. Given the fact that the young population has migrated (Sagynbekova, 2016), the number of pupils for each form of education has dropped considerably (because of the number of teachers who do not want to teach in rural areas (Ankrah-Dove, 1982), because of resignations and because of a poor wage motivation).

The higher figures for the investments are the result of a constant financial growth for the Romanian economy, which is confirmed by a 31.54% growth in the number of employees and also by a decrease of the unemployed by -18.82%. The social category represented by the number of households records an increase of 3.17% given the cultural perceptions of the Romanian people. Therefore, based on the above-mentioned factors, we can better understand the direction of the educational development in the rural areas in the county of Argeș.

In terms of the principal components analysis, we can see how in the year of 2010 the value of the first principal component is 67.74%, while in 2016 the value for the same component is 64.8%, aspect which is sustained by the Pearson coefficient (Fig. 3, Fig. 4), which shows that not all the indicators can be correlated because they express different social phenomena or contrary aspects (it is very unlikely for the number of employees to grow, when the number of unemployed grows). The variables that are expressed through the first principal component are represented in both analyses by: school population, teaching staff, number of classrooms, local budget expenses for education and the households, while the variables expressed through components 1 and 2 are represented by the number of employees, whereas the ones expressed through components 1 and 3 are represented by the number of laboratories. An interesting aspect to notice is the number of unemployed in 2010, which was at first represented by components 1 and 3, and then by component 2, aspect which is given by the dramatic decline in the number of unemployed (2401 persons).

The observation of the villages' general characteristics from an educational point of view, has been done through HAC, with 5 different classes, so as to highlight the socio-educational evolution for the villages under discussion, based on the standard deviations.

For each of the 5 classes there is a denomination, based on the category's characteristics. Thereby, 4 of these appear at the level of both the analyses and one of them disappears, being completely replaced by a new class.

We call the first class for the year of 2010 the category of settlements with a high level of education and which is characterized through low values for the number of unemployed, due to proximity to the county seat Pitesti. Because of this, some companies have decided to move their headquarters there. This aspect is strengthened by the expenses in education, which occurred because of big number of employees. As for the educational variables' values, they are positive because, having many employees and also taking into account the way the villages are positioned, there comes a great possibility to have children and also to have teachers willing to teach.

	The Inertia Matrix (*1000) . Coefficients of Pearson linear correlation							
	V01	V02	V03	V04	V05	V06	V07	V08
V01 School population 2010	1000	545	769	944	488	865	587	908
V02 Laboratories 2010	545	1000	444	611	283	585	248	539
V03 Households 2010	769	444	1000	781	550	748	421	783
V04 Teaching staff 2010	944	611	781	1000	417	892	573	889
V05 Employees 2010	488	283	550	417	1000	379	244	637
V06 Classrooms 2010	865	585	748	892	379	1000	497	830
V07 Unemployed 2010	587	248	421	573	244	497	1000	547
V08 Expenses in the local budget dedicated to education 2010	908	539	783	889	637	830	547	1000

Fig. 3: Fig. 3 The Inertia Matrix for the year of 2010

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	The Inertia Matrix (*1000) . Coefficients of Pearson linear correlation							
	V01	V02	V03	V04	V05	V06	V07	V08
V01 School population 2016	1000	563	745	946	438	895	376	927
V02 Laboratories 2016	563	1000	383	595	288	612	49	566
V03 Households 2016	745	383	1000	724	592	716	167	800
V04 Teaching staff 2016	946	595	724	1000	409	924	320	919
V05 Employees 2015	438	288	592	409	1000	377	-99	649
V06 Classrooms 2016	895	612	716	924	377	1000	302	875
V07 Unemployed 2016	376	49	167	320	-99	302	1000	244
V08 Expenses in the local budget dedicated to education 2016	927	566	800	919	649	875	244	1000

Fig. 4: Fig. 4 The Inertia Matrix for the year of 2016

An interesting fact is that the population in these villages has also high values for the school population and this is because of the local population's educational profile, when compared to the one in the cities.

We need to notice that we encounter the same category in the year of 2016. Modifications in this group are based on a larger population and on a much more developed school infrastructure, but we also encounter a bigger number of unemployed when compared to 2010. This development has been based on a high evolution of the social system, represented by the excessive migration to the suburbs and, consequently, the local economy did not have the same rhythm as the number of newcomers (a growth in population of 9.1% between 2010-2016).

In 2010, the second category is made up by localities which have all the values negative, being the most consistent category but also the most negative one from an educational point of view. The main aspect is given by the specificities of these localities with an aging population, whose children went to areas with a better possibility of economic stimulation (Scholich, 2007). One can say, based on the variable of the unemployed, which is very low, that the economy of these localities is based on elements belonging to the primary sector and that the only solution to this failure of capitalism is to sustain the poor rural population (Lipton, 1977). This category corresponds to the third class analyzing the year of 2016. An important thing to take into account is the geographic position of these localities (marginal areas in the county), having weak connections with the cities. The high number of communes in this category shows the inflexibility of these localities.

The third category is the opposite to the second one, having all the values positive, including settlements with high values but also high unemployment rate. This category has 5 standard deviations of maximums, being characterized by elevated values for the school population and the teaching staff, but also by a high degree of unemployment. An encouraging aspect is given by the high values of the expenses in education, which means that the local authorities want to offer the chance for social and educational development. This category is no longer identified in 2016.

The fourth category in 2010, i.e. localities with a disadvantaged population, includes settlements that are mainly situated in the north-eastern part of the county, being called the category of the. All the values are positive, but because of their disposal we can also state that this category has a high number of unemployed and a large school population, but lacking an advanced economy, in which the local communities do not offer sufficient funds for education. The low number of households indicates either low values for the local population or the fact that there are important communities of Romani people (Berevoiești 28%, Cetățeni 26%, Dragoslavele 21.6%, Stoenești 12.5% in the year of 2011). Similarly, in2016, we also have the fifth class, where one can see a greater compaction of the localities with these characteristics in the proximity of Câmpulung Muscel.

The fifth category includes localities where most of the active population works in the primary sector, a trace attributed mainly to the central-southern part of Arges county. This category has a positive standard deviation of 0.5, except the number of employees and also the one of the unemployed, which proves the fact that these areas represent centers, which could be developed more, given the fact that they gave an adequate school population and infrastructure. Also, the low number of the school population shows a great weight of the aging population (Bârla 24.8% and Ungheni 32.2% population older than 65), being similar to the second category, but having a better economic profile.

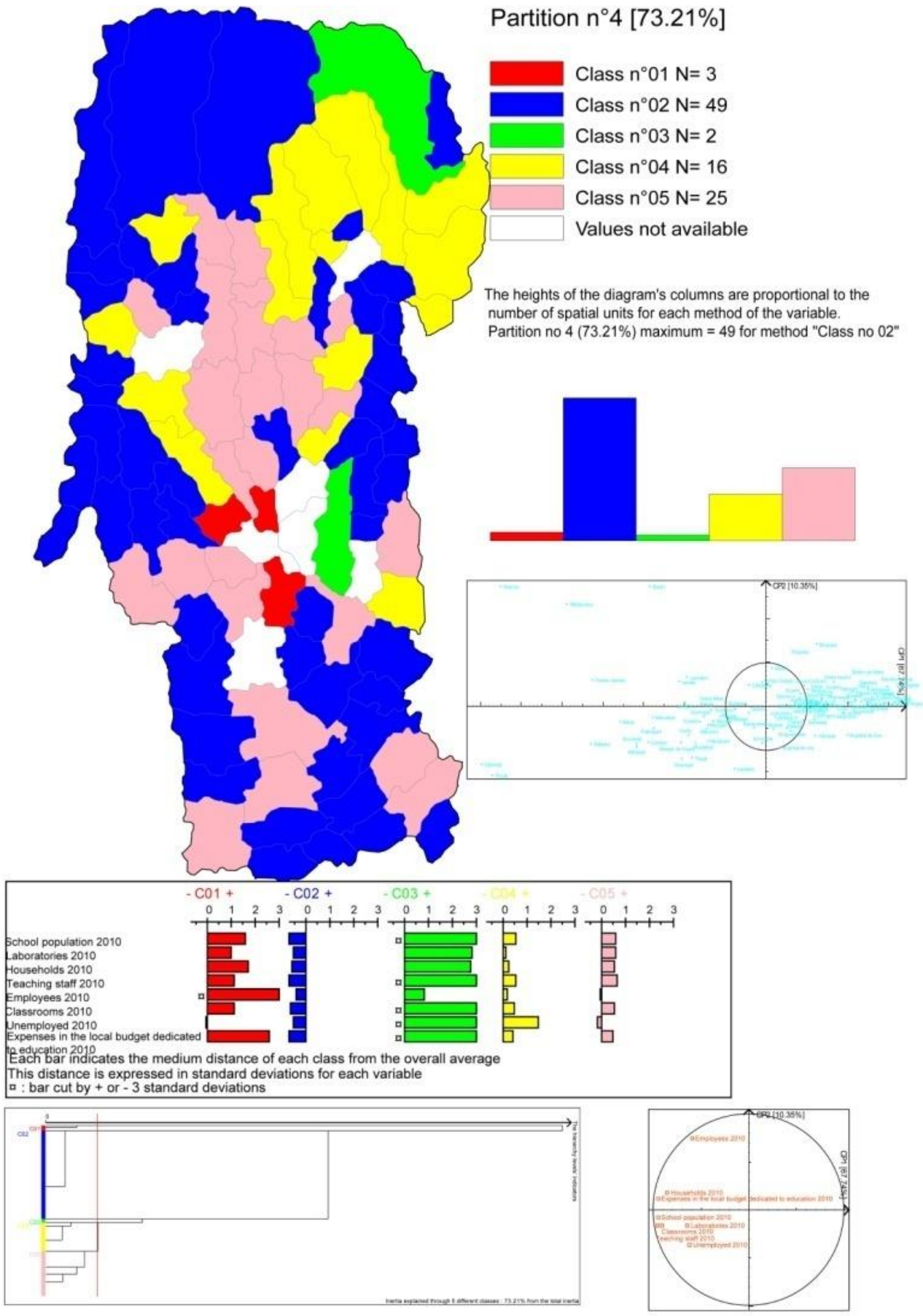

Fig. 5: HAC for the year of 2010. Processing after data from the National Institute of Statistics Made with Philcarto (http://philcarto.free.fr)

The fourth category in 2016 is a new one and it is composed of two localities, Mărăcineni and Bradu, which were part of the first category in the year of 2010. These units are characterized by a high number of employees with a much lower school population when compared with the analysis at the level of 2010, because of the economic instability in the municipality of Pitesti. As in the case of Bascov, we can identify here an high number for the unemployed, because of the sudden fluctuations in economy.

The category of the localities with a well-developed educational system but with a declining population in 2016 has been split off from the first category. This category replaces the one of the third class (from 2010). These units are characterized by an increased number of employees but with a much lower school population when compared the analysis based on the year of 2010 and this is due to the economic instability identified in the municipality of Pitesti. Also, there is a high number of unemployed, the same as in the case of Bascov.

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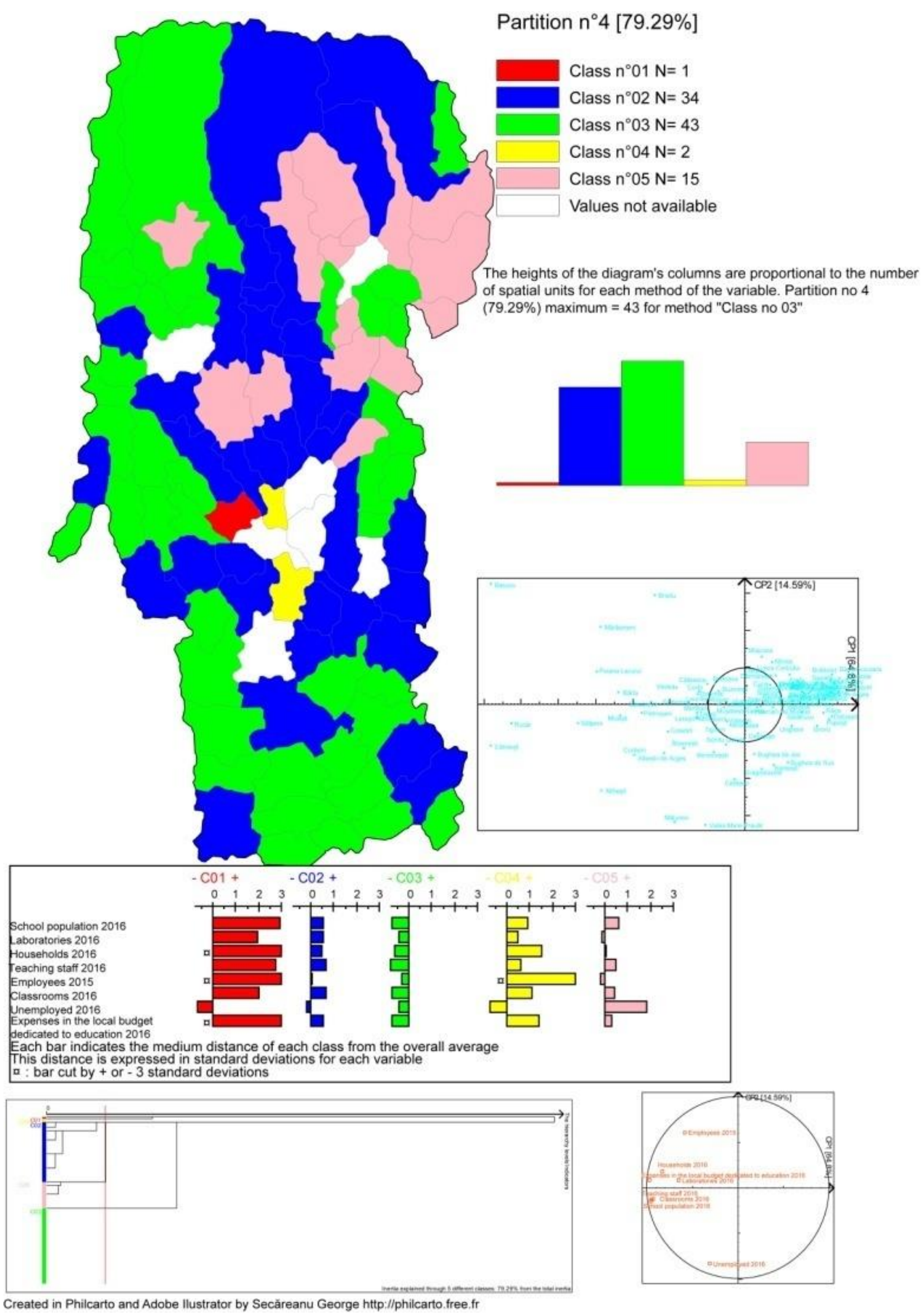

Fig. 6: HAC for the year of 2016. Source: National Institute of Statistics

Made with Philcarto (http://philcarto.free.fr)

The analyses for these two years, 2010 and 2016, offer a picture of the educational factors in the rural areas of Argeș, but it also shows a certain stagnation of the communities' characteristics: either they are at great distance from the main urban poles or they have a very well defined rural character which allows for changes throughout time. Another issue is represented by the disadvantaged communities who hardly want to give up their way of life. On the opposite side, we have the localities lying in the proximity of towns which are well connected to the national economy, therefore they constantly meet major changes in their socio-educational infrastructure. The migration of the young population towards more economically attractive areas is a problem for schools, impacting on the school population.

Conclusion

In our analysis, there are several types of categories for the educational structures, and, with them, we have also adjacent problems. One of these categories is represented by the fact that the localities found in the vicinity of towns are very receptive to changes in the socio-educational field and are also economically developed (Cruz & Teixeira, 2015), therefore they can financially sustain expenses in education. These categories are represented by class I from each analysis, being considered stable-positive.

The second category refers to the localities at the opposite side, which are dominated by an aging population because the young one chose to migrate to more financially attractive areas. This category corresponds to the third class being considered a stable-negative category.

The fourth category is the one representing the disadvantaged ethnicities, who have many children whose educational structure doesn't change when the economy or the society does (Aslund et al., 2010). The localities have the same characteristics from one analysis to another, presenting a below average level of development.

The fifth category is represented by the population whose main activity is found in the primary sector. These localities keep their characteristics during the two reference year, having an average stable character.

In terms of changes over time, two different trends should be pointed out. When comparing groupings at the beginning and at the end of the study period, 69 localities (73%) have not changed their category, indicating stability in the quality of education services. At the same time, 18 localities (19%) switched their initial category to a better one, showing a progress in education service provision comparing to other administrative units in the county. There are, also, 8 cases in which localities changed their category to a worse one, suggesting that these units stay behind comparing to the rest.

The approach in the analysis of certain small communes increases the intensity with which the socio-educational phenomena impact the social structure of the area and thus, for long periods of time, certain villages can be highly depopulated because of the industry in the big cities (Crescenzi et al., 2012). There are also localities with a young population coming from disadvantaged areas and with a weak education given their family conditions or the impossibilities of the local agents to invest in the society's development (Torres & Carte, 2016).

Another consequence that can be traced within the developed communities is the phenomenon of social emancipation. In this case, young people form a family much later, they do not want to have children or they cannot raise more than a child.

Therefore, the educational situation has suffered alterations after the financial crisis and its categories are constantly being reorganized. Even if the majority of the migrations have been made towards higher categories, qualitatively speaking, the problem of the negative categories will still be significant due to high share of these communes in the county.

Acknowledgements

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Author contribution

All the authors had equal contribution.

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Measuring the Complex Socio-economic Development of the Danube-adjacent NUTS2 Regions

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Abstract

The existing inner socio-economic discrepancies are one of the major stumbling-blocks to the sustainable development of the Danube region and to the successful realization of its different macro-regional development programmes, strategies, and action plans. That is why it is of extreme importance to assess these discrepancies on a complex base, going beyond the analysis of single indicators. From that point of view, we suggest that sophisticated methodology and approach are needed, similar to those used to elaborate thorough European spatial development models. In order to measure the current socio-economic spatial development of the Danube regions on a complex basis, we apply author's "Development and Prosperity Index" (DPI) calculated by using the latest available data for 8 key indicators. By contrast with the majority of the scientific studies that build their conclusions on NUTS0, or rarely on NUTS1 level analysis, our research is suited at NUTS2 level so that we can take a detailed picture of the situation in the Danube region. Another significant difference from the mainstream studies is that we concentrate predominantly on the Danube-adjacent NUTS2 regions, but not on the whole area (as defined in the EU Danube Region Strategy). That approach provides us with an opportunity to divide the study in two important stages. Firstly, we make a comparative analysis and a classification of the Danube-adjacent NUTS2 regions providing empirical evidence for the significant complex socio-economic discrepancies between them. Secondly, in a view to estimate the development role of Danube in different countries, we confront the DPI results for Danube-adjacent NUTS2 regions against those for the other regions in a given country. Although this approach is characterized with certain conditionality considering that development is a function of many diverse factors, the results of the study provide solid ground for building up adequate future policies.

Keywords: *Danube regions, socio-economic analysis, regional development, complex assessment, development and prosperity index*

Măsurarea nivelului de dezvoltare socio-economică a regiunilor NUTS2 adiacente Dunării

Rezumat. Existența discrepanțelor socio-economice interne reprezintă una din principalele piedici în dezvoltarea durabilă a regiunii dunărene și ducerea la îndeplinire a diferitelor programe, strategii și planuri de acțiune pentru dezvoltare macro-regională. De aceea, este extrem de important să se evalueze aceste discrepanțe ținând cont de bază complexă, care nu doar analizează individual anumiți indicatori. Prin urmare, considerăm necesare o metodologie și o abordare mai complexe, similare cu cele utilizate pentru elaborarea modelelor europene de dezvoltare spațială. Pentru a măsura nivelul actual al dezvoltării socio-economice a regiunilor dunărene în mod complex, am elaborat indicele denumit *Indicele de Dezvoltare și Prosperitate,* ce a fost calculat utilizând cele mai noi date disponibile pentru 8 indicatori cheie. Spre deosebire de majoritatea studiilor care analizează regiunile NUTS0 și foarte rar NUTS1, studiul de față se axează pe analiza la nivel NUTS2, astfel încât să ofere o imagine detaliată a regiunilor dunărene. O altă diferență semnificativă comparativ cu literatura de specialitate este dată de faptul că am analizat în general doar reiunile NUTS adiacente cursului Dunării, și nu toată regiunea în ansamblu (așa cum este definită în cadrul Strategii Regiunii Dunării). Această abordare ne oferă șansa de a desfășura această analiză în două etape importante. Mai întâi, se face o analiză comparativă și o clasificare a regiunilor NUTS adiacente Dunării, ceea ce oferă mărturii empirice privind discrepanțele socio-economice destul de complexe. Apoi, pentru a putea estima rolul Dunării pentru dezvoltare în regiunile NUTS2 adiacente, am comparat rezultatele obținute pentru DPI pentru regiunile analizate cu cele pentru alte regiuni dintr-o anumită țară. Deși există unele limitări ale acestei abordări, întrucât dezvoltarea depinde de numeroși factori, foarte diferiți, rezultatele acestui studiu oferă o bază solidă pentru elaborarea unor politici adecvate pe viitor.

Cuvinte-cheie: *regiuni dunărene, analiză socio-economică, dezvoltare regională, evaluare compleză, indicele dezvoltării și prosperității*

Introduction

The spatial socio-economic disparities signify different development patterns, social environment conditions, distribution of resources, uneven opportunities, etc. Thus they could be treated as a major threat ahead of sustainable development. The reasons for the inequalities are numerous: different natural conditions; historically inherited patterns; diverse role of the factors determining social, economic, and political development; specifics in the mobility of labour forces and capitals; uneven dispersion of technology and innovations; regional and local traditions of the population. The growing scientific interests in studying the inequalities, their dimension and impact over the society, and in finding possible ways and models of fostering more balanced development, has recently provoked many researchers to dedicate their work to these topics. Given that the Danube River is often perceived as "a central axis of the EU" (Nedea et al., 2012), there are also a number of studies on the socio-economic development of the Danube countries and regions over the past years. A good example of a large-scale study conducted by an international team is "Socio-

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Economic Assessment of the Danube Region: State of the Region, Challenges and Strategy Development" (2014). The research follows the notion of the term "Danube region" laid in "The EU Strategy for Danube Region" (2010), thus providing the widest possible spatial coverage and including, besides the typical Danube countries, also the Czech Republic, Slovenia, Bosnia and Herzegovina, Montenegro, Moldova, as well as border regions of Ukraine. The authors build their thesis after studying separately various economic, social, demographic, infrastructural, environmental, and other indicators. The analyses basically seek to scrutinize the overall competiveness of the Danube region, while the inner comparisons are generally made at country level. Some of the focal points in that paper are themes such as: Macroeconomic Performance and Competitiveness; Labour Market and Migration; Regional Development; Infrastructure and Environment; Entrepreneurship; SME Financing; Cluster Development. The research aims to find out potential opportunities, challenges, needs, and preliminary recommendations within each of these key topics.

In 2016, the Central European Service for Cross-Border Initiatives issued another study in accordance with the countries included in "The EU Strategy for the Danube Region". By analysing various indicators at the lowest possible administrative level, the authors provide convincing proofs for the existence of regional inequalities. Seventeen natural, economic, social, and infrastructural thematic areas are discussed in the study demonstrating in this way clearly the disparities between Western and Eastern Europe in different spheres.

Czakó et al., 2014 analysed the economic imbalances among the countries within the Danube basin, concluding that the German states of Baden-Württemberg and Bavaria, as well as Austria, are characterized by much higher growth rates than the other four countries, with Bulgaria and Romania particularly lagging behind. Winiwarter and Haidvogl (2015) emphasize that financial and institutional cooperation between prosperous areas in the upper catchment and less developed ones in the middle, and especially in the lower basin, is lacking. Building their analysis on a long-term sustainable development perspective, the authors state that "socio-economic disparities, a characteristic for the Danube region, are a huge challenge". Moreover, environmental issues have been created or exacerbated by economic and social inequalities, while also leading, among other things, to a veritable brain drain of much-needed expertise. The brain drain problem is also a key issue in the study of Savić and Dakić (2016). The researchers come to the conclusion that demographic variations in the Danube region have negative impacts not only on the overall economic development of the area but they also generate unfavourable trends in political relations between the countries.

By studying the economic transition in Central and Eastern Europe and the gap in the standards of living, Philipov and Dorbritz (2003) explain how the overall political, economic, and social transformation resulted in abrupt and significant demographic changes in the region. In line with that conclusion, the Common Spatial Development Strategy of the V4+2 Countries (2014) suggests increasing demographic imbalances between urban and rural, central and peripheral areas of the V4+2 territories, identifying also some development poles and development axes. Despite Central Europe is generally more developed than Eastern Europe, it is also characterized by significant variations in its spatial structure - a result of the region's pre-existing historical conditions (Central Europe Programme, 2012).

Research projects Donauregionen and Donauregionen+, aimed to strengthen the NUTS 3 level functional regions located on the Danube River corridor in supporting the European growth and competitiveness, offered a general scheme of spatial indicators, generally valid for all regions studied, to assess the potential socio-economic development of the Danube region in a broader context. Modern methods were used to assess the potential socio-economic development of the regions and define their typology. In addition, 5 Danube regions and 19 areas of Transdanube cooperation were identified based on GIS and on tools and techniques specific for spatial planning. Finally, development scenarios were made for the five Danube sub-regions based on external and internal factors that can influence the socio-economic development of the researched area (Tache et al., 2014). Territorial scenarios for the Danube region are also developed in a study by Gál et al. (2013) where diverse economic, social, demographic, and ecological indicators are taken into consideration.

The majority of these scientific works studying the development of the Danube region emphasize basically on the analyses of separate indicators and thematic fields, while at the same time attempts to assess the complex socio-economic development are rare. In line with the broader sustainable development goals and the evolution of the widening cohesion concept, there is an exigent need to create and apply innovative approaches suitable for making comparative analyses of the complex development at regional level. This could help us find out the essence of the existing problems and their solutions, estimate and coordinate better the general impact of different policies, as well as create alternatives strategies for the future development of the regions. In the light of the above considerations, the main goal of this article is to offer a new approach and methodology for better understanding the inequalities in the complex socio-economic development of the Danube region. The term "Danube region" is used in the analysis of our study to indicate exclusively the territory covered by the Danube-adjacent NUTS2 regions (including Bucuresti-Ilfov that is surrounded by Sud-Muntenia and gravitates in many aspects to the Danube).

The paper is organized as follows. Chapter 2 outlines the methodology for calculation of the so called "Development and Prosperity Index" (DPI) – an integral index created through author's algorithm in a view to provide a single measurement for the overall development of a particular region. After describing the precise algorithm, in Chapter 3 we present the general results and how the Danube region fits within our thorough European development model. Chapter 4 discusses the results from the "first level" of our empirical researches – the inequalities between the Danube-adjacent NUTS2 regions, while Chapter 5 is built upon the "second level" of analyses – the development patterns within the countries themselves. Finally chapter 6 summarizes the main results and points out the key conclusions and messages.

Methodological framework

Given the specific task of measuring the current socio-economic spatial development on a complex basis, we elaborate an integral "Development and Prosperity Index" (DPI). The author's index is calculated by using the latest available data for the NUTS2 regions, which is the most adequate level for the analysis as on one hand NUTS1 don't provide detailed picture and on the other – the data at NUTS3 level is largely insufficient. As one of our major goals is to compare the complex development of the Danube-adjacent regions to that of the other European regions, the DPI is calculated for all the NUTS2 regions of the EU countries, Switzerland, Norway, and Serbia, with the exception of the territories situated far outside continental Europe. However, the analysis in this paper concerns exclusively the NUTS2 regions of the Danube countries (Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, and Romania), while the DPI results for the other regions are used solely to build the general spatial development model at European level.

Table 1: The model for calculating the DPI result for a separate indicator

	interval between average and extremal values	relation to the average value	logical correlation between indicator's value and rating	formula for calculation
When	$I_{max} - I_{av} \geq I_{av} - I_{min}$	$I \geq I_{av}$	positive	$R = \left(5 + \frac{\left(\frac{I - I_{av}}{(I_{max} - I_{av}) \div 5}\right)^x}{y}\right) \times \frac{W}{11}$
		$I < I_{av}$	negative	
When	$I_{max} - I_{av} < I_{av} - I_{min}$	$I \geq I_{av}$	positive	$R = \left(5 + \frac{\left(\frac{I - I_{av}}{(I_{av} - I_{min}) \div 5}\right)^x}{y}\right) \times \frac{W}{11}$
		$I < I_{av}$	negative	
When	$I_{max} - I_{av} \geq I_{av} - I_{min}$	$I \geq I_{av}$	negative	$R = \left(5 - \frac{\left(\frac{I_{av} - I}{(I_{max} - I_{av}) \div 5}\right)^x}{y}\right) \times \frac{W}{11}$
		$I < I_{av}$	positive	
When	$I_{max} - I_{av} < I_{av} - I_{min}$	$I \geq I_{av}$	negative	$R = \left(5 - \frac{\left(\frac{I_{av} - I}{(I_{av} - I_{min}) \div 5}\right)^x}{y}\right) \times \frac{W}{11}$
		$I < I_{av}$	positive	
Where:	R = the result, i.e. the number of DPI points that a region receives for the particular indicator I = the value of the indicator for a given region I_{av} = the average value of the indicator for all the 281 NUTS2 regions (not weighted) I_{max} = the highest value of the indicator (from all the 281 NUTS2 regions) I_{min} = the lowest value of the indicator (from all the 281 NUTS2 regions) x = variable (from 0.57 to 1) determined after calculating the specific coefficient of dispersion for the indicator y = variable (from 0.50 to 1) determined after calculating the specific coefficient of dispersion for the indicator W = the set nominal weight of the indicator			

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The DPI is grounded on eight separate indicators: Regional GDP (measured in PPS per inhabitant), Unemployment rate (%), Employment in high-tech sectors (%), Total intramural R&D expenditure (% of GDP), Motorways network (km. per 1000 km.^{2}), Population density (persons per km.^{2}), Life expectancy at birth (years) and People at risk of poverty or social exclusion (%).

As DPI in its essence is an index for comparative analysis, the methodology itself strives for building an algorithm reasonable for a benchmarking tool. From that point of view estimates for the different indicators are formed within the framework of the calculation model (i.e. they are determined by the relative advantages or disadvantages of a region against the others) and are not dependent on preliminary set criteria and thresholds that could be more abstract and inapplicable when comparing different time periods.

The algorithm for calculating the index is based on the following steps:

1) We determine specific weight for each of the indicators with "Regional GDP" receiving the highest one (3) – it account for 3/11 of the final DPI result, „Population density" – for 2/11, while the other six – each for 1/11;

2) In order to optimize the methodology for calculating the results and eliminate the undesired effect of the extremities, we determine in advance certain limits for each indicator, i.e. either maximal or minimal value that would correspond to rating 10 or 0 in our assessment scale (so even if a value for a particular region surpasses that limit, the rating stays in the above-mentioned scale – from 0 to 10).

3) By using the average and the extremal values, we make mathematical normalization of each indicator's values into a scale ranging from 0 to 10. Moreover, aiming to avoid the unrealistic clustering of the ratings at the mean (that would undermine the significance of the differences), in the process of normalization we use complex algorithm based on non-linear functions when calculating the ratings for a particular indicator. Table 1 summarizes the complete methodology for calculating of the number of points that a region receives for a specific criteria (indicator).

4) Following the algorithm set by the previous steps, we calculate the DPI results for all the 281 NUTS2 regions in a scale from 0 to 10. The DPI for a particular region is in practice the sum of its points received for each of the eight indicators.

The Danube region within the general European spatial development model

First, on the base of the DPI calculations, we build generalized spatial development model at European level (Dokov and Stamenkov, 2015). The results suggest that the economic "heart" of Europe, the territory with the greatest potential for development and prosperity, lies within the green zone (Fig. 1) where NUTS2 regions' DPI is generally over 5.50. Outside the central/core zone we can also separate relatively easy the semiperiphery from the periphery. NUTS2 regions' DPI results in the semiperiphery are generally from 4.00 to 5.50, while those situated in the periphery have in most cases values under 4.00.

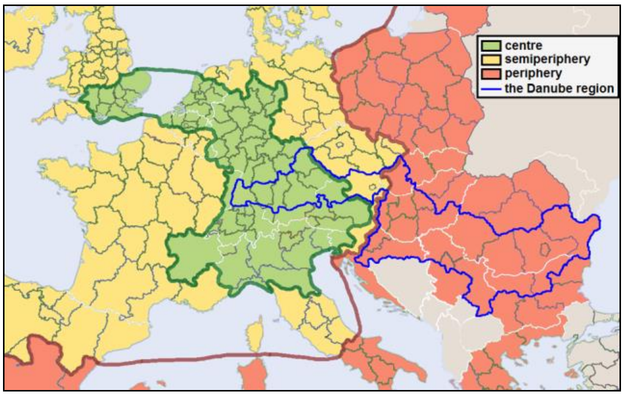

Fig. 1: The Danube region within the general European spatial development model

The Danube region falls into the three different zones, with the larger part of its territory being in the periphery. There are situated the Danube NUTS2 regions of Romania, Bulgaria, Serbia, Croatia, Hungary, as well as Západné Slovensko (Slovakia). The semiperiphery is represented by the regions of Bratislava, Vienna, and Lower Austria, while the central area – only by Upper Austria and the German Danube regions.

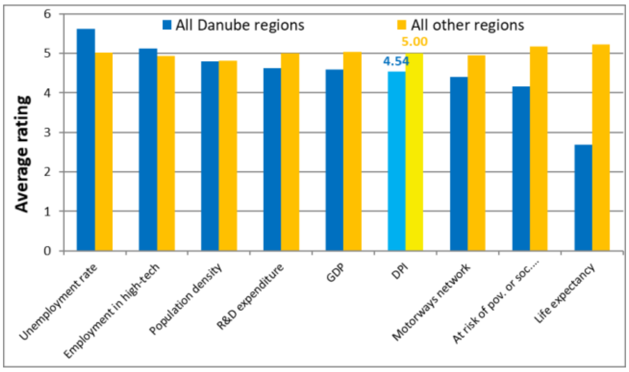

Fig. 2: Comparison between the Danube-adjacent and the other regions' average ratings for the different DPI indicators

Given all that, not surprisingly the average DPI rating for the Danube regions is lower than that for all the regions covered by the study – 4.54 to 5.00. The detailed analysis of the average ratings for each of the eight DPI indicators shows that the Danube regions have advantage only in Unemployment rate and Employment in high-tech sectors, while they significantly lag behind in terms of life expectancy (Fig. 2).

Encompassing 8.87% of the whole studied area (EU + Norway, Switzerland, and Serbia), the Danube region (as defined in our study) is where 9.43% of the total population lives and only 6.78% of the total GDP is produced. That supports the thesis for economic underdevelopment of the Danube region.

Comparison between the Danube-adjacent NUTS2 regions

The DPI for the Danube-adjacent NUTS2 regions varies in a wide range – from 2.49 to 7.46 (Fig. 3). Out of 27 studied Danube-adjacent NUTS2 regions, only two could be classified as regions with European importance (having DPI over 7), three of them are with supranational importance (characterized with DPI between 6 and 7), while at the same time the DPI result for thirteen regions is under 4, thus signifying serious underdevelopment (Table 2).

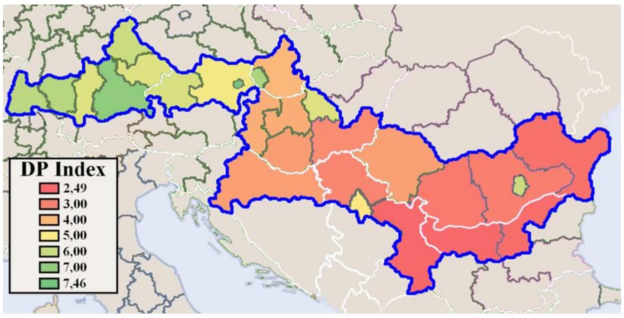

Fig. 3: The DPI results for the Danube-adjacent NUTS2 regions

Table 2: Classification of the Danube-adjacent NUTS2 regions based on the DPI results

group	№ of NUTS2	in countries
over 7	2	Austria, Germany
6 to 7	3	Slovakia, Germany
5 to 6	7	Germany, Romania, Austria, Hungary
4 to 5	2	Serbia, Slovakia
3 to 4	7	Hungary, Croatia, Romania, Serbia
under 3	6	Romania, Bulgaria, Serbia

Despite belonging to the semiperiphery in our general European development model (just because they are spatially isolated from the core area), Vienna and Bratislava are among the regions with the highest DPI results (Table 3). The list of the top five most developed regions is filled out with three German regions – Oberbayern, Tübingen, and Freiburg. On the other hand, the least developed NUTS2 are situated in Serbia, Bulgaria, and Romania, with the bottom two regions severely lagging behind (Table 3). Only the capital regions in Eastern and Central European countries have results that are closer to those of the Western European NUTS2 – Bucuresti-Ilfov in Romania (5.88), Közép-Magyarország in Hungary (5.58), and Beogradski region in Serbia (4.91). The results not only demonstrate convincingly the significant inequalities at NUTS2 level, but also outline eloquently the East-West polarization.

Table 3: Most and least developed Danube-adjacent regions according to DPI

Wien	Austria	7.46	Sud-Vest Oltenia	Romania	2.87
Oberbayern	Germany	7.06	Sud-Est	Romania	2.69
Bratislavský kraj	Slovakia	6.48	Severen tsentralen	Bulgaria	2.61
Tübingen	Germany	6.35	Severozapaden	Bulgaria	2.51
Freiburg	Germany	6.22	Region Južne i Istočne Srbije	Serbia	2.49

At country level, the socio-economic development of the Danube-adjacent regions is very high in Germany, Austria, and to some extent in Slovakia (respectively 6.13, 6.11, and 5.24 average DPIs). Hungary, Croatia, Serbia and Romania have averages between 3.5 and 4, while in Bulgaria the Danube-adjacent regions are in severe crisis clearly attested by the lowest average DPI result – 2.56. To find out the influence of the different indicators for the final DPI ratings, we should analyse each of them separately.

In terms of Regional GDP (measured in PPS per inhabitant) Danube-adjacent regions of Germany (6.49) and Austria (6.45) have a rating higher than the total for the last two countries (Bulgaria and Serbia, respectively 2.56 and 2.78). The third position is firmly occupied by Slovakia (5.95), while the other three countries – Hungary, Croatia, and Romania have ratings between 3.53 and 3.76.

Considering the Unemployment rate, again far ahead are the German and the Austrian regions (rated 7.12 and 6.42). With very good performance (over 5) are characterized Slovakia, Hungary, Serbia, and Romania. The last place in this case is for Croatia (2.47), lagging slightly behind Bulgaria (3.37).

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The best position in terms of Employment in high-tech sectors is for Slovakia (7.14), followed by Germany (6.28) and a little further back by Austria and Hungary – with ratings above 5. Croatia and Romania have averages of over 4, while the ratings for Bulgaria and Serbia are the lowest – respectively 3.49 and 2.74.

The analysis of the Total intramural R&D expenditures (as % of GDP) reveals stunning discrepancies. While the German and the Austrian Danube-adjacent regions reach ratings of 7.48 and 6.65, all the other countries fall heavily behind having ratings below 4, with Romania and Bulgaria – even lower than 3. Similar discrepancies are also typical considering the indicator Life expectancy at birth, which demonstrates to a great extent the differences in the overall living conditions between Western and Eastern Europe.

In terms of People at risk of poverty or social exclusion the leading trio of Germany, Slovakia, and Austria clearly stands out (respectively 7.11, 6.28, and 5.90). The ratings of Croatia and Hungary are 3.65 and 3.51 respectively, while the other three countries are lagging behind with particularly alarming being the situation in the Danube-adjacent regions of Bulgaria (0.60), where half of the population is exposed to such a risk.

The average ratings for the other two DPI indicators (Motorways network and Population density) are more balanced, however in both cases the Austrian NUTS2 regions occupy the first position, while the Bulgarian – the last one. The results of the whole empirical analysis, scrutinizing the role of the different DPI indicators in the separate countries, are summarized in Figure 4.

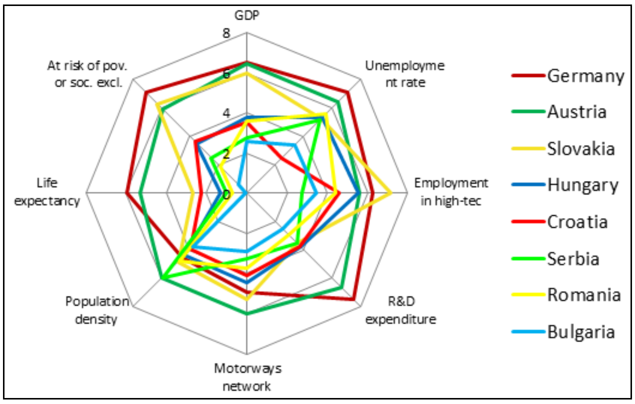

Fig. 4: Danube-adjacent regions' average ratings for the different DPI indicators (by countries)

Analysis of the development within the countries

Our "second level" of analysis is focused on comparing the development of the Danube-adjacent regions against that of the other NUTS2 within a particular country. The general results are presented in Fig. 5. We find out that in all the studied countries, with the only exception of Bulgaria, the Danube-adjacent regions are characterized with better DPI results. Undoubtedly, one of the main reasons is that the capital regions of Austria, Slovakia, Hungary, Croatia, Serbia, and Romania fall within the Danube region. In a view to provide more details about the socio-economic role and the importance of the Danube River, we scrutinize the DPI and its components on country by country base.

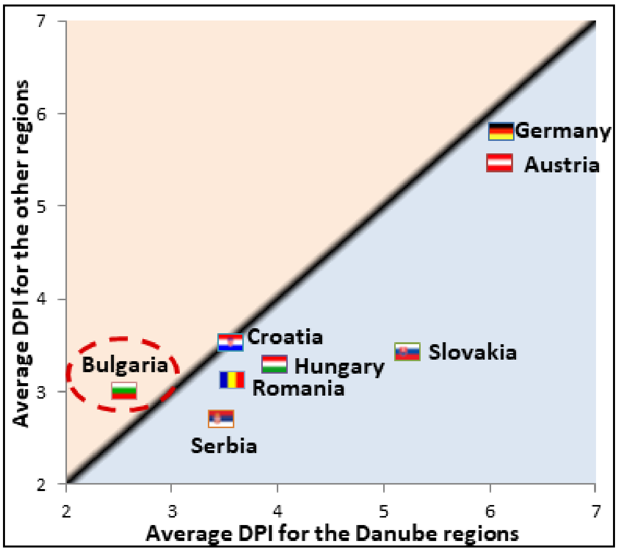

Fig. 5: Comparison between the Danube-adjacent and the other regions' DPI results within the countries

The only indicators where the Danube-adjacent regions of Germany defer to the other NUTS2 are Motorways network and Population density. The coincidence of these NUTS2 regions with some of today's most advanced German territories can be explained with the development of the country after World War II. Nowadays the main socio-economic disparities still remain primary connected with the wealth and income inequalities between former East and West Germany (divided for more than 40 years). For a long time the major economic power was concentrated in the northern parts of the former West Germany where were situated the major ports and stocks of minerals, but that lead to old-industrial specialization (ineffective at later stages), economic and social problems in the 70s and 80s, and need of economic restructuring. On the other hand, the southern regions developed in different way – because of their remoteness from the sea coast and the lack of rich mineral resources, up to World War II these regions were peripheral, characterized with economic indicators below the national averages and with less developed transport infrastructure. The preparations for the war however lead to rapid industrialization and utilization of the Danube Alpine tributaries' hydropower potential. Last but not least, after the 50s development of modern knowledge-intensive sectors was initiated. Today the Danube states of Bavaria and Baden-Württemberg are among the leaders in a number of social and economic indicators.

Although registering a bit higher GDP per capita and greater transportation density, the Danube-adjacent regions of Austria have disadvantages considering some other indicators, such as the Unemployment rate, Life expectancy at birth, and People at risk of poverty or social exclusion. One of the main reasons for the significant concentration of population, transport, and economy along the Danube (almost 60% of the population and the produced GDP) is naturally determined – about 2/3 of the Austrian territory, mainly the southern and western areas, are part of the Alps. The dominance of the Danube-adjacent regions in Austria is to a large extent due to the key role of the capital Vienna, while at the same time many of the cross-border regions of Upper and Lower Austria continue to experience difficulties. Moreover, taking into account for example solely economic indicators (such as GDP per capita), we can disclose certain West-East disparities (richer western provinces such as Salzburg, Tyrol, and Vorarlberg, at the expense of Burgenland, Lower Austria, and Styria).

Slovakia is the country with the greatest difference in terms of complex development between its Danube-adjacent (with average DPI of 5.24) and other (3.43) NUTS2 regions. All the DPI indicators have larger values for the Danube-adjacent regions – in some cases even more than twice higher: GDP per capita; Employment in high-tech sectors; Motorways network; Population density. Regardless of the over-10-year membership in the EU and all European measures and cohesion instruments, disparities between the rich metropolitan region and the other parts of the country continue to worsen. As a result Bratislava has advantages in many indicators even over some Western European NUTS2 regions, while the central and the eastern regions (Stredné Slovensko and Východné Slovensko) are among the least developed in our research.

The Danube-adjacent regions in Hungary have an average DPI result of 3.99 compared to 3.29 for the rest NUTS2. All their indicators have higher values with the only exception being Employment in high-tech sectors. Identifying the regional importance of the Danube on the base of the DPI results, however, is a difficult task because the river passes through five of the seven Hungarian NUTS2 regions. The only two non-Danube regions (Észak-Magyarország and Észak-Alföld) cover the most north-eastern and least developed parts of the country. One of the reasons for their underdevelopment could be sought in the specifics of the historical processes – while eastern Hungary was part of the Ottoman Empire, the western territories belonged to the richer Habsburg monarchy. The sound differences remained largely unchanged throughout the socialist period and even after the political changes in the late 80s the restructuring processes and the economic growth in eastern and north-eastern Hungary were the slowest.

In the case of Croatia, which has only two NUTS2 regions, we can see the greatest convergence of values and DPI results. Again, it is difficult to estimate the impact of the Danube River because it performs mainly border functions, while a number of territorial disputes with Serbia still exist. The greater advantages in favour of Kontinentalna Hrvatska are registered in terms of Employment in high-tech sectors, Total intramural R&D expenditure, and Population density. Once more we can indicate the belonging of the capital to the Danube-adjacent NUTS2 regions as a major reason for those results.

The passage of the river through the northern, more developed parts of Serbia logically leads to a reflection on the DPI results: 3.49 to 2.69 in favour of Danube-adjacent regions. The only indicators where Danube regions have disadvantage are Population density and Life expectancy at birth. The role and the importance of the Danube, however, are difficult to be determined by calculations at NUTS2 level because three of the four Serbian regions fall into the category "Danube regions" with only one left to be used as counterbalance in the comparative analysis (excluding the disputed area of Kosovo and Metohija).

Owing to the assignment of Bucuresti-Ilfov to the Danube NUTS2, similar is the situation in Romania: 3.59 to 3.12 DPI average ratings in favour of the Danube-adjacent regions. All the indicators (with the only exception of People at risk of poverty or social exclusion) are more favourable in these regions, with particularly large disparities registered in Motorways network (11 times higher) and Population density (4 times higher). However, aside from Bucuresti-Ilfov and Vest, the other three Danube-adjacent regions of Romania are among the least developed NUTS2 in all the studied countries. These regions are generally characterized with predominance of the agricultural sector, low stock of foreign direct investments, difficulties in restructuring of the economy, massive labour migration, and other negative socio-economic trends.

Taking into consideration that the Danube serves as a Bulgarian state border in the northern, underdeveloped parts of the country and that the metropolitan agglomeration does not fall into the

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Danube NUTS2 group, the better average DPI result for the other regions (3.01 to 2.56) is no surprise, making (as mentioned above) Bulgaria the only exception in this comparative analysis. Moreover, the Danube-adjacent NUTS 2 regions practically lag behind in all eight DPI indicators. The problems in these areas started in the socialist period and then deepened after the political changes in Eastern Europe. As a result nowadays these peripheral for the country regions are among the poorest in the whole EU. The relatively weak utilization of the Danube and its potential is the reason why the river continues to perform basically boundary functions and why it is still more a natural barrier than a bridge for cross-border cooperation between Bulgaria and Romania.

Conclusion

Building author's methodology and index (DPI) to assess the complex socio-economic development in Europe, we provide solid evidences for the existence of significant discrepancies that spread far behind single indicators. After conceptualizing a thorough spatial development model at European level, the study emphasizes on the key role of the Danube region, whose territory falls within the three major zones of our model – centre, semiperiphery, and periphery. The in-depth analysis of the Danube-adjacent NUTS2 regions suggests that the traditional dichotomy "rich Western Europe – poor Eastern Europe" is also observed at this level. Concentrating on the development patterns within the separate countries, we discover that in seven of the eight studied cases (with Bulgaria being the only exception) the average DPI results for the Danube regions are higher than those for the other NUTS2 in the given country. That is to say that the Danube regions are extremely important for the development of the countries and have huge potential in serving as "motors" of long-term sustainability. Moreover, the results provide clues that the Danube region itself could turn in the future into a key for the whole Europe economic zone. Our findings provide solid ground for building up adequate future policies and development strategies, as well as for overcoming some of the major problems standing on the way of the Danube region.

Author contribution

Hristo Dokov was primary responsible for the design of the methodological framework and for the processing of the statistical data, while Ivaylo Stamenkov was in charge of conducting literature overview and of interpreting the empirical results. Both authors contributed in the design of the thorough spatial development model at European level, as well as in summarizing the final results and conclusions.

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Time-spaces in Hungary

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Abstract

This paper firstly gives a general outline about the features of various spaces. Time spaces and cost spaces have non-metric characteristics, moreover, time spaces and cost spaces are not continuous. Therefore, topographic maps are not always an appropriate basis for cognitive information processing, the everyday behaviour and the study of spatial relationships. The paper demonstrates the differences between geographical space and time-spaces at two different scales, such as the road network time-space of Hungary and a district of the capital city Budapest. With the first example the rapidly changing Hungarian time-space during the last two decades can be vividly demonstrated, thanks to new motorway construction. The second example compares different types of space, as for example the difference between the time- space of a pedestrian and a vehicle.

Keywords: *distances, spaces, time-space, public road traffic, maps*

Raportul spațiu-timp în Ungaria

Rezumat. Această lucrare oferă în primul rând o schiță generală despre caracteristicile diferitelor spații. Conceptele de spațiu-timp și cost-spațiu au caracteristici nemetrice, în plus, spațiu-timpul și cost-spațiul nu sunt continue. Prin urmare, hărțile topografice nu sunt întotdeauna o bază adecvată pentru prelucrarea informațiilor cognitive, pentru comportamentul zilnic și pentru studiul relațiilor spațiale. Lucrarea demonstrează diferențele dintre spațiul geografic și raportul timp-spațiu la două scări diferite, precum spațiu-timpul rețelei rutiere din Ungaria și a unui district al capitalei Budapesta. În primul exemplu, spațiu-timpul maghiar care se schimbă rapid în ultimele două decenii poate fi demonstrat în mod clar, datorită construcției de autostrăzi noi. Cel de-al doilea exemplu compară diferite tipuri de spații, de exemplu diferența dintre spațiu-timpul unui pieton și al unui vehicul.

Cuvinte-cheie: *distanțe, spații, timp-spațiu, trafic rutier public, hărți*

Introduction

Human communication would be significantly poorer without visual communication. One of the basic tools of visual communication is the map, the graphical representation of spatial objects and relations. The most important role of topographic maps is the localization. This aim is attained by giving the scale and grid, the proportionate representation of geographical distance and by the help of a legend and verbal supplements. However, both everyday experiences and a long tradition of analysis of spatial phenomena teach us that the real obstacles of spatial mobility are not always connected to air distances, but they are proportionate with time distances and cost distances. Thus maps are of great help in localization, first of all for those people, who do not have direct experience in the area in question. At the same time, maps can suggest a deceptive view about the real obstacles of surmounting the distance between various points, if the proportions between air distances and time distances are significantly different and can serve as a misleading basis for cognitive information processing, everyday behaviour and the study of spatial relationships (Muller, 1982).

The aim of this paper is to present two examples for the time-space in Hungary and discuss the differences between geographical and time distances and refer to the specific characteristics of cost distances too. In the first section, the general characteristics of distances and spaces will be given. Then the geographical space and time and cost spaces will be compared. After this, the visual representation of time-spaces will be dealt. In the second section two examples of time-space maps are given. The first of them concerns the road network time-space of Hungary and the second one to one district of Budapest. With the first example the rapidly changing Hungarian time-space during the last two decades can be vividly demonstrated, thanks to new motorway construction. The last two maps compare different types of space, as for example, the difference between the time-space of a pedestrian and a vehicle. With the help of the maps we can visualize that the time influenced cognitive maps too. These examples were made with an own programmed algorithm, which is capable of modifying the structure of DXF files. These files contain the original-normal space co-ordinates which are modified by the program.

The basic concepts of time-spaces

Distances and spaces in general

The concept of distance and space are the central categories in all spatial research. In this paper it is not necessary to dwell long on the various concepts of space. For a detailed discussion, see for example Gatrell (1983) or Smith (2004) and about the visual representation of various spatial relations the path-breaking works of Waldo Tobler (Tobler, 1961, Tobler, 1963). However, it is important to stress that it is both impossible and unnecessary to give a general concept of space. The definitions of space face the problem either to substitute an intuitive well understandable notion with a sentence containing dimmer notions or to give a well understandable but specific meaning of space. It is much better to treat the space as an undefined basic notion which may have different shades of meaning in different contexts. The various concepts of space, such as absolute space, relational space, mathematical space or space as a Kantian a priori idea have reason to the existence in different contexts too and no one can be treated as an absolute or exclusive definition. However, it is a strange situation when for example the absolute space view of Euclidean geometry is challenged and criticized from the point of view of relativity theory. The discussions about the notion of space are justifiable just like a discussion about the proper use of the notion in different situation.

The shortest ways between the points of a network generate the space of transport network, the shortest (or average) time which is needed to reach from one point to another creates the time-spaces, the lowest (or average) cost which is needed to reach from one point to another that forms the cost spaces. The order of enumeration of different spaces corresponds to the order of their calculability. Firstly, the space of transport network has to be calculated. Then, knowing the physical characteristics of the network, time-spaces (for example time-space of public transport, individual transport, carriage) can be determined, and at last the various cost spaces can be identified. The shortest route between two points can be different in physical sense in various spaces, for example, using the motorway, the time can be shorter but the distance in kilometres can be longer and the monetary cost can be higher than other possible routes.

The operationalisation of time-space can be extremely difficult in any real situation, if schedule effect has to be taken into consideration or mode of transport changes are allowed (Erlandsson, 1982, Forer, 1974, O'Sullivan et al., 2000). In railway traffic, high speed trains operate typically only between pairs of large cities, with the consequence of spatial inversion: closer places in geographical space without fast train stops can be farther in time-space (L'Hostis, 2013). The different types of trains (stop trains, fast trains, Intercity or high speed trains) have to be joined when someone wants to travel from a small location to a farther bigger centre or back (see examples for this in Kotosz, 2007).

The complexity, time stability and other characteristics of various spaces are very different (Table 1).

Table 1: The various characteristics of different spaces

Type of space	Distance space	Time-spaces	Cost spaces
Complexity	Low	Medium	Large
Speed of change	Slow change	Rapid change	Permanent and very rapid change, loose structure
Types of change	Abruptly when a new element of network is implemented	Abruptly when a new element of network is implemented or the changing quality of network; continuously because of changing transport means; daily and weekly oscillation (due to rush-hour traffic and schedule)	All types of changes of time-spaces; Changing due to the vehicle operation costs and cost structure of transport, parking facilities, road safety and so on
Information	In principle perfect information about the space, In practice there can be imperfections	Non-perfect information	Non-perfect information
Calculability	In principle unambiguous and only one possible result; In practice there can be uncertainty	The result is method dependent and can only be treated as an estimation	The result is strongly method dependent and can only be treated as an estimation
Objectivity	Objective	Intersubjective and subjective	Intersubjective and subjective

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Network distance spaces, time-spaces and cost spaces can be grounded on homogeneous and separated network (for example only public road or railroad) or on a combination of many different networks. The complexity of the latter is of course significantly larger than the homogeneous networks. An extra complication arises in the case of cost spaces due to the inclusion of non-pecuniary costs. Speed and types of change are also different. For example, transport network spaces always change abruptly when a new element of network is implemented. Time-spaces and cost-spaces always change when network space changes, but they can also change on a daily or hourly basis. However, we don't have perfect information about this: the information of costs and times is dispersed among the members of society and it is impossible to concentrate it. The alteration of network space goes hand in hand with alteration of time-spaces and cost-spaces, but time-spaces and cost-spaces can also change when the network is unaltered.

There is just one and only one air kilometres and the kilometre distance between points of network can be determined more or less exactly. However, the time distances and cost distances fall into an interval and at best only about typical or least distances, typical or least lengths of time and typical or least costs can be spoken about. This is the first reason why we use the plural form, writing about time spaces and cost spaces. The other reason for the plural form is the different modes and types of networks on which the calculation can be grounded.

One of the previous readers of this paper told us, that the label "time spaces" should be reflected in a more careful way, because from a post-Bergsonian and post-Heideggerian perspective our approach can be disputed. However, we do neither deal with the space-times of decision making (see the guest editorial by McCormack and Schwanen, 2011 about this), nor with various philosophical concepts of time and space and with fruitless metaphysical concepts, nor with the psychological questions of space-time decision making, but only with the more or less measurable travel time.

Comparison of geographical space and time and cost spaces

Geographical space is continuous; each point of a topographic map can be interpreted as an element of space. However, the time and cost spaces contains nodes and lines. The geographical space has metrical characteristics; these axioms are true:

1. The distance between two points is zero if and only the two points are identical (the separation axiom).
2. The distance between two points is positive if the two points are different.
3. The distance from point A to point B is identical to the distance from point B to point A (symmetry axiom).
4. The distance from point A to point B cannot be larger than the sum of the distance from point A to point C and the distance from point B to point C (axiom of triangle inequality).

The first two axioms are also valid in time-spaces. Points which are different in geographical space, will be different in time-spaces too, because time is necessary for surmounting distance (apart from the special case of some type of telecommunication). In time-spaces, the following problem arising in connection with the first two axioms: an operational method must be given that permits us to identify the points themselves. Allocating the points of a network can be a vivid question in practical research. The validity of the first two axioms in the cost spaces is a more complicated question. The cost distance between two points can be zero if the two points are different because of the pricing policy of entrepreneurs.

Symmetry axiom is valid neither in time spaces nor in cost spaces. In the case of individual transport in cities, one way streets, the direction dependency of traffic and the vertical differences of roads invalidate the axiom. The axiom is not valid even in intercity traffic, but the differences between the directions are smaller than in intra-city transport. Flying time can also be different because of the dominant direction of wind (for example between Europe and North America). The time space of hitchhiking is also direction dependent: thumbing from small settlements to big centres is significantly easier and faster than hitchhiking from big centres to small settlements (see further examples in Halmos, 1990). In the case of time-space of public transport, the differences are also larger between directions as in the case of individual transport. As regards to the cost spaces we do not go into details, but there are several examples for direction dependence of costs (See for example in Cariou, Wolff, 2006, Jonkeren et al., 2008, Takahashi, 2011).

The triangle inequality axiom is valid in individual transport but it is invalid in public transport due to the dead time of change transport means or due to the different speeds of different lines (Figure 1). The triangles of geographical space are not identical with the triangles of time spaces and cost spaces: the former one is based on air distances, the latter one is based on time distances and cost distances, which can be distorted thanks to uneven density of network systems, the route sinuosity and different maximal or average speeds on different elements of the network, and because of the change between network subsystems.

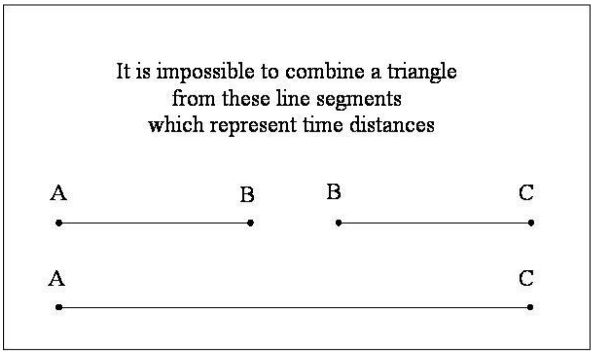

Fig. 1: The invalidity of triangle inequality in time-space

Data and methods

The visual representation of time-spaces

Along with the improvement in the technological conditions of transport, as well as in conjunction with their axial concentration, the time needed for access and the differences in accessibility times have become the main indicators of accessibility. As a consequence, the geographical space and the time-spaces have increasingly diverged; the relationship between space and time has substantially changed.

The traditional maps turned out to have a limited capacity to describe and represent this new relationship since geographical distance could no longer be an explicit measure of accessibility time. To solve this very problem, time-space maps were developed, of which we may distinguish two major types:

1) The "traditional" isochronal maps can describe time-relations in addition to retaining geographical distances, that is, they connect points from which a certain single other point can be reached within the same amount of time. Editing these maps has become considerably simpler since the spread of Geoinformatics programs; the use of interpolation permits the creation of isochronal maps even from a relatively small amount of data. Their application has become increasingly widespread and can be found in studies on transport history (Czére, 1991) as well as in models forecasting the impacts of network development (Hardi, 2000, Szalkai, 2003, Tóth, 2005).

2) The other major group of maps illustrating time relations are the so called "time-space maps". In this case, the distances indicated do not correlate with the actual geographical distances but with the accessibility times between two points. This means that two points between which the distance can be covered in a shorter time will be indicated closer to each other on the map than those two points which require more time to reach one another.

Furthermore, there are two sub-types within the time-space map category according to the number of relations between points:

- the "simple" time-space maps with n-1 relations, in which time distances are designated in relation to a single central point (Clark 1999, Vasiliev 1997). Other names of such time-space map are time-distance map, central-point cartogram, central-point linear cartogram, distance-by-time cartogram, distance cartogram (Vasiliev 1997, p. 14);
- the deformed time-space maps with n*(n-1)/2 relations (see Marchand, 1973; Ewing, 1974; Murayama, 1994; Spiekermann and Wegener, 1994; Gatrell, 1983, pp. 81-101; Axhausen and Hurni, 2005; Thévenin et al., 2013), where the relative locations of points are determined and represented based on the time-distances between each and every point. Another name for these maps is anamorphosis (deformed in Greek) maps. The naming is deceptive in a way, because these maps represent a deformed or distorted space only compared to the geographical space but it is not deformed from the point of view of represented space, namely the time-space.

Creating time-space maps is methodologically and computationally rather complex and requires a huge amount of data and calculation. The interpretation of these maps is not simple either, especially for the deformed time-space maps. However, after some sufficient "training" one can read information from them that is not obtainable elsewhere.

The difficulties mentioned above are the main reason for the fact that time-space maps have spread much less extensively than isochronal maps. Isochronal and time-space maps have a common feature, namely that accessibility relations can be retrieved from them only by taking the position of a selected centre. This means that the accessibility times between the rest of the points cannot be read from either map types.

As a third category, Spiekermann and Wegener (1994) also include cognitive maps – those which express subjective observations of the world – among the maps representing time relations. One of the major differences between cognitive maps and the two types described above is that the content of the former depends on the person, i.e. it is not objective or intersubjective, and there is no mathematical method for deducing the "real" space from them.

However – although the way different observers perceive the flow of time has an undoubtedly important role in the emergence of cognitive maps – cognitive maps cannot be unequivocally included among time-space maps since their making is influenced by several other conditions independent of the time factor.

Research database and methodology

After introducing the basic concepts, own maps will be shown which help comprehend the time-space problem, as well as to work out a methodology best fitting with our initial data. In all cases, our maps represent time-spaces that are related to single centres.

We have carried out our analyses on two different spatial levels. Beyond the spatial structure distorted by time, we have also managed to show the dynamics of change. In the case of Hungary, we illustrate the outcomes of the motorway network development during the historical period from the socio-economic and political system change to the present. The dominant feature of which has been the significant extension of the initially under-developed highway network and the consequent "shrinkage" of the national time space. In the case of the southern part of Budapest-City, we identify the differences between the pedestrian and the car traffic time-spaces.

The most complicated tasks in the analyses were:

- the production of the geometrical and attributive (accessibility) data, as well as rendering them together;
- and designing the methodology for recalculating the original map co-ordinates into time-space co-ordinates.

At the beginning of our research, the geometrical data (the digital maps) were already partially available; and we could make up for the missing data by digitalization. Furthermore, in our previous research, we had developed a data matrix of Hungarian municipalities and their accessibility on public roads with our own methods, and this was also available to us after having updated it for the purpose of the new analysis. Regarding the southern part of the City, we relied entirely on our own empirical data collection, and we took the average of our measurements as the norm in calculating time distances of pedestrians and cars in the area.

Having calculated the time distances, we assigned geographical coordinates to all points in the projection system which complies with that of the digital map databases. This way we could determine the time distances to the nearest municipalities from every breaking-point of the digital map objects; and so after solving a programming task it became possible to recalculate the original map coordinates into the new time-space coordinates defined by the time distances.

The designated central points and the vector defined by the destination points provided the basis of the analysis. The size of the vectors was modified according to the lengths of the time distances. This way we could ensure that the original directions between the central and destination points were not changed, whereas the values of geographical spatial distance were replaced by values of time distance.

While mapping the time-space of Hungary, we considered it to be necessary to indicate county borders, since they are well-known original topographic objects. With their help the visualization of the time-spaces could be much more spectacular than if relying merely on mapping the most important municipalities. Using a bar scale, we also show the absolute time distances on the maps. Obviously, these distance-ratios, as a consequence of the methodology, can assist in determining the time-distances only between the central point and the other points. We did not calculate any rate of space-time convergence which concept was introduced by Janelle (1968, 1969) and calculated for example by Carstensen (1981) too. If this concept were theoretically interesting, two points of time would be insufficient for calculating any trend. However, space-time convergence is obviously not a theoretical hypothesis with constant rate in space and time but a historical and empirical fact if it can be observed in various transportation modes. The economic and social effect of the changing accessibility is a more interesting and important question (See for example Clark, 1999; Janelle and Gillespie, 2004; Haugen, 2011).

Results and discussion

The time-space map of Hungary

The time space map of Hungary has been prepared according to the conditions of the public roads network at two different times. The conditions in January 1990, at the time of the system change are compared with the state of the network in October 2017. This makes it possible to also assess the developments in the time period since the political system change.

As a basis for comparison, Figure 2 shows the topographic map of the county-level division of Hungary; the time-space of the public roads network in October 2017 is demonstrated in Figure 3; and Figure 4 simultaneously illustrates the time-spaces in 1990 and at present. Administrative borders and the speed values used in calibrating the model reflect the conditions of 2017.

The last two maps (fig. 3 and 4) do not need much further explanation: they illustrate very clearly the main network development tendencies of the last 19 years. The maps created with Budapest as their central point, show the time distances between the capital and all other municipalities.

The shrinkage of the time-space of Hungary has been primarily influenced by the construction of the motorway network. The position of the county borders situated closer to Budapest has not changed significantly since the motorways had already reached out to most of them by 1990; the only completely new route opened has been the road no. 2/A to Vác (north of Budapest), which has brought the western part of Nógrád County (in northern Hungary) closer to the capital.

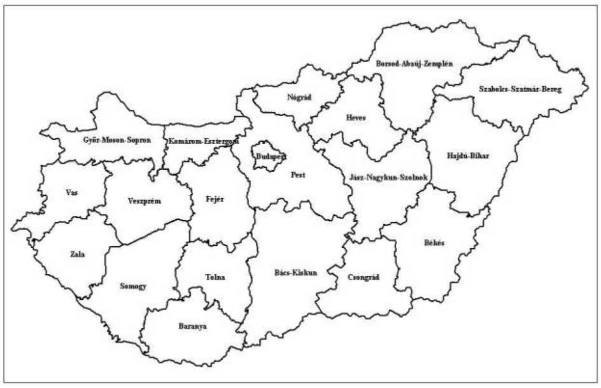

Fig. 2: The counties of Hungary

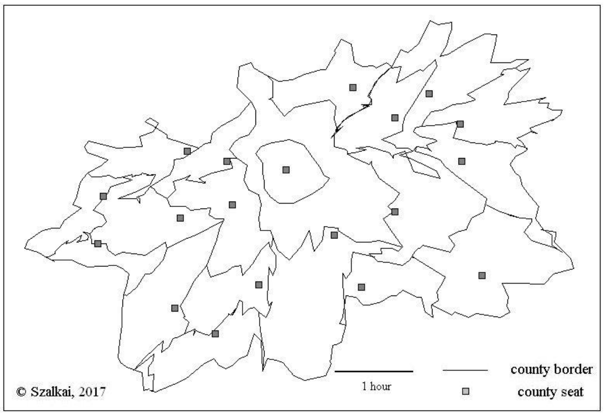

Fig. 3: The public roads time-space of Hungary (calculated from Budapest, October 2017)

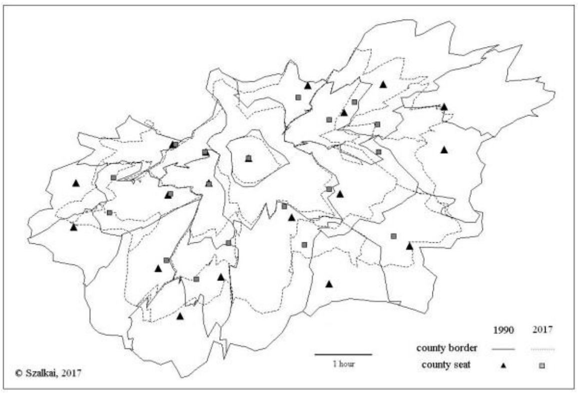

Fig. 4: The public roads time-space of Hungary (calculated from Budapest, January 1990, October 2017)

More visible changes can be observed concerning the county borders and parts of the national border which are situated further away from Budapest, and especially within the impact zones of the new highways, which have "pulled in" the three "compressed" eastern most counties as well as the south-eastern Csongrád County towards the capital city. The shifts in the locations of certain county headquarters and the unchanged positions of some others are also very indicative.

Nevertheless, in certain regions there has been very little or no observable change. This fact leads to the change of relative positions of the various regions in time-space. The continuing "remoteness" of Baranya and Tolna in south Hungary indicates a persistent lack of motorway network connections in these counties; while for instance, the unchanged position of the region of Salgótarján is an indication of a sufficient provision of public roads existing there already in 1990. It is also very demonstrative how the size of Budapest has grown in time-space due to the increased time demand of transportation within the city.

Another obvious phenomenon is the higher-than-average degree of zigzaggedness of certain county border sections. The direct cause of this is a situation where two settlements are located on the two sides of a county border in a more or less equal distance from the latter, and so the coordinates of one point of the borderline are adjusted according to the time distance of one of those two municipalities, and the coordinates of the next point change in proportion to the time distance of the other municipality.

While in the sparse settlement system of the Great Plain the substantial (straight-line) distances between municipalities already explains this degree of zigzaggedness, in certain Transdanubian regions the phenomenon can be attributed to the lack of connecting roads between neighbouring municipalities. The cause of the latter is that the municipal boundaries are historically running along higher watershed ridges in this region, and for this topographic reason, even today, they are not reached by paved roads everywhere.

To sum up, the general tendency indicated by the map-pair above has been a shrinking time-space with a rather strong regional variation. However, this shrinkage is less significant if the calculations are not based on Budapest as a centre. If we analyse the modification of the time-space for the same time period but choosing another centre than the capital city, the degree of shrinkage will be less due to the fact that network expansion has been centred on the capital.

The time-space map of the southern part of Budapest City

The time-space mapping of the southern part of Budapest-City brought the most spectacular results, yet at the same time, they are the most difficult to interpret. Several papers describe the reasons of the wide deviations from the straight-line paths (Angel-

Hyman 1970, Muraco 1972, Muller 1978, Ahmed-Miller 2007).

The example region is a well-known one in Hungary. Its selection was justified by the fact that it includes streets with both pedestrian as well as mixed traffic. Thus it could be assumed that the results of the analysis will be suitable to demonstrate the various potentials of the applied methodology and can be generalized to networks with one-way streets and other obstacles for car traffic. As other papers examined the difference between accessibility by car and public transport (see for example Kawabata, 2009), this examination focuses on the difference between pedestrian accessibility and car accessibility. The results can provide useful information about urban spatial structure too.

The time-spaces of the pedestrian and the car traffic flows were featured separately in our analyses. The Church of Saint Michael (or the Church of the Mary Ward Nuns, "Angolkisasszonyok") in Váci Street was chosen for the centre. Control points representing distinct objects in real geographical space help the orientation in the map.

Measuring intra-urban travel times for large number of street links would be a challenging task. A detailed overview of various methods used in different researches in Weber-Kwan 2002, and a more recent study by Salonen and Toivonen (2013) about the modelling travel time in urban networks. As in the latter paper can be read, "comparing the accessibility provided by different travel modes and identifying modal accessibility disparities can provide a useful approach in assessing the degree of auto-orientation in the urban structure" (Salonen – Toivonen, 2013, p.143).

In our research the measurement was manageable by personal experience therefore travel times were established by means of our own experience and observations in both cases (i.e. for pedestrian movement and the car traffic). In the case of cars, however, we had to take into account that one-way streets could be network components only as long as they were regarded as directional, vector-dependent elements of the graph, and pedestrian streets had to be left out entirely from the system. For more accuracy, we also measured the red and green signal lengths of the traffic lights found within the studied area, and we added the stop signals to the network as "traffic resistors" after having weighted them with their durations.

Figure 5 shows the topographic picture of the southern part of Budapest City. Figure 6 depicts the structure of its pedestrian time-space; and Figure 7 represents the car traffic time space of the same area.

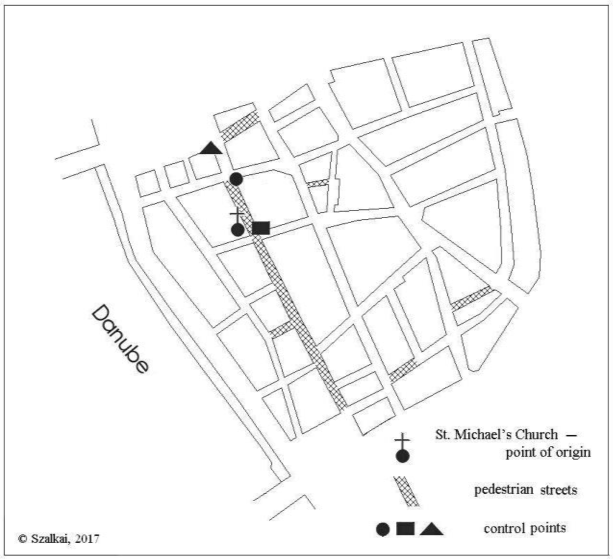

Fig. 5: The southern part of Budapest City

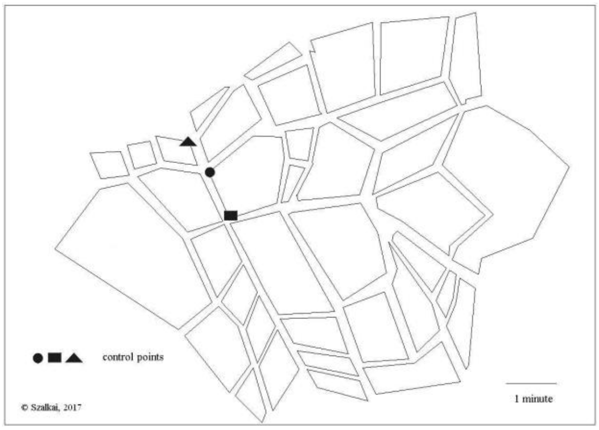

Fig. 6: The pedestrian time-space of the southern part of Budapest City

The time-space map in Figure 6 reflects well the "unrestricted" movement of pedestrians, i.e. the largest elongations can be traced at the longer, continuous housing blocks, which force the walker to make extensive detours, and thus considerably increase time distances. Of course, due to certain methodological features this distortion does not entirely come to surface since these blocks are digitalized only by their four corner points.

Unlike the rather harmonious picture of the pedestrian time-space, the image of the car traffic time-space can even be a bit alarming at a first glance, suggesting some sort of miscalculation. However, there is no mistake: it is the pedestrian streets, the one-way streets and the proximity of the Danube that upset the previously much clearer structure. In contrast with the pedestrian case, symmetry axiom is not valid in the car time-space. The figure is depicted according to time distances from the centre. The picture would be different with the time distances to the centre.

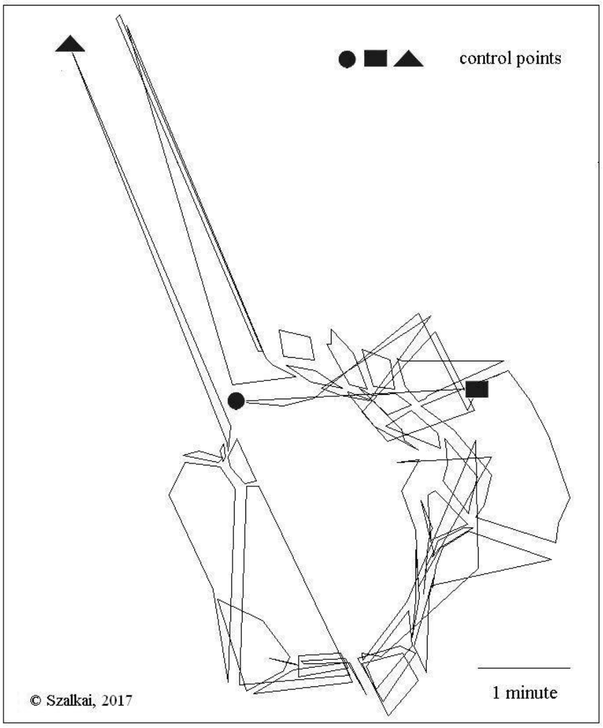

Fig. 7: The car time-space of the southern part of Budapest City

The most important feature in the map is the crescent-shaped, blank arc of the central sector. The reason for this is the pedestrian zone of Váci Street, which prevents car traffic from crossing it almost along its length entirely. Hence there is the paradoxical situation that one has to go around "half of the city" by car to get from the Church just to the opposite corner. This is how the reversed order of accessibility literally turns the blocks along the eastern side of Váci Street "inside out": their side that is closer in real geographical space turns up on the more distant side in the car traffic time-space.

The striking elongations in the northern section of the map are also interesting to observe. Their cause is similar to the facts mentioned above, though here the direct reason is the one-way streets that practically divide the road network of the area into two. This can be seen for instance when one tries to get from the Church to the ramp of Erzsébet Bridge by car, which can be done only by crossing the Danube twice. This major detour results in the extreme extension of time distances and the consequent high degree of distortion in the time-space map. While traveling ten minutes by car instead of walking ten seconds does not seem rational in most cases, this phenomenon shows that various spaces can be radically different from each other.

Conclusions

Economically and socially relevant spaces have a more complex geometry than geographical space. Some reasons for this thing were mentioned in the paper. There is not only one time and cost distance and the information about time and cost spaces is scattered among the members of society.

As the difference between the proportion of geographical distances and time and cost distances get larger, their visual representation become more complicated. This can be observed in the second example of the paper. It is necessary to select some aspects of the spatial relations for their effective visualization, because non metric spaces cannot be completely depicted in two dimensions. However, their visualization is an effective way of both the communication and the emphasis on the importance of differences between geographical space and time and cost spaces.

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