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A review of recent studies on heat wave definitions, mechanisms, changes, and impact on mortality

Adrian PITICAR[1*], Sorin CHEVAL[1, 2], Maria FRIGHENCIU[3]

[1] Faculty of Aeronautical Management, Henri Coandă" Air Force Academy, 160, Mihai Viteazul Street, Brașov, Romania
[2] National Meteorological Administration, 97, București-Ploiești Street, Bucharest, Romania
[3] Faculty of Sciences, Department of Geography, University of Craiova, 13, Alexandru Ioan Cuza Street, Craiova, Romania
* *Corresponding author*: adrian.piticar@gmail.com

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Abstract

Heat waves (HWs) represent a major danger to society and natural environment. The increasing occurrence of high magnitude and impact HWs has raised concerns worldwide and has attracted an increasing interest on this issue among climatologists over the past decade. In this review the research from 2007-2018 period on HWs definitions, driving mechanisms, present changes, future changes, and impact on human mortality is summarized. By reviewing the recent literature, it was found that whilst the atmospheric dynamic is considered to be the primary driver in HW occurrence, the sea surface temperature (SST) and land surface conditions are also essential driving components. The vastness of HW-definitions raises difficulties in selecting the appropriate methodology to identify heat episodes and to compare results from studies which used different definitions. However, by analyzing a sample of 109 papers, a preference for percentile-based definitions was observed. Therefore, 71.6% of the analyzed articles used only percentile-based definitions to identify HWs. Despite the wide variety of definitions, the analysis of changes in HWs converged to similar results. Thus, the existing recent literature provided extensive evidence of significant increase in HWs characteristics across large regions of the planet. Available scientific literature indicated that HWs have been responsible for a considerable increase in mortality in many regions of the world. In the future HWs are predicted to increase in their main characteristics leading to a greater impact on human mortality. Nevertheless, the implementation of rigorous adaptation measures can mitigate the negative impact on mortality. In conclusion, it was noted that a substantial progress has been done in the HW research, but there are still important gaps in this issue which need to be addressed.

Keywords: *climate change, extreme temperatures, heat wave, excess heat factor*

Rezumat. O revizuire a studiilor recente privind definițiile, mecanismele, schimbările undelor de căldură și impactul asupra mortalității

Valurile de căldură (HWs) reprezintă un pericol major pentru societate și mediul înconjurător. Creșterea frecvenței HWs cu magnitudine și impact ridicate a generat preocupare la nivel global și a atras interes asupra problemei în rândul climatologilor în ultimul deceniu. În articol sunt inventariate studiile realizate în perioada 2007-2018 privind definiţiile HWs, factorilor declanșatori, schimbărilor prezente și viitoare și impactul asupra mortalității. Prin inventarierea literaturii de specialitate recente, a fost evdențiat că deși dinamica atmosferei este principalul factor generator al HWs, temperatura apei de suprafață (SST) și condițiile date de suprafața terenurilor sunt de asemenea factori generatori importanți. Diverstatea definițiilor atribuite HWs determină dificultăți în selectarea unor metodologii potrivite pentru identificarea fenomenelor respectve și compararea rezultatelor unor studii care utilizează definiții diferite. Totuși, analizând un eșantion de 109 lucrări, a fost observată o preferință asupra unor definiții bazate pe percentile. Așadar, în 71.6% din articolele analizate au fost utilizate doar definiții bazate pe percentile pentru identificarea HWs. În ciuda marii varietăți de definiții, rezultatele analizelor au fost similare. Astfel, literatura recentă furnizează dovezi ample care atestă o creștere semnificativă a caracteristicilor HWs pe suprafețe extinse ale planetei. Literatura științifică indică faptul că HWs au fost unul dintre factorii responsabili pentru creșterea mortalității în multe părți ale lume. În viitor este anticipată o amplificare a caracteristicilor HWs, conducând la o creștere a impactului pe care acestea îl vor avea asupra mortalității. Cu toate acestea, prin implementarea unor măsuri riguroase de adaptare, poate fi diminuat impactul negativ care conduce la mortalitate. În concluzie, a fost remarcat faptul că s-a realizat un progres substanţial în cercetarea HWs, rămânând însă lacune importante care necesită abordare.

Cuvinte-cheie: *schimbări climatice, temperaturi extreme, val de căldură, factorul excesului de căldură*

Introduction

Over the last decade heat waves (HWs) received increasing attention from climatologists. Thus, a large number of climate studies focused on analyzing these events. The main aims identified in these studies were understanding the mechanisms and synoptic conditions behind HW occurrence and persistence, analysis of changes in their main characteristics (frequency, duration, intensity), and assessing the impact on mortality. The majority of these studies found important changes in the frequency, duration, intensity, and other indices related to these parameters (Perkins et al., 2012; Perkins and Alexander, 2013; Acero et al., 2017; Allen and Sheridan, 2016; Ceccherini et al., 2016; Ceccherini et al., 2017; Panda et al., 2017; Piticar et al., 2017;

Zhang et al., 2017a). It was estimated that as global warming progresses these changes will continue at even higher rates in the future. Therefore, we can expect HWs that are more frequent, longer, and more intense. This can have serious negative consequences on society. Zacharias et al. (2015) estimated that more frequent, longer, and more intense HWs may kill 5 times more people from ischemic heart diseases by the end of the century compared to the present. However, if 50% acclimatization approach will occur, excess mortality will be attenuated to a factor of 2.4 (Zacharias et al., 2015).

The abundance of HW studies in the last years could have been triggered among devastating high impact events such as that of the summer of 2003 (with estimated heat related deaths varying between 25000 and 70000 in Europe) (D'Ippoliti et al., 2010; Amengual et al., 2014), or that of 2010 in central Russia in which exceptional heat and poor air quality due to wildfires led to a high death toll (Dole et al., 2011). Another example, is the extreme HW of the summer of 2008/2009 in Australia which was followed by the most devastating bushfires in the Australian history (Perkins-Kirkpatrick et al., 2016). Moreover, a record-breaking persistent HW spanned over the Australian continent was unprecedented spatially and temporally lasting for seven consecutive days with maximum temperature above 39 °C and setting a new national temperature record of 40.33 °C (Perkins-Kirkpatrick et al., 2016).

The increasing occurrence of high magnitude and impact HWs in the last two decades (e.g. Europe in 2003, southern and southeastern Europe in 2007, Australia in 2009, and Russia in 2010) has raised concerns worldwide and has outlined the importance of understanding present changes and predicting future changes of these events. Anthropogenic influences played a leading role to their magnitude, forcing HW trends towards unprecedented rates of increase (Weaver et al., 2014; Perkins-Kirkpatrick et al., 2017). For instance, Australia's HW frequency and intensity during the 2012/2013 summer increased by two and three fold due to anthropogenic greenhouse gas emissions (Perkins-Kirkpatrick et al., 2016).

Extended periods of unusually high temperature are stressful to biologic systems. HWs have a negative impact on plant growth and development; they can damage plants, and cause illness or even death to animals and humans (Anandhi et al., 2016). A significant relationship between certain HW parameters and human mortality was observed in many parts of the world Son et al., 2012; Ma et al., 2015; Dong et al., 2016; Lee et al., 2016; Guo et al., 2017a).

Such events have also many ecological, hydrological, and socioeconomically negative consequences (Liu et al., 2015; Anandhi et al., 2016). For instance, HWs can induce changes in the growing season, milk production, and have implications on the water cycle and its quality (Liu et al., 2015; Anandhi et al., 2016). The number of HWs was found to be significantly correlated with the fire occurrences in western Turkey (Unal et al., 2013). In terms of regional distribution, the number of fires had slightly higher correlations with the number of HWs over the inlands regions than the coastline (Unal et al., 2013). In the Nanjing metropolitan region (China) the major issues caused by high temperature and HWs were energy consumption, power shortage, human health and human habitat deterioration (Liu et al., 2015). Heat episodes can also have a serious impact on the local or regional economy. Herbel et al. (2017) assessed the potential economic loss during HWs in the city of Cluj-Napoca (Romania) and estimated a loss of about 2.5 mil. EUR for each HW day in summer. In Zaragoza (Spain), the cost of heat events in terms of health-related impacts alone was estimated at approximately 100000 USD per year (Roldán et al., 2016, cited by Horton et al., 2016). A higher demand for energy (around 0.15 MW) is noticed in Serbia when air temperature is above 30 °C, mostly during HWs with a maximum electricity consumption during daytime (Savić et al., 2014). Moreover, HW episodes put pressure on health services and emergency call lines. Hospital admissions increase during HWs (WMO and WHO 2015). Another negative consequence of heat episodes is the major threat to global crop production with implications that go as far as food security and economy (Horton et al., 2016).

For extreme temperature events related to heat, including HWs, there are review articles already available in the existing literature to which readers may refer at a regional (Rusticucci, 2012; Bittner et al., 2013; Schubert et al., 2014; Grotjahn et al., 2016; Perkins-Kirkpatrick et al., 2016) or a global scale (Coumou and Rahmstorf, 2012; Xu et al., 2014; Perkins, 2015; Horton et al., 2016; Mora et al., 2017; Song et al., 2017).

The aims of this paper are to summarize the mechanisms behind HW formation and the factors that maintain such events, changes in their characteristics (frequency, duration, and intensity), impact on human mortality, and to address the issue of HW definitions by synthesizing recent studies published in the 2007-2018 period in peer-review journals.

This article is organized as follows: Section 2 addresses the issue of HWs definitions. In Section 3 the physical mechanisms that causes and sustain HWs are described. Section 4 is dedicated to changes in HW characteristics. Section 5 focuses on the relationship between HWs and mortality. Conclusions are provided in section 6.

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Definitions of heat waves

The purpose of this section is to address the issue concerning the various definitions related to HWs. Generally, a HW is defined as a prolonged period of excessive heat (D'Ippoliti et al., 2010; Perkins-Kirkpatrick and Gibson, 2017; Yan et al., 2017). Depending on the data availability, and the region and sector of interest (i.e. human health, agriculture, infrastructure) there are many ways to statistically define a HW. Typically, HWs can be identified and investigated based on daily maximum (TX) and minimum (TN) temperature separately or by combining these variables. Beside temperature data, other human impact orientated studies took in consideration supplementary variables as well. For instance, Basarin et al., (2016) assessed HWs and cold waves (CWs) in Serbia by employing physiologically equivalent temperature (PET) which incorporates air temperature, vapor pressure, wind velocity, and mean radiant temperature. This definition also includes information about clothing insulation, human activity and height and weight. Unal et al. (2013) analyzed HWs over western Turkey based on apparent temperature as a function of daily TX and relative humidity.

Based on the data availability and purpose of the study, a HW can typically be identified by a combination of duration and intensity thresholds. Thus, the duration thresholds can vary from a minimum of two to six or even more consecutive days (Ringard et al., 2016; Piticar et al., 2017). Some definitions take into consideration 1 or 2 days of no HW conditions included within a longer event, while others eliminate or break it into two or more events (Piticar et al., 2017). Intensity thresholds can take the form of relative (i.e. 90 – 99th percentile, deviation above n °C from the normal local climate) or fixed (i.e. 30 – 40 °C) thresholds. The most common approach to identify a HW is based on the exceedance of a relative or absolute threshold for daily temperature for a period of at least n consecutive days (usually 2 – 6 days). Although fixed thresholds can have some advantages they are limited to specific areas. Percentile thresholds are more flexible, allowing comparisons among regions with different climates and geographical features and identifying warm events which are not dependent on the warm season.

Although, there is no universal method for HW identification, by analyzing a sample of 109 articles published in the 2007-2018 period a preference for percentile-based definitions was observed (Fig. 1). Thus, 71.6% of the analyzed articles used only percentile-based definitions to identify and examine HW events and their characteristics. Definitions based on fixed thresholds were selected in the case of 11.9% papers. The WMO definition (when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5 °C, the normal period being 1961-1990) was used in 3.7% studies. Both percentile and fixed or WMO definitions were employed to analyze HWs in 3.7% articles. In the case of 9.2 % of articles, HWs were identified based on more complex definitions which could not be included in any class (percentile-based, fixed, WMO, and mixed definitions). For instance, Guo et al. (2017b) analyzed projection of HWs over China using a definition based on a combination of a percentile threshold and a fixed threshold. Thus, a HW was defined as a consecutive period of at least 3 days during which the daily TX exceeded the 95th percentile of the 1971-2000 reference period and where the percentile threshold was no less than 30 °C.

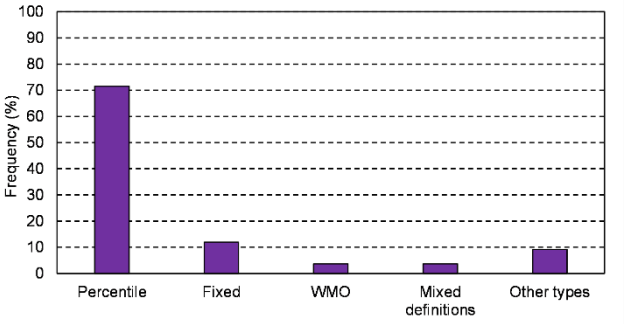

Fig. 1. Frequency of definition types identified in a sample of 109 studies published from 2007 to 2018 period.

The preference for definitions based on percentile thresholds could be explained by the advantages they offer, the effort of the Expert Team on Sector-Specific Climate Indices (ET-SCI) of the World Meteorological Commission for Climatology and Indices (CCI) to introduce a standardized set of definitions which are based on percentile thresholds, and the significant contribution of Perkins et al. (2012) and Perkins and Alexander (2013) that proposed the use of a set of HW definitions based on percentile thresholds in order to reduce the large number of metrics employed to measure these events (Perkins, 2015).

Understanding the role of using different definitions to analyze various aspects in HWs studies (i.e. changes, projections, impact) is crucial in selecting the appropriate methodology of HWs identification. In particular, the selection of HW-definitions is very important in human impact studies, since researchers suggested that they could affect mortality differently (Lee et al., 2016).

Beyond all these statistical definitions which indubitably have a strong physical basis, there are the driving physical mechanisms which generates and maintain such events. Thus, in the following section

the main drivers which generate and maintain HWs are described.

Physical mechanisms responsible for the heat waves formation and persistence

General considerations

Much effort was put into understanding the mechanisms that cause and sustain HWs in different regions of the world. Previous studies have indicated the significant role of large-scale atmospheric circulation and sea surface temperature (SST) on HWs occurrence (Cerne and Vera, 2011; Parker et al., 2014; Wang et al., 2017).

Persistent and intense anticyclone systems are the central components that generate and sustain HW events (Geirinhas et al., 2017; Kueh et al., 2017; Tomczyk and Sulikowska, 2017; Wang et al., 2017). These systems are also called blocking highs or persistent highs (Perkins, 2015). They occur when upper-level atmospheric winds split as a consequence the meandering of the jet stream (Pezza et al., 2012; Perkins, 2015). Other persistent highs may have other causes and occur at lower latitudes than the typical blocking region (Perkins, 2015). Such persistent highs were responsible for numerous HWs over Europe, Australia, and other regions of the planet (Purich et al., 2014; Perkins, 2015). The high anticyclone structures are extended vertically from the surface into the atmosphere with high pressure anomalies detected at the 500 and 250 hPa geopotential height levels (Loikith and Broccoli, 2012; Bumbaco et al., 2013; Perkins, 2015; Hafez and Almazroui, 2016). Blocking highs which generate HWs in the Northern Hemisphere are generally centered over the affected area, with the direction of wind flow guiding warm and dry air from south over the region in cause (Perkins, 2015). Blocking anticyclones through their persistence and stationarity or slow moving allow HWs the time to build (Horton et al., 2016). Over a recent period of time, the occurrence of mid-latitude anticyclone systems related to atmospheric blocking and climate change process increased (Morabito et al., 2017) leading to a higher frequency of HWs.

SST positive anomalies can also significantly contribute to HW formation and persistence (Feudale and Shukla, 2011; Jia et al., 2016) and can be a good predictor of their occurrence. For example, SST over the south sea of the Korea/Japan is warming about a week before HWs occur in Korea (Ham and Na, 2017). Understanding the relation between HWs and large-scale atmospheric circulation and SSTs is important for predicting these events.

Another fundamental element which contributes to HW development and severity are surface heating and soil moisture (Loughran et al., 2017; Wang et al., 2017). Dry soil tends to intensify HWs and extend their duration. For example, the 2003 HW over Europe was up to 40% more intense as a result of dry conditions (Fischer et al., 2007b; Perkins et al., 2015; Horton et al., 2016).

Furthermore, the intensity of HWs is built by regional land surface feedback and intense radiation. Fischer et al. (2007a) investigated major summer HWs of 1976, 1994, 2003, and 2005 in Europe conducting regional climate simulations with and without land-atmosphere coupling. The results of the experiment revealed that land-atmosphere coupling was an important factor in the evolution of the investigated HWs both trough local and remote effects. Soil moisture-temperature interactions increased the analyzed HWs duration and account for 50 - 80% of the number of hot summer days. This effect occurred mainly due to the limitation of evaporation caused by drought conditions. Moreover, it looks like spring precipitation deficits could enhance the strength of summer HWs (Fischer et al., 2007a, 2007b).

Teng and Branstator (2017) investigated linkages between HWs in the Northern Hemisphere and the quasi-stationary planetary wave anomaly produced by atmospheric internal variability based on the 12000-year integration of a climate model. The main findings suggested that when circulation anomalies had unusually high projections onto circumglobal teleconnection patterns, the probability of HWs can be increased/decreased over much of the hemisphere by a factor of 4, both concurrently and in the following two weeks. These circumglobal teleconnection patterns are quasi-stationary, through their influence on the likelihood of HWs and therefore they provide a viable source of predictability of HWs on subseasonal timescales (Teng and Branstator, 2017).

Regional considerations

Europe

In Europe HWs are closely linked to the atmospheric blocking regime and SST anomalies (Purich et al., 2014). In Western Europe, HWs are strongly related to the high pressure centers over Scandinavia and central Western Europe (Della-Marta et al., 2007; Wang et al., 2017). For instance, SST anomalies and convection processes in the Atlantic Ocean associated with the Rossby wave train system and downstream atmospheric blocking lead to summer HW formation across Europe and Russia (Della-Marta et al., 2007; Purich et al., 2014). In the United Kingdom (UK), Sanderson et al. (2017) showed that higher numbers and lengths of HWs are related with the positive phase of the Atlantic Multidecadal Oscillation (AMO), while negative phases of the AMO moderate the number and duration of

such events. However, there are other atmospheric modes and weather conditions which can exacerbate HWs even when negative phases of the AMO are in progress. For example, the long HWs of 1975 and 1976, were exacerbated most likely because of the simultaneously manifestation of drought (Sanderson et al., 2017). The same study also suggested that the summertime North Atlantic Oscillation (NAO) moderates the number and duration of HWs. Tomczyk and Sulikowska (2017) indicated that the occurrence of HWs in northern Germany was related to a ridge of high pressure over Europe with a local anomaly of high-pressure in the Baltic Sea center. In Serbia almost 84% of the longest HW days were possible under anticyclonic conditions and southerlies major types of Grossweterlagen patterns (GWL) (Unkašević and Tošić, 2009). Unkašević and Tošić (2009, 2015), also indicated that the severe HWs of summers of 2007 and 2012 in Serbia occurred as a consequence of warm and dry air advection from North Africa. The synoptic conditions generating HWs in Greece consist in the Subtropical Jet Stream (STJ) shifting northward to the North of the Greek area resulting in warmer than normal temperatures at the surface thus facilitating conditions for the North-African warm air masses to invade Greece and move northward over the Balkans (Theoharatos et al., 2010). The displacement of STJ can be determined by low-pressure systems over southwestern England and Northern Biscayan Gulf areas, combined with ridges projected from Africa towards the Mediterranean (Theoharatos et al., 2010). This type of mechanism causes a powerful intrusion of heat in the Balkan region (Theoharatos et al., 2010). In eastern Europe, HWs are strongly related to warmer SSTs in the Mediterranean and Black Sea which reinforces upper-level anticyclonic flow (Unal et al., 2013).

Asia

The stationary Rossby waves play a key role in the development of HWs in the Northern Eurasian region, including events such as the one in 2010 in Russia (Schubert et al., 2014). Mid-latitude heat episodes are often associated with strong Rossby wave activity in the upper troposphere (Fragkoulidis et al., 2018). A study over West Asia indicated that severe HWs in Georgia are attributed to negative sea level pressure (SLP) anomalies over southern Scandinavia and Red and Black Sea, and positive SLP anomalies across western Asia in association with mid-tropospheric anticyclonic conditions (Keggenhoff et al., 2015b). This atmospheric configuration blocks westerlies, and allows warm air from the Southeast to cause extreme high temperature over Georgia (Keggenhoff et al., 2015b). Moreover, high atmospheric stability, intense insolation, and pronounced soil dryness contribute to the increased severity of HWs in this region (Keggenhoff et al., 2015b).

HW occurrence over India is related with large scale atmospheric anomalies connecting sub-tropical high quasi-stationary Rossby waves over the mid-latitudes, pronounced soil dryness, and clear sky (Rohini et al., 2016). Moreover, Rohini et al. (2016) also suggested that SST anomalies of the Indian Ocean and of ENSO events have a large contribution on Indian HWs and changes in these features are expected to have consequences on the frequency and the duration of extreme heat episodes. Based on observed patterns and the statistical analyses of the TX variability Ratnam et al. (2016) identified two types of HWs over India. The first type is specific to north-central India and was found to be associated with blockage over the North Atlantic which results in a cyclonic anomaly in the western region of North Africa at upper levels. The stretching of vorticity generates a Rossby wave source near the entrance of the African Jet. The generated quasi-stationary wave train along the jet has a positive phase over India causing anomalous sinking motion and thereby HW conditions over this region. The second type of HWs is common to coastal eastern India and is generated by the anomalous Matsuno-Gill response to the anomalous cooling in the Pacific. Thus, the Matsuno-Gill response results in northwesterly anomalies over the land reducing the land-sea breeze, conducting in HWs occurrence.

Wang et al. (2017) identified three leading modes governing the spatiotemporal distribution of extreme heat episodes in China: interdecadal (ID), interannual-tripole (IA-TR), and interannual-dipole (IA-DP) modes. ID pattern generated more frequent, longer and stronger events over North China. The IA-TR structure underlines a tripole anomaly pattern with positive (negative) anomalies centered on north and south China and negative (positive) anomalies in central China. The IA-DP mode exhibits a meridional dipole pattern with anomalies of opposite signs between the north and most of the southern areas of China (Wang et al., 2017). Wang et. al (2017) also emphasized the important role of SST anomalies on HWs genesis over China. Thus, the considerable SST warming over Tropical Western Pacific (TPWP) leads to convective processes. The positive and negative SST anomalies over the tropical western and eastern Pacific strengthen Walker circulation resulting in intense convective processes over TPWP in the case of the IA-DP and IA-TR patterns. Furthermore, the increase of TPWP diabatic heating associated with the convection triggered northward, propagates Rossby wave trains leading to an anomalous descending motion and less precipitation over the high pressure nodes influencing HWs in China. Luo and Lau (2017) analyzed HWs in southern China and indicated that these events are accompanied by anomalous surface high pressure and anticyclonic circulation. The dominant anomalous northwesterly flow reduces

moisture advection from sea to land. Thus, the region is dominated by dry and warm conditions and along with clear sky, which prolongs sunshine duration and enhances the solar radiation leading to a greater solar heating. The SLP and temperature anomalies are associated with the westward displacement of the western North Pacific subtropical high (WNPSH), suggesting that westward circulation of this system is partially responsible for the occurrence of HWs in south China (Luo and Lau, 2017). In Yangtze River valley approximately two third of the total HW variability in the July-August interval can be attributed to anomalous SST forcing, whereas the other one third is due to internal variability (Chen and Zhou, 2017). ENSO also plays an important role in the SST forcing. Wang et al. (2017) suggested that intensity of HWs in China could be strongly enhanced by the deficiency of soil moisture.

A recent study over Taiwan indicated that HW events over this region are associated with abnormal warming and drying atmospheric conditions controlled by enhanced WNPSH (Kueh et al., 2017). The drying magnitude is suppressed by surrounding waters which serve as a vast moisture source (Kueh et al., 2017). The WNPSH, a key component of the East Asian summer monsoon system, is a major regulatory element of the summer monsoon rainfall and tropical storm activities over the western North Pacific (Kueh et al., 2017). The anomalous WNPSH is a major cause of weather extremes, HWs included, in the region (Wang et al., 2016; Kueh et al., 2017; Luo and Lau, 2017). HWs in East Asia were attributed to the variation of WNPSH and could be further enhanced by the ENSO and the tropical Indian Ocean warming (Kueh et al., 2017). However, there still are gaps in the scientific analysis of the physical causes which generate extreme heat events in this region.

Lee and Lee (2016) found that the number of HWs in South Korea are related to a north – south dipole pattern between the South China Sea and Northeast Asia. When this large-scale circulation configuration facilitates deep convection in South China Sea, it tends to weaken moisture advection from this region to Northeast Asia. Intense deep convection in the South China Sea triggers a Rossby wave train along southerly winds which lead to the formation of positive geopotential height anomalies around Korea and Japan, accompanied by large-scale subsidence and therefore providing favorable conditions for extreme hot and dry days in Korea.

Africa

Summer HWs in Northern Africa are related to a cyclonic anomaly activity in central Sahel favoring the monsoon eastward to 0° longitude and a midlevel anticyclonic anomaly over the Western Sahara, increasing southward the flux divergence associated with the African Easterly Jet (Fontaine et al., 2013). In the March–May period, two to three HWs propagate toward east. They are preceded by an abnormal warm cell over Libya and southwesterlies over the West Sahara. Midtropospheric subsidence and anticyclonic rotation associated with a large trough which stagnates over North Atlantic reinforce across the continent, then moves toward the Arabian Peninsula. These signals are spatially coherent and might suggest the role of short Rossby waves with an eastward group velocity and a baroclinic mode, possibly associated with jet stream deformation (Fontaine et al., 2013). In spring, heat episodes are also connected to midlevel cyclonic rotation over Morocco associated with a Rossby wave pattern, lessening the Harmattan (Fontaine et al., 2013).

Another important driver which generates HWs (day-time events) in the western Sahel region is the increased shortwave radiation and a reduction in cloud cover (Oueslati et al., 2017). Nigh-time events are explained by the greenhouse effect of water vapor increasing longwave radiation (Oueslati et al., 2017). Atmospheric circulation has an important role in sustaining these warm anomalies during the night by transporting moisture from the Atlantic Ocean and the Guinean coasts into Sahel. ENSO is also a key factor in the occurrence and variability of HWs in Sahel, favoring high TN and increased event frequency (Oueslati et al., 2017).

The African Intertropical Convergence Zone (ITCZ) is also an important element of HW occurrence in North Africa. An outstanding significant positive correlation between the abrupt shift of ITCZ position and HW occurrence was found in Egypt in the summer of 2015, suggesting that the southerly movement of the eastern African ITCZ controls the weather over this country and led to the extreme HWs (Hafez and Almazroui, 2016). The geopotential height at a 500-hPa anomaly becomes positive for the duration of a HW over Egypt for the summer season (Hafez and Almazroui, 2016). The stability conditions of high pressure system in the upper atmosphere over this area create lower inversion of temperature near the surface and cause the heat accumulation (Hafez and Almazroui, 2016).

We could not identify any study between 2007 and 2018 which analyzed mechanisms that generated HWs over the southern half of the African continent. Therefore, future research should identify the key mechanisms which generate and maintain such events in this area of the globe.

Australia

In Australia as in the case of other continents, both large-scale atmospheric circulation and land surface conditions are some of the most important drivers in the HW genesis and persistence (Pezza et al., 2012; Gibson et al., 2017). Australian HWs conditions of occurrence can roughly be described as

a consequence of a high pressure system of the subtropical ridge advecting warm air from the North (Loughran et al., 2017). The high pressure system is often embedded in a stationary Rossby wave. Loughran et al. (2017) found that ENSO has a great influence on HWs in Australia, especially on frequency days, duration, and number in northern and northeastern areas of the continent.

The fundamental mechanism of HWs in southern Australia was identified as a transient pulse arriving from the Indian Ocean which resonates with the Australian continent projecting a very strong ridge towards the south (Pezza et al., 2012). Events in Southern Australia are also related with feedbacks between SST anomalies and atmospheric variability and interactions with tropical variability (Purich et al., 2014). In southeastern Australia extreme heat events occur under persistent subtropical high pressure systems associated with northerly winds, while in the southwestern part of the continent high pressure systems in the Great Australian Bight produce easterly winds which can induce conditions for HWs formation (Purich et al., 2014). Parker et al. (2014) have also analyzed the physical mechanism behind HW formation in southeastern Australia and found that these events are accompanied by a slow-moving transient surface anticyclone over the Tasman Sea to the East, which directs warm continental air over this region. Also, summer HWs over southeastern Australia seemed to be related with heavy rainfall in the northeastern areas of the continent (Cowan et al., 2014; Parker et al., 2014). The mechanism behind this dipole of extreme heat in the southeast and heavy rainfall in the northeast and adjacent waters is generated by upper-level cyclonic potential vorticity troughs which rainfall by vertical motion, high instability, and modification to moisture flux (Parker et al., 2014).

North America

Extreme heat episodes in North America are associated with anomalous circulation at 500 hPa geopotential height (positive anomalies) and SLP anomalies (Loikith and Broccoli, 2012). These episodes are accompanied as in the case of other areas on the globe by quasi-stationary mid-latitude Rossby waves (Teng et al., 2013). Other processes, such as low soil moisture content can be an important component of HW formation in this area as well (Loikith and Broccoli, 2012). Some of the most severe high impact HWs in the North America occurred in relation to low-humidity and drought conditions (Peterson et al., 2013).

It was found that HW frequency over this region is dominated by two distinct modes. (i) The interdecadal mode primarily depicts a HW frequency increasing pattern over most of North America except some western coastal areas (Wu et al., 2012). (ii) The interannual mode resembles a tripole anomaly pattern with three centers over the northwestern, central, and southern continent. The interdecadal mode is closely associated with the prior spring SST anomaly in the tropical Atlantic and tropical western Pacific that can persist during the summer, whereas the interannual mode is related to the development of ENSO. For the interdecadal mode the tropical Atlantic sea surface anomaly can induce a Gill-type response which extends to North America, while the northwestern Pacific sea surface anomaly excites a Rossby wave train propagating eastward towards the continent. These two circulation patterns jointly contribute to the formation of the large-scale circulation anomalies associated with the interdecadal mode. For instance, SSTs over the North Atlantic, Tropical Atlantic, tropical Pacific, North Pacific, and uniform global SST warming contributed to the 2012 summer warm temperature anomalies over large areas of the US (Jia et al., 2016). In the case of interannual mode, the corresponding circulation anomalies are similar to a Pacific-North America pattern. The subsidence associated with high-pressure anomalies warms and dries the boundary layer, inhibiting cloud formation. The resulting surface radiative heating further warms the surface (Wu et al., 2012). Moreover, some patterns suggest influence from other large-scale teleconnections, such as Arctic Oscillation and the Pacific-North American mode (Loikith and Broccoli, 2012). The orientation, physical characteristics, and spatial scale of these circulation patterns vary based on latitude, season, and proximity to major geographic features such as mountains, coastlines and others (Loikith and Broccoli, 2012).

Bumbaco et al. (2013) analyzed day-time and night-time HWs in the Pacific Northwest and found that stronger 850 hPa winds, higher 500 hPa geopotential heights, and larger SLP gradient associated with TX events over the region indicated that downslope warming across the west side of the Cascade Mountains is more important for the day-time events. Moreover, this finding was supported by a positive relationship between the strength of the 500 hPa anomalies and the magnitude of the TX regional anomalies. On the other hand, nigh-time events had a less pronounced 500 hPa ridge and a weaker 850 hPa easterly winds, a weaker SLP gradient, and there was no relationship between the strength of the 500 hPa Z and the regional anomaly.

Hence, the atmospheric dynamics, land initial conditions, SSTs, and radiative forcing are all important drivers, and source of predictability for North America HWs (Jia et al., 2016).

South America

One important characteristic of South America HWs is that they are less common and intense

compared to the Northern Hemisphere ones (Rusticucci, 2012). A study over subtropical South America found that 73% of HWs which occurred in this region were related to an active South Atlantic Convergence Zone (SACZ) associated with the strengthening of an anticyclonic anomaly in the subtropical region (Cerne and Vera, 2011). Moreover, the high anticyclonic activity over this area is embedded in a large-scale Rossby wave train extended along the South Pacific Ocean which was found to be linked with intraseasonal changes of the convective processes at the equatorial western and central Pacific Ocean (Cerne and Vera, 2011). Jacques-Coper et al. (2016) also found similar results in southeastern Patagonia in respect to the relation of HW events to convective conditions in the SACZ (two thirds of the HWs in southeastern Patagonia were related to SACZ). A low number of HWs (7 of 26 identified in the 1979-2003 period) were not related with active SACZ (Cerne and Vera, 2011). They occurred under warmer than normal conditions over the subtropical regions. These conditions are sustained by the persistence of advections of very warm and moist air promoted into the region by a quasi-stationary frontal system located at the southern tip of South America (Cerne and Vera, 2011). Therefore, HWs in the subtropical South America occur even when the activity of the SACZ is suppressed (Cerne and Vera, 2011; Rusticucci et al., 2016). Over Brazil, HWs can be induced by a westward migration of the South Atlantic Subtropical high in association with SST anomalies over the South Atlantic Ocean (Geirinhas et al., 2017). In the equatorial areas, HWs are related to the migration of the Intertropical Convergence Zone (ITCZ) northward and warmer SST over the North Tropical Atlantic Ocean and also with the ENSO (Geirinhas et al., 2017). The radiative balance at the surface has been also found to be an important driver for the development of HWs in some locations of Brazil (Geirinhas et al., 2017).

Changes in heat waves across the globe

Observed changes

Even though there is a wide variety of definitions, the analysis of changes in HWs converged to similar results: increase in frequency, duration and intensity. Globally averaged, HWs (analyzed by the warm spell duration indicator - WSDI) have increased by approximately 8 days since the middle of the twentieth century (Donat et al., 2013). The increase was more evident since 1990. Conversely, the duration of cold spells (analyzed by the cold spell duration indicator - CSDI) has significantly decreased over large areas, by circa 4 days since 1950 (Donat et al., 2013). Thus, these results indicated that the warming process at a global scale is reflected more in HWs than in CWs. Large areas of the globe experienced significant increasing trends in WSDI for the 1951-2010 period. However, these changes are not uniform from a spatial and temporal point of view. The most affected regions seemed to be Europe, almost the entire surface of Asia and Australia, Southern Africa, the northern half of North America, and sparse regions of South America located in the north, west, and south (Donat et al., 2013). These results are similar with those reported by Perkins et al. (2012) which analyzed HWs at a global scale by employing three different definitions: TX above the 90th percentile for at least three days, TN above the 90th percentile for at least three days, and excess heat factor (EHF). Moreover, the global area affected by HWs has increased in recent decades (Russo et al., 2014).

In all of the regions of the planet, short-term downward trends in HWs are followed by a rise in their metrics within 5 – 10 yr, indicating that those areas will experience an increase within the next decade (Perkins-Kirkpatrick et al., 2017). Changes in the metrics of these events are highly sensitive to changes in mean global-scale warming (Horton et al., 2016; Perkins-Kirkpatrick and Gibson, 2017). Thus, limiting the global warming to 2 °C as recommended by the Paris agreement can avoid considerable changes in HWs (Perkins-Kirkpatrick and Gibson, 2017).

Regional changes

Europe

The European continent faced many extreme heat events in the last decades. A considerable number of studies showed an important increase in HW frequency, duration, and intensity over large regions of Europe. Thus, these changes were observed in: Spain (Acero et al., 2017), Northern Europe (Tomczyk et al., 2017), lowland Germany (Tomczyk and Sulikowska, 2017), the Carpathian Region (Spinoni et al., 2015), Ukraine (Shevchenko et al., 2014), Romania (Croitoru et al., 2016; Piticar et al., 2017), and Serbia (Unkašević and Tošić, 2015; Basarin et al., 2016). Long-term changes analysis showed that the duration of intense HWs has doubled in Western Europe between 1880-2003 (Della-Marta et al., 2007). Sanderson et al. (2017) found some positive trends in the number and duration of HWs at some stations in the United Kingdom. However, for some stations in the south-eastern of England, the duration of very long events (over 10 days) had decreased since 1970s, whereas the duration of shorter events (up to 10 days) had slightly increased.

Asia

Trend analysis of HWs over western Asia (Georgia) demonstrated a significant increase in the frequency,

duration, and intensity of these events (Keggenhoff et al. 2015a, 2015b). Unal et al. (2013) also found increasing trends in the frequency and duration of HWs in western Turkey. Important changes were found in HW variables related to frequency, duration, and intensity in China, pointing out towards more severe events (Dian-Xiu et al., 2014; Liu et al., 2015; Chen et al., 2017; Chen and Li, 2017; Luo and Lau, 2017; Wang et al., 2017; Yan et al., 2017; Zhang et al., 2017a). Rohini et al. (2016) and Panda et al. (2017) found statistically significant increasing trends in HW frequency, total duration, and maximum duration in India, especially in central and northwestern regions.

Africa

For the African continent the situation is similar to Europe and Asia in respect to changes in HWs. Thus, the number of HWs increased both in day-time and night-time events in the 1981-2015 period over Africa (Ceccherini et al., 2017). Russo et al. (2016) indicated that in the recent years Africa experienced hotter, longer, and more extent HWs than in the last two decades of the 20th century. The annual number of diurnal and nocturnal events increased over the coastal regions of the Gulf of Guinea in the second half of 20th century, becoming more accelerated after 1980s period (Ringard et al., 2016). Oueslati et al. (2017) also reported that over the last three decades, HW frequency, duration, and intensity increased in the Sahel region. In southern Africa, a shift toward higher heat wave frequency in recent years occurred (Lyon, 2009).

Australia

Significant changes were also found across large areas of Australia in different HW parameters which measured frequency, duration, and intensity (Perkins and Alexander, 2013; Parker et al., 2014; Nairn and Fawcett, 2015; Perkins-Kirkpatrick et al., 2016).

Greater statistical significance was found in frequency-based indices (Perkins and Alexander, 2013). In terms of intensity-based indices, the results of the same study showed that changes are more substantial in the highest intensity values than in average ones.

North America

North America experienced an increase of the number of HWs (Keellings et al., 2018). Peterson et al. (2013) indicated that over the last decades HWs are generally increasing in the US. Smith et al. (2013) have also found positive trends in HWs indices over most of the US territory. Only few significant negative trends were found in portions of the Southwest, Northwest, and Great Plains (Smith et al., 2013). Anandhi et al. (2016) found a general increase in the number of warm spells (WSs) in winter in Kansas and a decrease over the whole year. In Florida HWs have become more frequent and intense (Keellings and Waylen, 2014). The duration and intensity of HWs have increased in summer in Mexicali City (Mexico) (Cueto et al., 2010). Allen and Sheridan (2016) analyzed spatio-temporal changes in HWs in 55 US metropolitan areas over the 1948-2012 period and found that across many locations these events have become more frequent, longer, and earlier occurring. Mazdiyasni and AghaKouchak (2015) showed a substantial increase in concurrent droughts and HWs across most areas of the US and a statistically significant shift in the distribution of concurrent extremes. Bumbaco et al. (2013) noted that a significant increasing trend in the frequency of nighttime HWs is the only significant increasing trend in the Pacific Northwest.

South America

The analysis of changes in HWs in South America also showed that these events became more frequent, more intense, and longer. Ceccherini et al. (2016) revealed an increase in the intensity and frequency of HWs in South America. Rusticucci et al. (2016) found increasing frequency in HWs in Argentina over the 1961-2010 period. Geirinhas et al. (2017) revealed the existence of positive and significant trends in HW frequency in Brazil, particularly for the cities of São Paulo, Manaus, and Recife.

Future changes

Projections of HWs indicate that these events will continue to increase in the future at higher rates in terms of frequency, duration, and intensity compared to the present situation and at a greater magnitude than the global mean temperature (Amengual et al., 2014; Perkins, 2015; Perkins-Kirkpatrick and Gibson, 2017). HWs as defined by present-day standards, will have an extraordinary duration which will vary from several weeks (under the optimistic B2 scenario) to months (under the A2 scenario) (Zittis et al., 2016). These changes could lead to increased discomfort and mortality, especially among elderly, children, and people with health problems if appropriate adaptation measurements will not be considered.

At a global scale, model predictions indicated an increase in the probability of occurrence of extreme and very extreme HWs in the coming years, in particular, by the end of the century (Russo et al., 2014). HWs of the same severity as those in Russia in the summer of 2010 are projected to occur as often as every 2 years in southern Europe, North America, South America, Africa, and Indonesia under the most severe IPCC AR5 scenario (Russo et al., 2014). However, the extreme Russian heat event can still be considered a rare event in the future under the less severe scenarios (RCP2.6 and RCP4.5) (Russo et al., 2014).

Amengual et al. (2014) analyzed HW projections with high impact on human health in Europe over the 21st century and concluded that the population will

be exposed to higher health risk related to these events. Other studies also found that until 2100 HW variables may increase drastically in Europe (Ballester et al., 2010; Fischer and Schär, 2010; Jacob et al., 2014; Lelieveld et al., 2014; Schoetter et al., 2015; Zacharias et al., 2015; Ouzeau et al., 2016). However, changes in HW metrics are estimated to vary considerably across different regions of the continent. The most pronounced changes are projected to occur in southernmost Europe for frequency and duration, in further north for amplitude, and in low-altitude southern regions for health-related indicators (Fischer and Schär, 2010).

As in the case of European continent, large areas of Asia will face more severe heat episodes. Zittis et al. (2016) indicated that all variables that characterize HW severity are estimated to strongly increase compared with the control period of 1961-1990 in the eastern Mediterranean and the Middle East. The Northern Eurasia region will experience more HWs especially by the second half of the 21st century (Schubert et al., 2014). The Indian subcontinent is expected to experience more intense, longer, higher numbers of HWs, and earlier occurrence across the year (Murari et al., 2015). Moreover, Southern India, currently not influenced by HWs, is expected to be severely affected by the end of the century (Murari et al., 2015). Guo et al. (2017b) analyzed the projection of HWs over China using 12 CMIP5 models and found that as global temperature will cross the 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 °C targets, HWs would become more frequent, longer, and more intense. HWs are also forecast to become more severe in the future in Taiwan (Kueh et al., 2017). Coupled Model Intercomparison Project Phase 3 (CMIP3) models projected that the number of HW days will increase in northern, eastern, and western Japan (Nakano et al., 2013). Also, the duration of HW days is estimated to increase in areas in which HW days frequency will increase as well (Nakano et al., 2013).

In a recent review article, Perkins-Kirkpatrick et al. (2016) indicated that observed increasing trends in HW metrics in Australia are projected to continue at higher rates until the end of the century. CMIP5 projections over this continent showed more frequent, hotter, and longer summer HWs and winter WSs by the end of the century with more extreme conditions under RCP8.5 compared to RCP4.5 (Cowan et al., 2014).

50% of regional climate projections over Africa suggest that HWs which are unusually severe under the present climate will occur on a regular basis by 2040 under the RCP8.5 scenario (Russo et al., 2016). The Gulf of Guinea, the Horn of Africa, the Arabian Peninsula, Angola, and the Democratic Republic of Congo are expected to face, every two years, HWs of a length comprised between 60 and 120 days under the RCP8.5 scenario (Dosio, 2017).

Over North and South America HWs are estimated to increase considerably in frequency and duration during the 21st century (Lau and Nath, 2012; Marengo et al., 2014; Grotjahn et al., 2016; Li et al., 2017; Angeles-Malaspina et al., 2018).

The impact of heat waves on mortality

HWs have a considerable impact on various systems. Nevertheless, the most direct and brutal societal impact is death (Perkins, 2015; WMO and WHO, 2015). A significant impact on mortality has been clearly demonstrated in numerous studies (D'Ippoliti et al., 2010; Barnett et al., 2012; Lee et al., 2016; Guo et al., 2017a; Zhang et al., 2017b and many others). The most illustrative example is the HW of the 2003 summer that caused between 25000 and 70000 excess deaths in 12 European countries (D'Ippoliti et al., 2010; Amengual et al., 2014; WMO and WHO, 2015). HWs have been responsible for more deaths in Europe, US, and Australia than any other natural hazard (Nairn and Fawcett, 2015).

Extreme heat episodes can also have a serious impact on humans from a health perspective causing heatstroke, heat exhaustion, heat cramps, heat syncope, heat oedama, and heat rush (WMO and WHO, 2015). Heat is also responsible for severe dehydration, acute cerebrovascular accidents, and contributes to thrombogenesis (WMO and WHO, 2015). Moreover, HWs can aggravate chronic pulmonary and cardiac conditions, kidney disorders, and psychiatric illness (WMO and WHO, 2015). In Korea it was found that cardiovascular hospitalizations were significantly associated with high temperature during HWs, particularly in women and younger persons (Son et al., 2014).

A comprehensive study analyzed the impact of HWs on mortality in 18 countries in different regions of the globe using 12 HW-definitions (each 90th, 92.5th, 95th, and 97.5th percentile intensity thresholds combined with duration thresholds above 2, 3, and, 4 days) and found significant association in all countries for all types of HWs (Guo et al., 2017a). The same study indicated that HWs had a higher association with mortality in moderate cold and moderate hot areas than cold and hot areas. Barnett et al. (2012) found that HWs generally increased the risk of death in the US. The largest increase was found for the most extreme temperatures (Barnett et al., 2012). Linares et al. (2015) showed that the impact of heat on daily mortality was greater than that of cold in Spain. Other factors such as interaction between HWs and air pollution from wildfires substantially increase the number of deaths as was the case of Russian mega-HW in 2010 (Shaposhnikov et al., 2014).

HWs impact on mortality can vary according to their characteristics and severity. Thus, variables such as duration and intensity, and their degree of severity correlate and affect differently the number of deaths.

The increase in mortality was up to 3 times greater during long duration and high intensity events (D'Ippoliti et al., 2010). HW duration was of major importance in all-cause and respiratory-cause mortality in Spain (Linares et al., 2015). Kim et al. (2016) has also indicated that the duration of HWs is highly correlated with the number of deaths from heat. This can be explained by the fact that as the HWs progress, the thermal stress accumulated in the human body increases (Kim et al., 2016). Therefore, the maximum duration of HWs is of a great concern. The intensity of HWs also plays a major role in the number of deaths. Thus, the more intense a HW is, the higher the number of deaths will be (Guo et al., 2017a; Lee et al., 2016; Zhang et al., 2017b).

Mortality risk also varies significantly within regions and cities (Horton et al., 2016). These differences are mainly determined by the level of development of each country, the pyramidal structure of population, poverty, level of education, climate, geographical features of each region, intensity of the heat island in urban environments, and others. D'Ippoliti et al. (2010) studied the impact of HWs on mortality in 9 European cities and found that the effect of these events showed a great geographical heterogeneity. The increase in mortality during HW days varied from 7.6 % in Munich (Germany) to 33.6 % in Milan (Italy) (D'Ippoliti et al., 2010). It was also found that heat episodes showed a greater impact in the Mediterranean (21.8 %) than in northern Europe (12.4 %) cities. The highest impact was noted in the case of those with respiratory diseases in terms of preexistent condition. Women between 75-84 years old seemed to be the most affected in terms of gender and age (D'Ippoliti et al., 2010).

The number of deaths also vary across the year. In a study on the impact of HWs on mortality in seven major cities in Korea the results showed an average increase of 4.1 % and a higher effect of episodes that occured earlier in the summer (Son et al., 2012). Similar to the results of D'Ippoliti et al. (2010) for Europe, in Korea, cities mortality was higher during longer and more intense heat episodes and has affected more women than men (Son et al., 2012). This is also the case of Whan (China) (Zhang et al., 2017b). Contrary to results of D'Ippoliti et al. (2010), Son et al. (2012), and Zhang et al. (2017b), other studies did not found any difference in estimated HW effect on mortality by gender (Basu and Ostro, 2008; Huang et al., 2010).

Selecting the appropriate HW-definition to estimate the excess deaths in a specific area or for a specific category of death (i.e. cardiovascular, respiratory) is crucial. For example, a study in Beijing (China), found that the added effect of HWs on cardiovascular mortality was best captured by using a duration threshold of at least 5 consecutive days and a temperature intensity threshold equal or higher than the 93rd percentile (Dong et al., 2016).

In general, a greater association of HWs defined by higher percentile thresholds with mortality was found (Guo et al., 2017a). Lee et al. (2016) investigated the impact of heat episodes on mortality in Korea and showed that mortality increased by 14.8 % when HWs were identified based on the 98th percentile. When the intensity threshold was lowered to the 95th and 90th percentile, the excess mortality during HWs decreased to 8.6 – 11.3 % and 3.7 – 5.8 %, respectively.

HWs defined by daily mean temperatures and TX generated similar HW-mortality association, while there was statistical difference in effect estimates by TN. Therefore, using daily mean temperature and TX can estimate mortality excess better than daily TN (Guo et al., 2017a). Another study analyzed the impact of HWs identified by different definitions on daily mortality in Wuhan (China) and found that the daily mean temperature threshold ≥ 99th percentile and the duration ≥ 3 days had the best predictive ability in assessing the mortality effects of HWs (Zhang et al., 2017b). Therefore, the definition of HWs is critical in estimating their relationship with mortality (Lee et al., 2016).

In many cases HWs lead to higher mortality among elderly, children, women and persons with pre-existent cardiovascular and respiratory diseases (Fischer and Schär, 2010). Obesity may also increase the risk of death during HW episodes. In 66 Chinese communities, a total of 5 % excess deaths were associated with HWs, with the highest value in north China (6 % excess deaths) (Ma et al., 2015). Greater effects were observed on cardiovascular, cerebrovascular, and respiratory mortality. Also, elderly, females, and those living in urban or densely populated communities were more affected by HWs in terms of mortality. Bell et al. (2008) investigated heat-related mortality for three Latin American cities (Mexico City, Mexico; São Paulo, Brazil; Santiago, Chile) and found increased susceptibility for older population in all cities. Thus, the increase in mortality risk for those ≥ 65 was between 2.69% and 6.51%.

A systematic review on the relationship between HWs and children's health indicated that the existing literature does not consistently suggest that mortality among children increases significantly during HWs, even though infants were associated with more heat-related deaths (Xu et al., 2014). Pediatric diseases or conditions associated with HWs include renal and respiratory disease, electrolyte imbalance and fever (Xu et al., 2014). The same study suggested that future research should focus on the development of a HW definition from a children's health perspective.

Despite the increase of HW frequency, duration, and intensity, a recent study found an attenuation of heat-mortality risks in the past decades in a multi-country analysis (Australia, Brazil, Canada, Ireland, Japan, South Korea, Spain, Switzerland, UK, USA)

(Vicedo-Cabrera et al., 2018). Significant decrease in heat-related mortality risk during recent decades have been also reported in other studies (Gasparrini et al., 2015; Urban et al., 2017). In England and Wales, deaths related to heat showed only a small increasing trend in the 1976-2005 period (Christidis et al., 2010). These results suggest that non-climatic driven attenuation mechanisms, such as infrastructure changes and improved health care, have made a large contribution to the decrease in susceptibility to heat (Vicedo-Cabrera et al., 2018). Thus, these facts indicate that there is reason for the development of adaptation and public health strategies to mitigate negative impact of HWs on mortality (Vicedo-Cabrera et al., 2018).

By the end of the century, the annual number of ischemic heart diseases excess deaths in Germany attributable to HWs is expected to rise by factor 2.4 and 5.1 in the acclimatization and non-acclimatization conditions (Zacharias et al., 2015). Roldán et al. (2016) showed that expected mortality caused by extreme temperatures in the form of HWs in Zaragoza (Spain) will increase by 0.4 % for the 2014-2021 period. This effect is expected to increase until the end of the 21st century due to an increase in HW severity. Thus, in the future HW-induced mortality is projected to be higher (Murari et al., 2015; Kim et al., 2016). However, the increase of mortality caused by HWs can be limited if global warming is restricted to 2 °C (Murari et al., 2015) and appropriate adaptation strategies are considered and implemented. Furthermore, the number of strong and extreme stress HWs could increase in densely populated regions until the end of the century (Amengual et al., 2014). Mora et al. (2017) reviewed papers published between 1980 and 2014 and found 783 cases of excess human mortality associated with heat from 164 cities in 36 countries. Their results showed that in the present around 30% of the world's population is exposed to climatic conditions exceeding the deadly threshold (Mora et al., 2017). By 2100, this value is projected to increase to 48 % under a scenario with drastic reduction of greenhouse gas emissions and 74% under a scenario of growing emissions (Mora et al., 2017). Therefore, overcoming the societal vulnerabilities related to these events and the role of political decision making in this direction are essential aspects (Amengual et al., 2014). However, in many countries, governments do not perceive HWs as a major risk problem, although they caused the highest number of deaths among natural hazards.

Conclusions

During the last decade, research on HWs has greatly expanded and has brought significant knowledge in terms of causes, changes, and impact on human mortality. This review summarized the current state of knowledge in HW definitions, driving mechanisms, observed changes, future changes and impact on human mortality in the period 2007-2018.

HW definitions are the core elements of studies which investigates these events. However, the vastness of methodologies used to identify these episodes can make comparisons between the results of different studies quite difficult and the need of a unified set of definitions has aroused interest among climate researchers. Despite the abundance of definitions used to identify these events, by analyzing a sample of 109 papers, a preference for percentile-based definitions was observed. Thus, 71.6 % of the analyzed papers used only this type of definitions. However, percentile-based definitions may also differ between them by using different reference periods (i.e. 1961-1990, 1971-2000, 1981-2010), and intensity and/or duration thresholds which can also make comparisons between the results of different studies difficult.

The atmospheric dynamics are the main drivers of HW occurrence and persistence. Other key factors such as soil low humidity and high temperature, and SST anomalies add an important contribution to the frequency and severity of these events. ENSO seems to have a global influence on HWs, while other teleconnection structures play a key role at a regional scale (i.e., NAO, AMO, Pacific-Japan pattern). Efficient forecast for extreme heat episodes requires a high level of knowledge of the characteristic patterns in key atmospheric variables. Therefore, understanding the associated physical mechanism plays a crucial role in building reliable predictions (Oueslati et al., 2017). Although there is consensus on many aspects of HW driving mechanisms such as the role of blocking systems, researchers pointed out that there are still many gaps in the knowledge of this issues (Perkins et al., 2012; Hartmann et al., 2013; Schubert et al., 2014; Rusticucci et al., 2016).

The reviewed scientific papers which analyzed changes in HWs, provided extensive evidence of significant changes in these events for large regions of the world. Thus, HWs increased in their frequency, duration, and intensity in the past decades. Models suggested that HWs and Mega-HWs are expected to become more frequent and severe under a warmer climate and also to occur in regions rarely affected by such events. There is proof that adaptation measures can significantly reduce the number of deaths. For instance, Christidis et al. (2010) found that adaptation has prevented a significant increase in heat-related mortality. Thus, adaptation strategies are of crucial importance in order to mitigate the negative impact of such events on society and natural environment.

HWs were found to be significantly associated with increased mortality. Despite the recent high impact mega-HWs and intense mediatisation, the population does not perceive these events as a serious threat to

human life, especially for vulnerable categories (children, elderly, and persons with pre-existent diseases). This may happen because of the lack of sudden dramatic manifestation of these events as in the case of hurricanes and floods (Morabito et al., 2017). To prevent the harmful effects of HWs on human health some measures can be effective. These consists in wearing lightweight clothes during hot episodes, rehydration, reducing excess weight, rigorous emergency planning, heat health warning systems, and reduction of heat stress in outdoor or indoor environments (Cueto et al., 2010).

Although, much effort was put into studying these extreme events across the world, there are still large areas with insufficient scientific information especially in Africa, Latin America, and Asia (Perkins et al., 2012; Hartmann et al., 2013; Rusticucci et al., 2016). This is mainly caused by poor quality of reliable climate data or even lack of it. It is important to note that there are very limited published results on HWs driving mechanisms, changes and impact on human mortality in Africa. Therefore, further studies should focus on this region.

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Hydro-ecological investigation of the Lazeshchyna River in Transcarpathian region of Ukraine

Vasyl LETA[1,*], Olga PYLYPOVYCH[2], Taras MYKITCHAK[3]

[1] Uzhhorod National University, Faculty of Geography, Department of Physical Geography and Environmental Management, Universytet·s'ka street, 14, Uzhhorod, Ukraine
[2] Ivan Franko National University of Lviv, Faculty of Geography, Department of Applied Geography and Cartography, Petro Doroshenko street, 41, Lviv, Ukraine
[3] Institute of Ecology of the Carpathians Nasu, Department of Population Ecology, Kozelnytska Str., 4, Lviv, Ukraine

* *Corresponding author*: vasyl.leta@uzhnu.edu.ua

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Abstract

This paper focuses on the hydro-biological and hydro-chemical analysis of the Lazeshchyna River, one of the tributaries of the Tisza River from the cross-border territory within Rakhiv area of Ukraine's Transcarpathian region. For this purpose, we used the results of route survey, hydro-biological and hydro-chemical analysis of the Lazeshchyna River surface water samples, which were collected forhydrochemical studies in 2017-2018. On the basis of water sampling we thoroughly analyzed the hydro-chemical water quality indicators of Lazeshchyna River according to the following groups of indicators: physic and chemical features, organic matter, water mineralization, major ions, nutrients, trace elements and specific pollutants. Hydrobiological studies were conducted in 2015-2016. Based on them, the water quality was assessed according to the Trent Biotic Index bioindication.
The ratio of actual and maximum permissible concentration (MPC) hydro-chemical parameters are investigated, moreover we pointed out the seasonality in the ratio of water consumption and concentration of individual indicators. The study underlines the role of natural and anthropogenic factors for the Lazeshchyna River water quality.

Keywords: *river, hydro-chemical characteristics, hydrological regime, bioindication, water pollution*

Rezumat. Analiza hidro-ecologică a râului Lazeshchyna din Regiunea Transcarpatică a Ucrainei

Lucrarea de față se axează pe analiza hidro-biologică și hidro-chimică a râului Lazeshchyna, unul dintre afluenții râului Tisa, în zona transfrontalieră Rakhiv din regiunea Transcarpatică a Ucrainei. Materialele pentru studiu sunt oferite de analiza cursului râului, analizele hidrobiologice și hidrochimice ale probelor de apă de suprafață prelevate din râul Lazeshchyna, în 2017-2018. Pe baza acestor probe, am analizat în detaliu indicatorii de calitate hidrochimică ai râului Lazeshchyna grupați în următoarele categorii: caracteristici fizice și chimice, materie organică, mineralizare a apei, ioni majori, nutrienți, oligoelemente și poluanți specifici. Studiile hidrobiologice au fost realizate în 2015-2016. Pe baza acestora, calitatea apei a fost evaluată conform indicelui de bioindicație Trent Biotic Index.
A fost analizat raportul dintre parametrii hidrochimici reali și maxim admis, evidențiind totodată și sezonalitatea raportului dintre consumul de apă și concentrația indicatorilor individuali. Este evidențiat rolul factorilor naturali și antropici pentru menținerea calității apei râului Lazeshchyna.

Cuvinte-cheie: *râu, caracteristici hidrochimice, regim hidrologic, bioindication, poluarea apei*

Introduction

Rivers are an important component of ecosystems and, in general, crucial for the formation of microclimatic conditions and water balance of territories, which has a direct impact on the status of all natural and anthropogenic complexes within river basins. At the same time, rivers undergo major changes due to human economic activities, as they are the basis of erosion and other biotic or abiotic factors.

It is important to preserve the natural conditions of formation of the ecological status of rivers, including the mountain ones, since their hydrological and hydrochemical regime determines the ecological status of downstream waters. Thus, the ecological status of the upper part of the Tisza River basin and its tributaries directly affects the status of the Tisza ecosystems downstream in other countries. This prompted us to study changes in the ecological status of the upper part of the Tisza River within the Transcarpathian region, which we consider appropriate, given that its waters are actively used for household water supply and industrial water supply. It should also be noted that individual sections of the Tisza River serve as a border line between Ukraine and Romania, Ukraine and Hungary, and the river basin generally covers the territories of five European countries: Ukraine, Slovakia, Romania, Hungary and Serbia. This determines the transboundary nature of ecological studies of the Tisza River Basin.

The object of the research is to analyze the hydro-chemical water quality indicators of the Lazeshchyna River, a left tributary of the Chorna Tisza, which, in fact, gives rise to the Tisza River within the Rakhiv area of Transcarpathian region of Ukraine. The river originates within the Chornohora mountain range at the altitude of 1520 m, between the highest peaks of Petros and Hoverla.

This study aims to identify the natural and anthropogenic factors, as well as regularities of the formation of ecological state of surface water, of one of the sub-basins of the Tisza River using the analysis of hydrochemical and hydrobiological indicators. The purpose of our study is to determine the role of the Lazeshchyna River and its catchment area in shaping the ecological status of the upper Tisza River within Ukraine.

In order to achieve this goal we carried out a number of route surveys of the Lazeshchyna River and its basin during 2015-2018, and took water samples for chemical analysis, as well as conducted preliminary scientific studies on the subject. We also conducted hydrobiological studies of the Lazeshchyna River using the Trent Biotic Index bioindication method.

Characteristics of the Study Area

By the nature of the water regime and the structure of the valley, the Lazeshchyna is a typical mountain river. The river valley is slightly curvy, V-shaped, sometimes in the form of a gorge, with very steep slopes, and the floodplain is found only within the lower part of the channel. According to the studies of denudation processes in the Ukrainian Carpathians (Kovalchuk et al., 2012), river bank erosion can reach 200-250 meters along the Lazeshchyna River. The channel is slightly curvy, branched, and full of rapids. The river is 21 km long, the basin area covers 159 square km, and the density of the river network is 1.33.

The terrain within the basin is mountainous and highly indented due to a lot of watercourses, (149 in total), with a total length of 212 km (Kaganer, 1978). The catchment area of the Lazeshchyna River includes part of the mountain range of Chornohora in the Ukrainian Carpathians. It consists of sandstones and tertiary conglomerates of Tertiary age of the Cretaceous period. At the top of the basin there are traces of ancient glacial relief (Palienko, 2004). The most part of the studied area is occupied by brown earth and brown mountain forest soils. With change of altitude, forest formations of beech (Fagus sylvatica) and oak (Quercus robur L.) change to formations of fir trees (Picea abies). In general, forests cover about 53% of the Lazeshchyna basin (General management of the land cadaster, 2016). Subalpine vegetation grows starting from the altitude of 1500 m and is replaced by stripes of rhododendron (Rhododendron) and sedge (Carex sempervirens) at the altitude of 1800 m. The average precipitation quantity is 1200-1400 mm per year, most of which falls in the spring-summer period, which undoubtedly affects the hydrological regime of the river and causes an increase in water consumption and frequent floods, up to 10- 12 times during the year.

Fig. 1: The origins of the Lazeshchyna River; view from Petros Mountain

Wikipedia cartographic materials and Digital Elevation Database SRTM 90m data (SRTM 90m, 2003; Wikipedia, 2011) were used to view the location and topography of the Lazeshchyna river basin. With the help of the ArcMap 10.2.2 software and selection of the appropriate tools, an action algorithm was compiled to build a digital elevation model (DEM) of the Lazeshchyna river basin: Geoprocessing> ArcToolbox> Spatial Analyst Tools> Interpolation> Topo to Raster (Fig. 2).

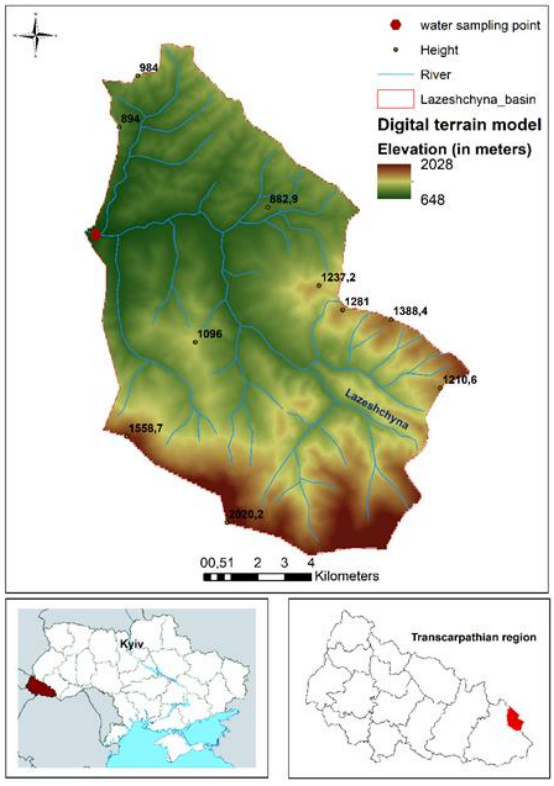

Fig. 2: Location Map of the Lazeshchyna river basin

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Human activities

The catchment area of the river is actively used in economic activities, tourism and recreation. The extent of economic load on river waters and floodplains, built up in some places or performing the function of agricultural land, is growing downstream. Such utilization of the catchment area of the upper Tisza is due to the predominance of mountainous terrain and, as a result, a small amount of land suitable for development and construction.

The economic impact on the Lazeshchyna River's basin is made mainly by agricultural crops along the river bank territories, farming, tourism and recreational activities, as well as technological load. The industrial activity is represented only by forestry enterprises. Still, livestock, especially cattle breeding, became widespread taking into account mountainous terrain, the presence of 2,000 hectares of hayfields and pastures, and historical way of life of highlanders. Grazing of sheep, cows and horses is done on 4 meadows within the studied basin. Farms and household activities are expanding and developing.

It is worth mentioning that the settlements within the catchment area of the Lazeshchyna River have no centralized water supply and sewerage systems, which causes pollution of river water by domestic runoff. Among the factors affecting the environmental status of the surface waters of the Lazeshchyna River, we mention the landfill site, located in the close vicinity to the river, as well as the fact that the garbage is collected from merely 8% of the population living there (General management of the land cadaster, 2016). It can be said that the banks of the river become landfills which during the floods flow and get accumulated downstream of the Tisza River.

Fig. 3: Landfill on the banks of the river Lazeshchyna

The tourist routes to the Chornohora mountain range including Petros and Hoverla peaks are laid through the settlements upstream. There are estates, tourist camps, and shelters that accommodate tourists throughout the year. Within the Lazeshchyna river basin, there are 35 tourist and recreational facilities, the presence of which contributes to the development of green tourism. The recreational activities are provided mainly from rural estates and the only "Kozmeshchik" recreation place.

It is also worth considering the technological load on the river. During the middle of the 20th century, there were 3 functional dams, with the help of which timber was alloyed (General map, 1910). At present, these dams are abandoned and destroyed. Today the influence on the formation of the channel is done through river bank fortification and new construction of dams. We also note that at the mouth of the river there are practically no natural banks and they are currently occupied by restaurants which also discharge sewage directly into the river (Fig. 4).

Fig. 4: The mouth of the Lazeshchyna river

Materials and Methods

Hydrochemical studies of the Lazeshchyna River were carried out on the basis of hydrochemical measurements during 2017-2018 at a site located 0.5 km above the mouth of the river within the village of Yasinya, Rakhiv area, Transcarpathian region. Water sampling coordinates are 48°16'15.6 "N; 24°21'48.0" E. Sampling of river waters was taken in different seasons, respectively: one sample in the spring, (29.04.2017); second sample during the summer (29.08.2017); third sample in the autumn (18.11.2017); fourth samples in the winter (27.01.2018). The chemical analysis was done at the Tisza Water Basin Administration (Uzhhorod, Ukraine), hydrochemical laboratory for monitoring the waters and soils of the Tisza Water Basin Administration (Uzhhorod, Ukraine). In particular, we have identified and analyzed the following hydro-chemical parameters: pH, dissolved oxygen, permanganate oxidation, chemical oxygen demand - COD, biochemical oxygen demand - BOD5, water mineralization and major ions, N-NH4, N-NO2, N-NO3, P-PO4, Fe, Cu, Zn, Mn, Cr, Pb, the content of petroleum products, anionic surfactants (Rules for receiving wastewater, 2002).

In order for the results of the analyzed selected water samples to be of a comparative nature, we used the maximum permissible concentrations for fishery

waters (MPC) as value limits for all parameters in our study, which are adopted at the legislative level (Rules for receiving wastewater, 2002).

Water quality was also assessed by using the Bioindication Index or the Trent Biotic Index (TBI) of Woodiwiss (Semenchenko, 2004; Woodiwiss, 1964). Score rating of water quality by this index is translated into standardized categories of water quality according to the state norms of Ukraine (Arsanet.al. 2006; Methodology, 1998; Oksiyuk, and Zhukinsky 1993).

The index is based on two parameters of the benthic group: the general diversity of invertebrates that inhabit the body of water and the presence of organisms belonging to bioindicator groups. In June 2015 and July 2016, five areas of river channel of the Lazeshchyna River and two areas of the river channel of the Black Tisza River were studied in the area upstream and downstream the confluence of this tributary.

The following mathematical methods of physical geography were used to report the results of our studies: method of determining arithmetic means, ratio of quantitative indicators, statistical, tabular and graphical methods of analysis, computer processing of experimental data, synthesis and identification.

Results and Discussion

The values of the TBI index indicate that the waters of the source and middle reaches of the Lazeshchyna (from 700 m above sea level and above) are very pure (I grade water quality); within the Lazeshchyna village the water quality deteriorates to "good" (grade II); and near the confluence with the Chorna Tisza River it is slightly polluted.

The Chorna Tisza River itself is characterized by very clear waters before the confluence of the Lazeshchyna River tributary, but after the confluence the water quality deteriorates by one grade (up to "good").

In the lower reaches of the Lazeshchyna river there are no representatives of Perlidae in the benthos, which are indicators of very clear waters.

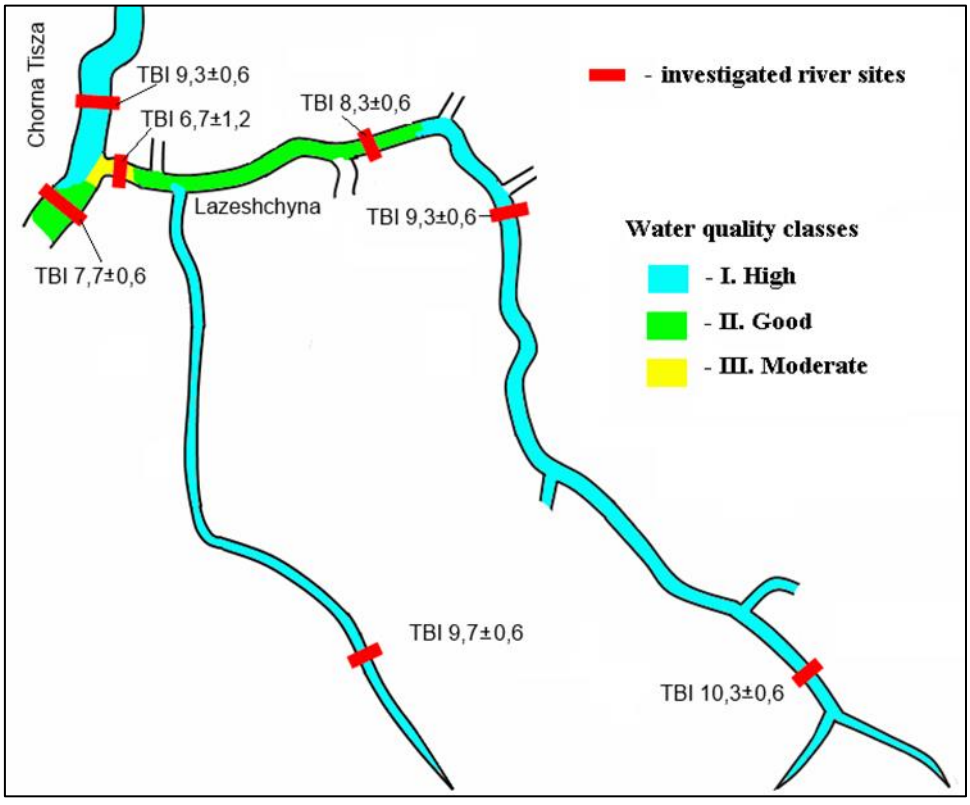

Fig. 5: Changes in the water quality of Lazenshchyna according to the TBI index

Physical and chemical indicators. Hydrogen (pH) is important for all chemical and biological processes in natural waters. During the study period, the pH oscillation amplitude was 0.5 units (7.8-8.3) which makes it possible to attribute the surface waters of the Lazeshchyna River to the category of slightly alkaline. The concentration of hydrogen ions is prone to seasonal changes.

The dissolved oxygen indicator in water is an important sanitary indicator of biological processes in streams and reservoirs. For fishery waters, the minimum dissolved oxygen content in water must be not less than 4 mg O2/dm3 in winter and 6 mg

O2/dm3 in summer. In the waters of Lazeshchyna River, the dissolved oxygen indicator varies from 5.7 mg O2/dm3 in summer, 6.3 mg O2/dm3 in autumn and 5.9 mg O2/dm3 during the winter low water period, which allows them to be classified as polluted waters (quality categories moderate) due to exceeding the norms of MPC during the study period. Non-significant fluctuations are seasonal in nature and depend on the processes of oxygen absorption from the atmosphere, the release of vegetation in the process of photosynthesis, over-flowing with rain or thawing snow-water, and the reactions of oxygen demand on the oxidation of organic matter (BOD5, COD). This is evidenced by the results of water samples taken in autumn when the dissolved oxygen content did not reach the acceptable level.

Organic substances. Biochemical and chemical oxygen demand (BOD5, COD) are indicators that characterize the extent and dynamics of river water self-purification due to the reactions of biological, biochemical, and chemical oxygen consumption. They are expressed by the amount of oxygen spent on the oxidation of chemicals (Fe2+, Mn2+, N-NO2-, N-NH4+, CH4, H2S) and organic substances contained in water. Measurements indicate fluctuations in BOD5 and COD content within fisheries standards (MPC - 3 mg O2/dm3 and 15 mg O2/dm3).

According to the data below (Tab. 1) the increase in the chemical demand index up to 12.1 mg O2/dm3 may also be a consequence of pollution of the Lazeshchyna River by the household wastewater that, in the absence of centralized sewage, is a permanent negative contributor to both organic and inorganic toxicants. Permanganate oxidation (PO) is an indicator of the content of organic compounds readily available to aquatic organisms. The highest value (2.7 mg/dm3) of PO is during spring time, the lowest is during summer low water (1.9 mg/dm3) which indicates the dependence of the indicator on different phases of water volume.

Table 1: Seasonal variability of some hydrochemical parameters in the water of the Lazeshchyna River for the period 2017-2018

№	Indicator	Unit of measurement	Date				MPC**
			29.04.17	29.08.17	18.11.17	27.01.18	
1.	pH	un. pH	7,8	8,3	7,9	8,0	6,5-8,5
2.	permanganate oxidation	mg/dm^3	2,7	1,9	2,7	2,2	< 5,0
3.	dissolved oxygen	mgO_2/dm^3		5,7*	6,3	5,9*	> 6,0
4.	COD	mg/dm^3	5,5	10,2	11,9	12,1	< 15,0
5.	BOD_5	mg/dm^3	2,7	1,9	2,2	2,3	< 3,0

* - excess of value limits
** - MPC (Rules for receiving wastewater, 2002).

Water mineralization. The results of the studies indicate that the average rate of mineralization in the Lazeshchyna River was 170 mg / dm3.

In the studies of landscape complexes (Karabinyuk et al., 2017) water mineralization rates of 134 mg/dm3 and 179 mg/dm3 downstream were recorded. The maximum values of mineralization are characteristic for summer-autumn (183 and 167 mg/dm3, respectively) and winter boundary (172 mg/dm3), respectively during spring period it drops at least during the year values (158 mg/dm3).

Maximum mineralization values are characteristic for the summer-autumn period (183 and 167 mg/dm3, respectively) and winter low water period (172 mg/dm3) respectively, which drop by at least a year during spring time (158 mg/dm3). The general mineralization of the waters of the Lazeshchyna River indicates a low saturation of salts. The degree of mineralization is low; the category of mineralization is hypo-branched water. According to Horiev, Peleshenko, Khilchevskyi, 1995) the waters of the Lazeshchyna are moderately fresh (0.1-0.6 g/dm3), and - slightly mineralized (100-200 mg/dm3) (Alekin, 1953). Therefore, in terms of mineralization, the water from the river can be used for drinking supply.

Biogenic substances (compounds of nitrogen and phosphorus). An important set of surface water quality indicators are biogenic substances, the main of which are nitrogen compounds: N-NH4-, N-NO2-, N-NO3- and P-PO4-. Nitrogen-containing compounds are formed in water due to the ingress of humus substances, decomposition of urea and protein compounds, from precipitation, with runoff from agricultural land after the use of nitrogen fertilizers, farmland, with household waste. During the study period MPC norms were not exceeded and seasonal variability in the content of biogenic substances in the Lazeshchyna River depended on water consumption, the share of soil and surface runoff, meteorological conditions, as well as on household wastewater. Thus, the concentration of N-NH4- and P-PO4- increases in the summer-autumn period (0.14 and 0.15 mg/dm3, 0.05 and 0.06 mg/dm3, respectively) when agricultural land is being actively used because of the glass-bottom structure of a narrow river valley, the coast line of the Lazeshchyna River is often occupied

by agricultural lands. The concentration of N-NO2 in the waters of the Lazeshchyna practically does not change during the study period, but the content of N-NO3- increases with increasing water flow in the river from 1.2 mg/dm3 during the summer limit to 3.2 mg/dm3 during the passage of the watershed.

Table 2: Seasonal variability of indicators of biogenic substances in the water of the Lazeshchyna River for the period 2017-2018

№	Indicator	Unit of measurement	Date				MPC*
			29.04.17	29.08.17	18.11.17	27.01.18	
1.	$N\text{-}NH_4^-$	mg/dm^3	0,12	0,14	0,15	0,12	< 0,5
2.	$N\text{-}NO_2^-$	mg/dm^3	0,03	0,03	0,03	0,04	0,08
3.	$N\text{-}NO_3^-$	mg/dm^3	3,2	1,2	1,8	2,3	40,0
4.	$P\text{-}PO_4^{3-}$	mg/dm^3	0,05	0,05	0,06	0,04	0,17

** - MPC (Rules for receiving wastewater, 2002).

Trace elements. Trace elements are compounds of chemical elements whose concentration in water is measured in tens of micrograms per 1 dm3. In our case, they are Fe, Mn, Cu, Zn, Cr, Pb. At high concentrations, these elements can be toxic for the living organisms.

Concentration of Fe in the water of the Lazeshchyna River exceeds the MPC (0.05 mg/dm3), and it also exceeds MPC for commercial and drinking water (0.3 mg/dm3) in autumn (Fig. 6). The high concentration of iron can be explained by the processes of chemical weathering of rocks which are accompanied by their mechanical destruction and dissolution. Iron concentration has a clear seasonal variability and is also dependent on the chemical composition of the water and the pH. The studies on the content of heavy metals in the waters of the Upper Tisza basin (Lynnyk et al., 2018) show that the content of this metal can increase due to the dominance of inorganic substances.

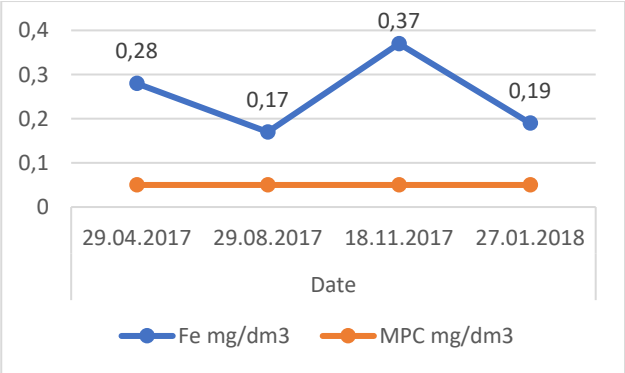

Fig. 6: Seasonal change in Fe content (mg/dm3) in the Lazenshchyna River (2017-2018)

The manganese (Mn) quantity in the water of the Lazeshchyna River in all cases exceeded the MPC (0.01 mg/dm3) (Fig.7). The highest concentrations of Mn were observed in spring and winter (0.08 mg/dm3), slightly lower in summer and autumn, respectively 0.06 and 0.07 mg/dm3. Such fluctuations in Mn content in the waters of the Lazeshchyna River indicate the dependence on water consumption (the lowest figure during the summer low water), on the increase in surface runoff in the spring and on the predominance of subsurface feeding during winter low water. Manganese in nature does not occur in free form, its high concentrations in natural waters may be due to the leaching of manganese ores and minerals, the processes of decomposition of aquatic animal and plant organisms, the reproduction of blue-green, diatomaceous algae, as well as higher aquatic plants. Given that we did not observe any excess of biogenic elements in the mountain at the Lazeshchyna River, we attribute high manganese content to leaching of this element from the rocks (Zhovinsky et al., 2008; Technical report, 2009; Lynnyk et al., (2018).

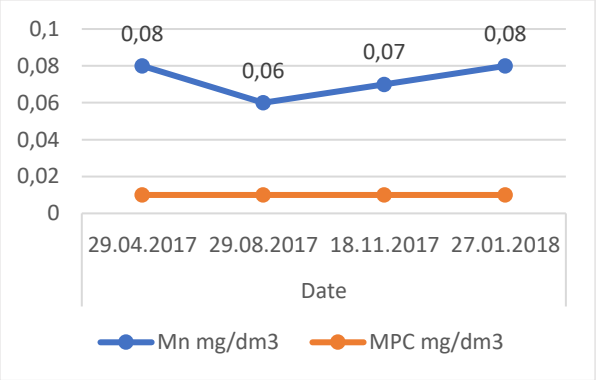

Fig. 7: Seasonal change in Mn content (mg/dm3) in the Lazenshchyna River (2017-2018)

Copper (Cu) according to Zabokrytska, Khilchevsky, and Manchenko (2006) is a widespread element, ionic form in compounds with organic and mineral substances. During 2017-2018 we recorded an excess of MPC Cu of 0.001 mg/dm3 5-6 times (Fig. 8). As in the case of Mn, high concentrations of Cu are associated with the leaching of this element from

rock (Zhovinsky et al., 2008; Technical report, 2009; Lynnyk et al., 2018).

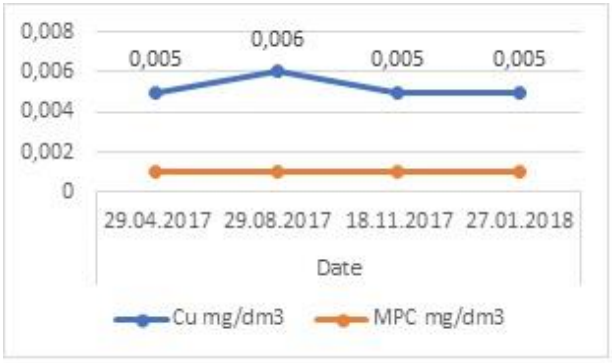

Fig. 8: Seasonal change in Cu content (mg / dm3) in the Lazenshchyna River (2017-2018)

The zinc (Zn) content was slightly higher than the summer-autumn limit and reached the MPC level in winter. Only in the spring this figure was within normal limits. Chromium (Cr) enters surface water in the process of chemical leaching of its compounds from rocks and minerals. According to the technical report (Technical report, 2009), a high Cr content in the soils of the Rakhiv district, within which the catchment area of the Lazeshchyna River is located, is also recorded. The results of four hydrochemical measurements of water samples for 2017-2018 showed a chromium content at the level of the normalized MPC value - 0.001 mg / dm3, which, given its toxicity, allows to speak about the threat of contamination, especially during the period of summer and winter. As for the concentration of lead (Pb) in the waters of the Lazeshchyna River, it does not reach the permissible standard MPC Pb of 0.1 mg / dm3, but it is in the range 0.003-0.005 mg/dm3, which allows to speak about the safety of water for the needs of fisheries (Tab.3). Increasing Pb concentration in winter and spring indicates anthropogenic impact from adjacent and adjacent territories (Zhovinsky et al, 2011).

Our studies are in line with the results of studies conducted from 1950 to 2007 by the Transcarpathian exploration expedition, which indicate that the increased content of Zn, Cu and Pb is mainly related to the natural manifestations of ore mineralization (leaching from the rocks).

Table 3: Seasonal change of Zn, Cr, Pb (mg/dm3) content in the Lazeshchyna River (2017-2018)

№	Indicator	Unit of measurement	Date				MPC**
			29.04.17	29.08.17	18.11.17	27.01.18	
1.	Zn	mg/dm^3	0,006	0,015*	0,012*	0,01	0,01
2.	Cr	mg/dm^3	0,001	0,001	0,001	0,001	0,001
3.	Pb	mg/dm^3	0,005	0,004	0,003	0,005	0,1

* - excess of value limits.
** - MPC (Rules for receiving wastewater, 2002).

Specific contaminants. Petroleum products are among the most common hazardous substances that contaminate surface water. During the sampling period, the content of petroleum products (non-polar hydrocarbons) did not exceed the regulatory value of 0.05 mg/dm3, and the level was 0.01 mg/dm3. Anionic surfactants are inorganic and organic substances that are included in detergents, emulsifiers and disinfectants, and thus come to the Lazeshchyna River with domestic sewage. Anionic surfactants content did not exceed 0.01 mg/dm3 at MPC <0.1 mg/dm3.

Given the complex terrain and low land, settlements of the Lazeshchyna basin are located along narrow valleys or high in mountainous terrain which complicates the laying of water supply and drainage network. Therefore, the population is independently provided with water at the expense of private wells or river water. This problem is particularly urgent for tourists and holidaymakers alike, as many tourist and recreational facilities use river water for domestic use, despite their inappropriateness for a number of chemical indicators. Accordingly, the absence of a centralized sewerage system causes the population to dump wastewater directly into the Lazeshchyna River.

Conclusion

Summarizing the results of our research, we can say that the main hydro-chemical indicators that exceed MPC are trace elements: iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn), as well as low content of dissolved oxygen.

The values of the TBI index indicate that the waters of the source and middle reaches of the Lazeshchyna (from 700 m above sea level and above) are very pure (I grade water quality); within the Lazeshchyna village the water quality deteriorates to "good" (grade II); and near the confluence with the Black Tisza River it is slightly polluted.

The Black Tisza River itself is characterized by very clear waters before the confluence with this tributary,

but after the confluence the water quality deteriorates by one grade (up to good).

Based on the study materials, we can distinguish such types of anthropogenic influence on the Lazeshchyna River as: residential, agricultural, transport, recreational and domestic influence. The narrow river valley determines the complex nature of constructed houses and development of the banks, which in turn leads to non-observance of water protection measures, in particular for plowing, construction of structures, arrangement of landfills, contamination of fertilizers and pesticides, discharge of household waste. The combination of natural and anthropogenic factors leads to seasonal changes in the hydrochemical regime of the Lazeshchyna River as a consequence of the deterioration of water quality.

Due to the economic development of the Lazeshchyna basin, we observe a deterioration of the ecological status of the waters according to individual hydro-chemical indices and data of bioindication. Considering the fact that the upper Tisza, including part of the basin of Lazeshchyna, are key territories of the ecological network of the Transcarpathian region (Scheme of ecological network, 2013), it is necessary to emphasize the necessity of solving the problems related to the contamination of the channel and river banks, plowed banks, over-loading of recreational facilities, which, like the settlements located along the Lazeshchyna river, lack sewage systems and water treatment facilities.

Taking it is highly recommended that the Tisza Water Basin Administration (TWBA) (Uzhhorod, Ukraine), as part of the development of a new Integrated Management Plan for the Tisza River Basin within the Transcarpathian Region, take into account the results of this study to develop measures to eliminate the problems we identified and environmental loading factors on the Lazeshchyna River and its water intake territory.

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Human impact due to the capitalization of water resources within the Jiu Gorge National Park

Emil MARINESCU[1,*], Oana MITITELU-IONUȘ[1]

[1]Geography Department, Faculty of Sciences, University of Craiova, 13 A I Cuza Street, 200252 Craiova
* *Corresponding author*: emilmrnsc@yahoo.com

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Abstract

Within the Jiu Gorge National Park, there was a project, which almost draws to an end, for the hydro-energetic capitalization of the river, which implies a potentially negative impact of this investment on the aquatic sector of the Jiu river in this sector. The current study analyses the hydrological regime of the Jiu river within the gorge sector (natural flow and controlled flow for the technical-economic capitalization parameters) and the impact on natural landscapes due to building and construction sites, bringing arguments and solutions for meeting the declared objective of conserving the aquatic ecosystems within the Jiu Gorge National Park. Thus, there must be ensured a minimum discharge (ecological discharge) on all rivers within the national park and Natura 2000 sit, to provide for this mere purpose of this category of protected areas.

Keywords: *national park, inner zonation, Natura 2000, water resources, hydrological regime, ecological flow, Jiu Gorge National Park*

Rezumat. Impactul antropic datorat valorificării resurselor de apă din Parcul Național Defileul Jiului

În Parcul Național Defileul Jiului s-a executat, aproape de finalizare, un proiect de amenajare hidroenergetică a râului care implică un impact potențial negativ al acestei investiții asupra mediului acvatic al râului Jiu în acest sector. Prezentul studiu analizează regimul hidrologic al râului Jiu în sectorul defileului (debit natural și debit controlat pentru asigurarea indicatorilor tehnico-economici de exploatare) și impactul asupra peisajelor naturale generat de șantierele deschise cu ocazia amenajării hidroenergetice, aducând argumente și soluții pentru îndeplinirea obiectivului declarat de conservare a ecosistemelor acvatice din Parcul Național Defileul Jiului. Se impune astfel asigurarea unui debit minim (debit ecologic) pe toate cursurile de apă din interiorul parcului național și sitului Natura 2000 care să asigure scopul acestor categorii de arii protejate.

Cuvinte-cheie: *parc național, zonare interioară, Natura 2000, resurse de apă, regim hidrologic, debit ecologic, Parcul Național Defileul Jiului*

Introduction

Due to their special status as natural protected areas from the second IUCN category, the management of water resources use within national parks must be taken into consideration for the management of riparian or aquatic species and habitats within these territories.

There are 13 national parks in Romania, covering an area of 3158 sqkm (1.32% of the national territory), and 12 of them are located in the Carpathians mountains, an area with huge potential of natural resources (woods, mineral reserves and water resources).Considering the need for the preservation of some samples of the Carpathians landscape, where the ecosystems are not yet altered by the human capitalization and settlements, these 12 national parks were established. All of them are also Natura 2000 sites, components of the ecological European network that aims to maintain the favourable conservation status for the species and habitats of community interest.

The water resources within three national parks (NP) (Retezat N.P., Domogled-Valea Cernei N.P., Cozia N.P.) are used for the production of hydroelectrical power, with large hydro-technical harnessing, such as artificial lakes (Iovan Lake and Cerna Lake - Domogled-Valea Cernei NP; Gura Apei Lake – Retezat NP; Turnu Lake, Gura Lotrului Lake - Cozia N.P.), or works for providing water to some settlements (Gozna Lake, Poneasca Lake - NP Semenic-Cheile Carașului). In some river basins, there are also detours of some rivers to supplement the discharge in neighbouring basins, providing water for the settlements (eg. The Timis and Nera – blown off course towards the Bârzava river within Semenic-Cheile Carașului NP).

These engineering works for the capitalization of water resources were made long before the respective territories were declared natural protected areas (Law 5/ 2000), and consequently, there is finally a sort of equilibrium within the ecosystems affected by these changes. The studies for the scientific foundation of national parks took into consideration the characteristics of the new aquatic and riparian ecosystems that resulted following the hydro-technical works.

In Europe a growth of hydropower production is aimed to achieve emission targets within the European Union by 2050. The most discussed European region regarding hydropower deployment is the Balkan region, with 37% of the hydropower

projects planned to be installed in areas with a high protection status (e.g. national parks or Natura 2000 areas) (Wagner et al., 2019).

Due to a lack in awareness of sedimentological challenges (e.g. lack of process understanding), various huge economical, technical and ecological problems emerge with an increasing relevance for hydropower industry, water management authorities and the society in future (Hauer et al., 2018).

In Romania, following the year 2000, another two national parks were declared, i.e. Buila – Vânturarița N.P. (2004) and the Jiu Gorge N.P. (2005), protected areas that were also included in the category of Natura 2000 sites beginning with 2007, the year Romania joined the EU. From this perspective, the Jiu Gorge Natura 2000 site includes 14 habitats of community interest, of which 3 are priority habitats and 22 species of community interest, of which 4 fish species. The Jiu Gorges National Park, located in the central part of the Southern Carpathians, covers an area of 11,127 ha (of which 10,927 ha are Natura 2000 sit – SCI), and it includes the banks of the Jiu river for some 33 km, length were the river carved an impressive gorge, with numerous entrenched meander (fig.1). The minimum altitude within the park is just 305 m at the end of the gorge, while the maximum altitude reaches 1688 m. At Livezeni, where the gorge sector begins, the height reaches 555 m.

The main ecotourism activity in the national park is rafting, the gorge area having the most favourable conditions for this sport among all the mountain rivers in Romania.

Figure 1: Entrenched meander within the Jiu Gorge National Park and the main ecotourism activity (rafting)

The proposals for the inner zonation of the Jiu National Park (Stociulescu et.al., 2005) were legalized following a government decree that same year. But in 2004, works for the hydroelectrical capitalization of the Jiu hydrographical basin began, on the territory of the future national park. The environment permits were obtained before this territory was declared natural protected area (national park, Natura 2000 sit), the technical and economic indicators for the objective *Hydro-energetic harnessing of the Jiu river along Bumbești-Livezeni sector* having been approved since 2003.

After it was declared protected area, the new research undertaken for the area pointed to a major human impact on the aquatic and riparian ecosystems in case the technical-economic indicators were to be maintained, as stipulated in the initial project.

Results and discussions

The study considers two main directions regarding the human impact on the ecosystems within the Jiu Gorge National Park: 1) the analysis of the hydrological regime, the change of which greatly affects some species and habitats of community interest; 2) the impact on natural landscapes due to the construction works and building sites within the national park.

The analysis of the hydrological regime implied the quantification of multiannual mean discharge, monthly mean discharge and seasonal discharge within the Jiu basin, on Livezeni –Sadu sector. However, the minimum mean monthly discharge is the most important from the point of view of the planned 2.7 m^3/s returned flow.

The mean annual discharge is the most general index of water resources, while the mean monthly discharge is an important index for the estimation of uniformity degree of the discharge of the Jiuriver. Its variation is conditioned by the meteorological factors (precipitations, water temperature, snow layer), as well as by the retaining and restitution capacity within the Jiu basin. The climatic elements have a rather altitudinal variation within the basin, considering there is a level difference of 1383 m, with a transversal mountainous sector; consequently, the flow is dependent on the direction and precipitation charge of air masses.

In order to highlight the variation of the annual discharge (Q_{an}) along the rivers and on the whole analyzed sector, we analyzed the *modulus coefficients* (k) compared to the mean multiannual discharge (Q_o). Thus, we obtained coefficients that point to the entire range of the annual discharge variation along the time frame that was analyzed.

The two extreme modulus coefficients represent the limits of the variation amplitude.

$K_{max} = Q_{anmax} / Q_o$; $K_{min} = Q_{an\ min} / Q_o$;

Table 1 presents the values and the variation amplitude of the annual discharge for multiannual profile (Barbălată, 2005). For a better correlation, the hydrological sections of two tributaries of the Jiu river within the gorge sector were also analyzed (Polatiște, Izvor), considering that the hydrotechnical harnessing works stipulate for extra water resources apart from the Jiu river, basically two tributaries (Bratcu and Dumitra), of the same hierarchic order (Horton-Strahler) and with similar hydrological characteristics.

Table 1 Characteristics of the mean multiannual and annual discharge within the Jiu basin in Livezeni-Sadu sector

Station (river)	Q_0 m^3/s	Maximum mean discharge			Minimum mean discharge			C_v
		$Q_{anual. max}$	K_{max}	Year	$Q_{anual. min}$	K_{min}	Year	
Livezeni (Jiul de Est)	**8.18**	12.4	1.51	1975	5.33	0.65	1990	2.32
Iscroni (Jiul de Vest)	**10.70**	17.4	1.62	1970	6.42	0.60	1993	2.71
Strâmbuța (Izvor)	0.752	1.09	1.50	1975	0.358	0.47	1996	3.04
Polatiște (Polatiște)	1.67	2.46	1.47	1967	0.940	0.56	2002	2.61
BorziiVineți (Jiu)	**21.60**	31.8	1.47	1970	13.5	0.62	1990	2.35
Sadu (Jiu)	**22.90**	32.4	1.41	1981	13.9	0.60	1990	2.33

The maximum modulus coefficients (K_{max}) vary between 1.41 – 1.62, while the minimum modulus coefficients (K_{min}) vary between 0.47 – 0.65, which reflects a compensatory situation of the most important physical-geographical factors for discharge (Tab. 1). The discharge variation coefficient (C_V) varies between 2.32 (Livezeni) and 3.04 (Strâmbuța), a fact explained by the controlled retention of water resources within Petroșani Depression (Valea de Pești Lake – Uricani).

The multiannual variation of mean discharge is better reflected in the rapport of these modulus coefficients (K_{max} / K_{min}), which in the case of the Jiu in this sector, has similar values for the two extreme sections (2.32 at Livezeni and 2.33 at Sadu). The lowest amount of precipitations (drought years) were registered in 1990, 1993, 1996, 2000, 2002, 2003, 2012, while the highest discharge was registered in 1967, 1970, 1975 şi 1981 (1960-2012 being the analyzed period). The mean monthly discharge varies from one month to another, being dependent on the climatic conditions, which differ within the same sector. The highest mean monthly discharge is registered during April-June, with a share of 15.3% in April to 17.6% in May, the month with the highest discharge at Livezeni, while in June it drops to 12.65% (Tab. 2, 3) (Barbălată, 2005). At Sadu hydrometric station, the highest discharge is registered in May, accounting for 17.1% of the annual discharge.

The mean seasonal discharge highlights the contribution of the feeding sources of the river under the influence of the climatic conditions proper for each season. Spring accounts for the highest input (some 41% of the water quantity that flow through this section), as a result of the frequent spring rains overlapping snow layer thawing due to positive temperatures. The lowest shares are registered during autumn and winter (16.3% and 15.5%, respectively), caused by the humidity deficit during autumn, while in winter, there is basically only snow, especially on the southern slopes of the Parâng and Vâlcan mountains. The uneven distribution of the discharge causes a considerable hydro-dynamic aggressiveness, which influences the intensity of the active processes within the Jiuriver bed and its tributaries within the gorge sector (Izvor, Polatiște, Dumitra, Chițiu, Bratcu),

which is also visible in the rapport between the discharge from the rainiest season (Rs) and the dry season (Ds) (Tab. 4) (Savin, 2008).

Table 2 Mean monthly multiannual discharge and the mean multiannual discharge within Jiu hydrographical basin (Livezeni-Sadu sector)

Hydrometric station (river)	Q_0 (m^3/s)	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Livezeni (Jiul de Est)	**8.18**	4.38	4.98	7.67	14.2	17.7	14.0	9.07	5.98	5.57	5.21	4.64	4.84
Iscroni (Jiul de Vest)	**10.70**	6.47	6.81	10.1	21.3	21.1	14.7	9.29	7.03	6.8	7.74	8.17	8.51
Livezeni(Jiu)	**18.88**	10.85	11.7	17.77	35.5	38.8	28.7	18.36	13.01	12.37	12.95	12.81	13.35
Strâmbuța (Izvor)	0.752	0.36	0.51	0.79	1.33	1.46	1.39	0.85	0.52	0.53	0.48	0.36	0.41
Polatiște (Polatiște)	1.67	0.82	0.83	1.37	3.22	3.43	2.81	1.79	1.26	1.21	1.15	0.994	0.991
BorziiVineți (Jiu)	**21.60**	12.4	13.7	20.7	41.3	44.9	34.6	21.0	14.1	12.7	14.4	14.6	14.3
Sadu (Jiu)	**22.90**	13.8	14.4	23.1	44.6	47.2	36.2	22.2	16.0	15.0	15.5	16.1	16.8

Table 3 The percentage of mean monthly liquid discharge compared to the mean multiannual volume within the Jiu hydrographic basin (Livezeni – Sadu sector)

Hydrometric station (river)	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Livezeni (Jiul de Est)	4.5	4.7	7.9	14.2	18.4	14.0	9.4	6.2	5.6	5.4	4.7	5.0
Iscroni (Jiul de Vest)	5.1	4.9	8.0	16.4	16.8	11.3	7.4	5.6	5.2	6.2	6.3	6.8
Livezeni*(Jiu)	4.8	4.8	7.95	15.3	17.6	12.65	8.4	5.9	5.4	5.8	5.5	5.9
Strâmbuța (Izvor)	4.0	5.3	8.9	14.5	16.5	15.2	9.7	5.9	5.9	5.5	4.0	4.6
Polatiște (Polatiște)	4.2	3.9	7.0	15.9	17.6	13.9	9.1	6.5	6.0	5.9	4.9	5.1
BorziiVineți (Jiu)	4.9	4.9	8.1	15.7	17.7	13.2	8.3	5.5	4.8	5.7	5.6	5.6
Sadu (Jiu)	5.0	4.7	8.4	15.7	17.1	12.7	8.1	5.8	5.2	5.6	5.6	6.1

Table 4 Variation of mean multiannual discharge and seasonal discharge of the Jiu river

Hydrometric station (river)	Q_0 m^3/s	Months								Rs /Ds
		Spring		Summer		Autumn		Winter		
		m^3/s	%	m^3/s	%	m^3/s	%	m^3/s	%	
Livezeni (Jiul de Est)	**8.18**	3.37	41.2	1.98	24.3	1.39	17.0	1.37	16.8	2.46
Iscroni (Jiul de Vest)	**10.70**	4.33	40.5	3.16	29.6	1.67	15.7	1.51	14.2	2.87
Livezeni (Jiu)	**18.88**	7.70	40.8	5.07	26.9	3.07	16.3	2.92	15.5	2.64
Strâmbuța (Izvor)	0.752	0.30	39.9	0.23	30.8	0.11	15.4	0.10	13.9	3.00
Polatiște (Polatiște)	1.67	0.67	40.5	0.49	29.5	0.28	16.8	0.22	13.2	3.04
BorziiVineți (Jiu)	**21.60**	8.96	41.5	5.83	27.0	3.47	16.1	3.32	15.4	2.70
Sadu (Jiu)	**22.90**	9.43	41.2	6.09	26.6	3.75	16.4	3.61	15.8	2.61

The minimum mean monthly discharge (Tab. 5) (Barbălată, 2005) is very important from the perspective of ensuring a minimum returned flow but especially for a minimum *ecologic discharge* (*salubrions discharge*) to secure the survival of fish, and especially the four species of fish and a mammal (*Lutra lutra),* of community importance. The *returned flow* is the minimum discharge that must be kept at all times in any section of the valley, downstream a dam, made up of the ecological discharge and the minimum discharge required by the users downstream. The minimum discharge on the Jiu river represents a hydrological phase that is extremely important for the evaluation of the impact on the aquatic ecosystems following the use of water resources for hydro-electrical purpose. Although from a methodological point of view and the means for measuring the minimum discharge there are no significant problems, it should be mentioned that there is no possibility for measuring the exact minimum daily discharge since there is no way to know exactly the water consumption for daily discharge. Consequently, the hindcast for natural flow during low waters was carried on only for the spent mean monthly discharge.

Table 5 Minimum mean monthly discharges within the Jiu hydrographic basin

Hydrometric station (river)	Q_0 (m^3/s)	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Livezeni (Jiul de Est)	**8.18**	0.168	0.196	3.06	3.95	5.78	4.16	2.95	1.91	1.22	1.43	1.46	1.61
Iscroni (Jiul de Vest)	**10.70**	1.87	1.93	3.36	7.38	2.91	3.06	2.48	1.88	1.42	1.55	1.46	1.98
Livezeni (Jiu)	**18.88**	2.03	2.12	6.42	11.33	8.69	7.22	5.43	3.79	2.64	2.98	2.92	3.59
Strâmbuța (Izvor)	0.752	0.046	0.068	0.162	0.305	0.440	0.090	0.053	0.011	0.035	0.008	0.008	0.037
Polatiște (Polatiște)	1.67	0.163	0.156	0.579	0.636	0.580	0.756	0.634	0.432	0.370	0.340	0.317	0.286
BorziiVineți (Jiu)	**21.60**	4.76	5.89	10.2	12.3	29.3	19.0	12.0	7.76	6.58	7.43	6.99	6.53
Sadu (Jiu)	**22.90**	4.88	4.58	10.5	12.5	11.4	8.83	6.43	5.26	5.31	4.07	4.13	4.86

In order to highlight the impact, we also analysed the mean discharge on gliding 5-year intervals (Tab. 6) (Savin, 2008). Thus, the decreasing values for these discharges (eg. from 10.2 m^3/s for the entire observation period to 8.62 m^3/s for the last 5 years that were analyzed). This drop can be correlated with the current climatic changes, and especially the temperature increase (favoring the evaporation on water bodies) and a draught tendency. From the perspective of ensuring a *returned flow* on the Jiu river bed of only 2.7 m^3/s at Livezeni section, overlapping a period with minimum monthly discharge, it must be mentioned that for three months a year (January, February and September), the hydrographical section will have a negative input (there is no possibility for providing this discharge), while for other two months (October and November), there will be a close call to cover it (0.28 m^3/s and 0.22 m^3/s, respectively, productive discharge for the hydro-energetic harnessing plant (Tab. 7).

Table 6 Mean discharge of the Jiu river (Livezeni – Sadu sector) for gliding time intervals (1950-2004)

Hydrometric station (river)	Mean discharge for gliding time intervals										
	1950-2004	1955-2004	1960-2004	1965-2004	1970-2004	1975-2004	1980-2004	1985-2004	1990-2004	1995-2004	2000-2004
Iscroni (Jiul de Vest)	10.20	10.20	10.20	10.30	9.96	9.49	9.09	8.87	8.84	9.29	8.62
Sadu (Jiu)	21.70	21.80	21.70	21.90	21.30	20.50	19.40	19.10	19.40	20.50	18.60

Table 7 Productive discharge overlapping the period with minimum monthly discharge within Livezeni Sector (the Jiu river)

Livezeni section	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Minimum mean monthlydischarge	2.03	2.12	6.42	11.33	8.69	7.22	5.43	3.79	2.64	2.98	2.92	3.59
roductive mean montlydischargeafter-coveringtheservitutedischarge	- 0.67	- 0.58	3.72	8.63	5.99	4.52	2.73	1.09	-0.06	0.28	0.22	0.89

We chose to analyse the least favourable situation, i.e. the minimum monthly discharge. After covering the servitude discharge (2.7 m^3/s) that was stipulated as technical-economic indicator, the productive discharge from the hydro-energetic point of view will vary between 0.89 m^3/s and 8.63m^3/s, on average 3.93m^3/s.

In this case, due to the morphometric features of the sections along the Jiu river within the gorge sector (*entrenched meander*),the turbulent flow regime that naturally characterizes the entire length of the river in this sector, will have a laminar character (laminar flow regime, with wet film between 7.1 and 10 cm related to the low-water discharge and the mean rapport of 1/1.4 between the minimum and maximum registered section).

Fish fauna will be most affected by this minimal regime flow. It includes four species of fish of community interest: steingressling (*Gobio uranoscopus*), southern barbel (*Barbus meridionalis*), Balkan spined loach (*Sabenejewia balcanica*), European bullhead (*Cottus gobio*) and a mammal species of community interest: european otter (*Lutra lutra*) (Habitats Directive 92/43/EEC). The habitat of priority community interest 91E0* alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* is also affected. To ensure a favorable conservation status for the fish species, a minimum ecologic discharge of 9.44 m^3/s is highly

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necessary (this amount represents half of the modulus multiannual discharge at Livezeni and downstream). This brings to an increase of water level in the section with an average coefficient of 3.49, and a mean level of 24.77 – 34.9 cm, respectively.

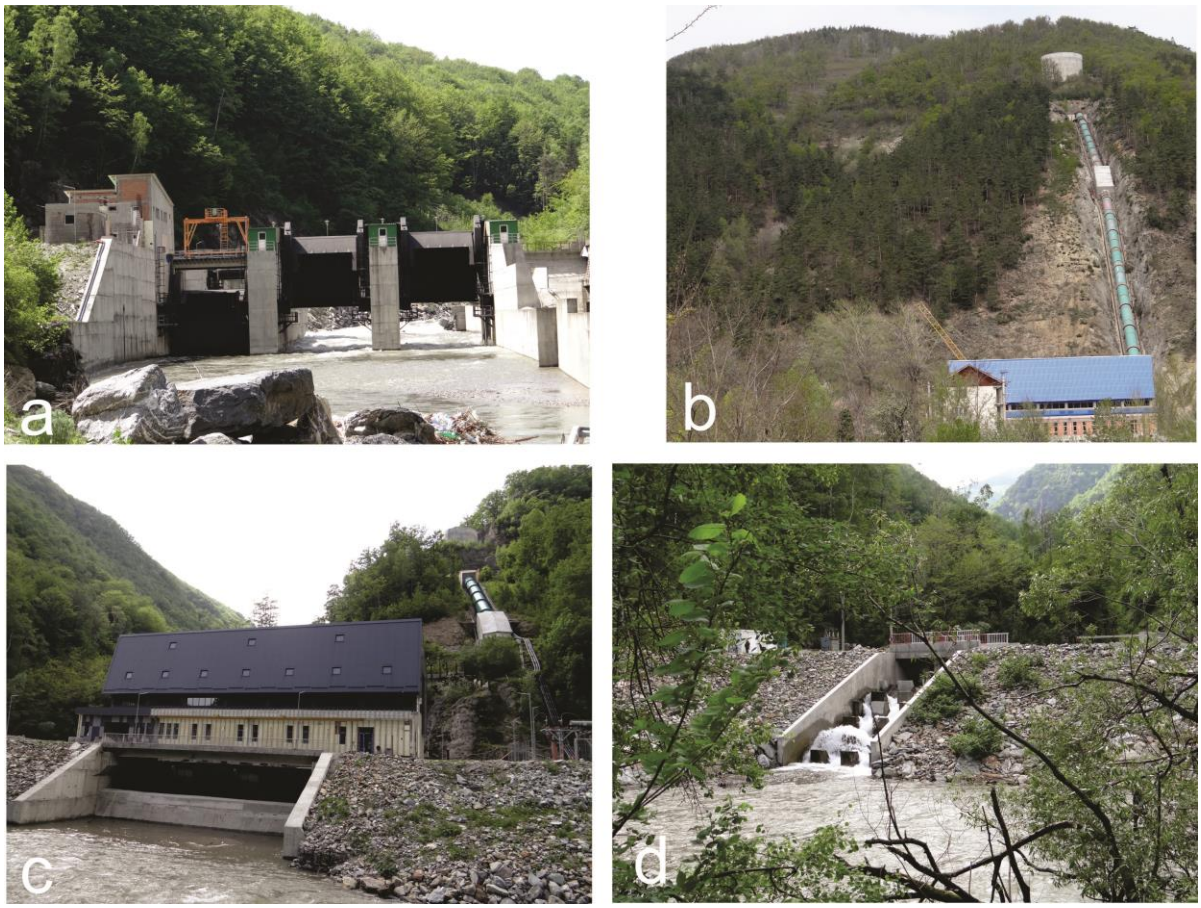

Figure 2: The main endpoints of the hydro-energetic harnessing of the Jiu river that were finalized (a. Livezeni dam, b. Bumbești hydro-energetic power plant, c. Dumitra hydro-energetic power plant, d. Dumitra tailboard)

Consequently, some measures are highly needed: a) regularization of the discharge within the upper basin of the Jiu by the catchment of new rivers upstream, including the neighboring basins (the Strei, Sebeș and Lotru); this is also justified from a medium term perspective of industrial revival of the economic area of the Jiu Valley; any further development will trigger an increase water consumption for economic units. b) re-evaluation of opportunities for water deviations that were built in the previous decades in order to supplement the water discharge in the neighboring basins (such as Jieț deviation toward the Lotru); c) changing the technical-economic indicators for the hydro-energetic system functioning (micro-power plant at Livezeni should not function permanently, giving up the energetic intake on the right bank, adjacent to the dam and changing of spillway from the dam body at its upper part; d) relinquish the secondary catchment for two tributaries within the Jiu gorge (Dumitra and Bratcu), for which no servitude discharge were envisioned, which leads to a disruption of their direct connection with the Jiu, thus affecting the aquatic systems. The contribution of the two tributaries on the gorge sector between the two hydro-electrical power plants (Dumitra and Bumbești) is 1.6 m^3/s.

The impact on natural landscapes due to constructions, the building sites that were abandoned within the national park is another aspect that affects the integrity of the national park.

The main objectives that were required constructions sites along the Jiu river are: 9m dam with a micro-hydroelectrical power plant at Livezeni, holding up to 130,000 $m^3$of water; two ground power plants (Dumitra and Bumbești), each one with a pressure knot comprising the surge chamber, gate house and pressure pipe-line (Fig.2); socket case with tailboard at Dumitra receiver, two main adductions (first step Livezeni-Dumitra – 7 km long and inner diameter of 3.80 m and the second step Dumitra-Bumbești, 12.5 km long and inner diameter of 4.00 m); secondary catchments at Dumitra and Bratcu. Currently, the works were suspended, but the construction sites remained, causing a great

prejudice to the natural landscape, especially in three locations within the national park: Livezeni – Măgura Tunnel, Dumitra Valley – Păiuș Tunnel and Păiușu Valley – Cerbanașu Mare Valley (Fig. 3). Such changes to the ground cover are not compatible with the national park status.

Figure 3: Abandoned construction sites that were opened for the hydro-energetic harnessing of the Jiu river (a-b, d. Dumitra valley – Păiuș tunnel, c. Cerbănașu Mare)

Conclusions

Currently, in some national parks, water resources are also used for the production of electrical energy, considered a renewable resource (green energy). However, the water resource is, at the same time, a component of the ecosystem that ensures a favourable preservation status for the species and habitats that are the object of conservation (especially those of community interest). Thus, there must be ensured a minimum discharge (ecological discharge) on all rivers within the national parks, to provide for this mere purpose of this category of protected areas. Within the Jiu Gorge National Park, there was a project, which almost draws to an end, for the hydro-energetic capitalization of the river, which implies a potentially negative impact of this investment on the aquatic sector of the Jiu river in this sector. The works were brought to a stop, the beneficiary being forced to reduplicate the procedures for environment approval, since the project was carried on within a national park and Natura 2000 site. It also emphasizes the extent of the potential negative impact of the hydro-energetic harnessing of the Jiu river within the gorge sector on the aquatic environment, as a result of a drastic decrease of river discharge, most of the habitats occupied by the rheophile species as well as by the riparian habitats will be affected to a great extent.

The catchment of Dumitra and Bratcu tributaries, without ensuring a servitude discharge, will break the direct connection with the Jiu, thus affecting the salmonide population that is find in these tributaries.

The most valuable fish species in the area, i.e. the four species of community interest (*Gobio uranoscopus, Barbus meridionalis, Sabenejewia balcanica, Cottus gobio*) will be ranked as unfavourable conservation status. The habitat of a mammal species of community interest (*Lutra lutra)* will be affected.

The change of the flow regime, from turbulent flow, with rapids and small waterfalls, to laminar flow in narrow wet film will render impossible any ecotourism activities (rafting) along the gorge sector

of the river. All these effects must be considered for the re-evaluation of the technical and economic indicators for the hydro-electrical harnessing of the Jiu along Bumbești-Livezeni sector in order to assess the environment according to the new environment legislation (establishment of the Jiu Gorge National Park and Natura 2000 ROSCI0063 site).

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How much open water do waterbirds have in the Banat Plain? The first permanent inland water bodies inventory at 10-m resolution using Sentinel-2 imagery at regional – scale

Marcel TÖRÖK – OANCE[1], Rodica TÖRÖK – OANCE[2,*]

[1] Faculty of Chemistry, Biology and Geography, Department of Geography, West University of Timișoara, Timișoara, Romania
[2] Faculty of Chemistry, Biology and Geography, Department of Biology and Chemistry, West University of Timișoara, Timișoara, Romania
* *Corresponding author*: rodica.torok@e-uvt.ro

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Abstract

In the Banat Plain were recorded more than half of the number of bird species in Romania. There are eleven Nature 2000 Bird Protection Sites (SPAs) and in all of them have been registered aquatic bird species. The water surface areas were greatly reduced since the starting of the hydro-technical works 300 years ago. Nowadays, the anthropic pressure associated with the more frequent drought periods continues to threaten the water bodies, on whose existence the numerous aquatic birds depend. For the mapping and evaluation of open water surfaces in the Banat Plain, in the context of a lack of precise, consistent maps and data, the first water bodies inventory at 10-m resolution was made based on Sentinel-2 multispectral satellite images. The heterogeneous and fragmented landscape, with a great diversity of aquatic units, conducted us to develop an object-oriented approach, which allowed a multi-scale classification process. Both spectral bands and normalized differentiation water indices were used in the rule-based classification algorithm for water detection. The accuracy assessment indicated a very good overall accuracy of 96%, with a Kappa coefficient of 0.91. Also in our dataset, the small water bodies were mapped more accurately than in the other six water bodies datasets at global or European scale we compared with. The results drawn from both qualitative and quantitative assessments indicated that the water dataset developed in this study could be used as an inventory and a reference map for the permanent open water areas from the Banat Plain. It may represent the starting point for better aquatic management and elaboration of ecological strategies to support bird necessities and to counteract the increasing vulnerability and environmental threatening of waterbird species.

Keywords: *Water body inventory, Waterbirds, Sentinel-2, Object-based image analysis, the Banat Plain*

Rezumat. De câtă apă dispun păsările acvatice în Câmpia Banatului? Prima inventariere la scară regională a suprafețelor acvatice la o rezoluție spațială de 10 m utilizând imagini satelitare Sentinel-2

În Câmpia Banatului au fost consemnate peste jumătate din numărul de specii de păsări din România. Aici există unsprezece Situri de Protecție Avifaunistică (SPA) Natura 2000, în toate fiind prezente și specii de păsări acvatice. Suprafețele acvatice s-au restrâns foarte mult odată cu demararea lucrărilor hidrotehnice acum cca. 300 de ani iar în prezent intervenția antropică asociată cu perioadele secetoase tot mai frecvente continuă să amenințe suprafețele acvatice, de a căror existență depind numeroasele păsări acvatice. Pentru evaluarea suprafețelor acvatice, în lipsa unor hărți și date oficiale precise și actuale, s-a realizat prima cartare a suprafețelor ocupate de apă din Câmpia Banatului, la o rezoluție spațială de 10 m, pe baza imaginilor satelitare multispectrale Sentinel-2. Peisajul eterogen și fragmentat, cu o mare diversitate a unităților acvatice, ne-a determinat să utilizăm metoda de clasificare orientată – obiect, care a permis o abordare multi-scară. S-au utilizat atât benzile spectrale cât și indici normalizați de diferențiere a apei. S-au realizat două segmnentări ale imaginilor: prima a dus la obținerea unor obiecte ce au permis clasificarea unităților acvatice de mari dimensiuni iar cea de-a doua a avut ca rezultat generarea unor obiecte folosite penru detectarea suprafețelor acvatice mici. Clasificarea a avut o acuratețe generală foarte bună, de 96 %, cu un indice Kappa de 0.91. Setul nostru de date a fost comparat cu alte șase seturi de date ale suprafețelor acvatice la nivel global și european, observându-se o cartare mai precisă a corpurilor de apă de mici dimensiuni. Astfel, rezultatul acestui studiu reprezintă primul inventar a unităților acvatice permanente pentru Câmpia Banatului, la rezoluția de 10 m. Acesta poate fi utilizat ca suport pentru o mai bună gestiune a unităților acvatice în vederea elaborării unor strategii privind protecția păsărilor acvatice și al contracarării amenințărilor crescânde asupra habitatelor acestora.

Cuvinte-cheie: *inventarul suprafețelor acvatice, păsări acvatice, Sentinel-2, analiza imaginilor orientată – obiect, Câmpia Banatului*

Introduction

The essential role of the inland water bodies to terrestrial ecosystems, socioeconomic development, and global biogeochemical cycles is already well known (Harrison et al., 2008; Likens, 2009, 2013; Verpoorter et al., 2014). Inland waters and swamps represent the main habitat for waterbirds and play an important role for the stopover of migratory birds (Gyurácz et al., 2011). The degradation or loss of wetland stopovers has a negative influence on birds

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migration and survival (Merken et al., 2015). The small water bodies have also great importance for biodiversity and ecosystem services (Biggs et al., 2016) with the direct implication in waterbirds conservation or even in farmland birdlife (Davies et al., 2016). As they are belonging to the top level of the food chain, aquatic and semiaquatic birds represent biological indicators in aquatic ecosystems (Kupekar et al., 2015).

Despite this importance, for many areas of the Earth, a complete and accurate inventory of the water bodies is still missing. Thus, remote sensing data have been used often for the water bodies mapping, with different results according to the spatial resolution of the satellite images and the classification method. Most of the previous studies used Landsat imagery for water mapping, at a spatial resolution of 30 m. There were several normalized indices derived mainly from 30-m resolution Landsat imagery (Feyisa et al., 2014; Li et al., 2016; McFeeters, 2007; Shen & Li, 2010; Xu, 2007) but also from 10-m resolution SPOT multispectral bands (Lacaux et al., 2007) for better discrimination of the water from non-water areas. Some automated methods for water delineation from Landsat images were also developed, with promising results (Feyisa et al., 2014; Jiang et al., 2014; Rishikeshan & Ramesh, 2018). Since 2015, when the first Sentinel-2 satellite was launched, the European Space Agency (ESA) provides free images with a higher spatial and radiometric resolution and a shorter revisit time than Landsat, with great potential in the land cover mapping (Drusch et al., 2012). In the last five years, Sentinel–2 images had been used for water mapping based mainly on previous normalized indices, which were transferred and adapted to Sentinel-2 images, using both pixel-based and object-based image approaches (Du et al., 2016; Gordana Kaplan & Ugur Avdan, 2017; Wang et al., 2018; Yang & Chen, 2017; Yang et al., 2017). Although the majority of the previous studies were focused on smaller regions, there are some global inland water body datasets, at the medium and high spatial resolution, derived either only from remotely sensed data (Feng et al., 2015; Liao et al., 2014; Pekel et al., 2016; Verpoorter et al., 2014) or from remotely sensed data in association with other types of data and information (Lehner & Döll, 2004). There are also two datasets developed for Europe in the frame of the Copernicus Land Monitoring Service (https://land.copernicus.eu/), one of them being derived from Sentinel-1 and Sentinel-2 data (Table 3).

Study area

The Banat Plain is one of the largest plains of Romania, with an area about 7450 km2. It is located in the western part of Romania and it overlaps mostly over the Timis County and partly over Arad and Caraș – Severin Counties (Fig.1). The plain is formed by alluvial fans of the main rivers running from the Carpathians: Mureș River, in the northern part, and Timiș, Bega and Bârzava Rivers in the central and southern part (Badea et al., 2011). The mean altitude of the study area is 102 m. The maximum of 290 m is reached at the contact with the Banat Hills and the minimum altitude of 66 m is recorded in the western half part, where the entire area is subsiding. The slopes are gentle with a mean value below 2 degrees. The Mureș River, which is the most important river in the area, has a slope between 20 and 30 cm/km (Kiss et al., 2012). As a consequence, the area is distinguished by the meandering rivers, braided channels, abandoned river channels, oxbow lakes, ponds, and wetlands. In the past, the almost entire area of the subsiding plain was covered by wetlands, swamps, lakes, and low-order streams, but the hydro-technical works, started in the 18th century and continued to '70s of the 20th century, have decreased most of the water surface area and drained the majority of the swamps and wetlands (Kiss, 1999; Török-Oance & Török-Oance, 2004; Török-Oance & Török-Oance, 2005; Torok-Oance & Torok-Oance, 2005). Even so, the main rivers and the remnant small waters and swamps preserve rich biodiversity and a diverse waterbird species protected in 11 Natura 2000 Special Protection Areas (SPA) totalizing above 8% of the Banat Plain area.

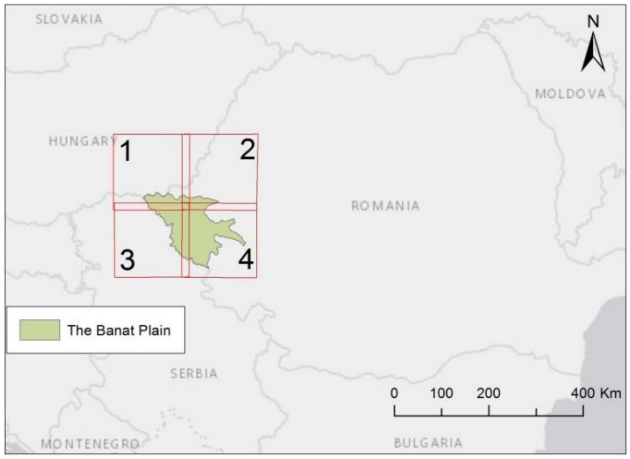

Fig. 1: Location of the Banat Plain and the swath of the Sentinel-2 images (1-4)

The objectives of this study are: (1) to realize the first permanent surface water bodies inventory of the Banatului Plain at the 10-m resolution, using Sentinel-2 multispectral data; (2) to evaluate the performance of this inventory by comparing it with similar water body datasets and statistical data; (3) to make a quantitative and qualitative analysis of the inland water bodies related to water birds life and conservation.

Materials and methods

Remote sensing data

Four clouds free Sentinel-2 scenes acquired on 12 October 2019 covering the Banatului Plain were used for the open water detection (Table 1). The Sentinel scenes were downloaded from Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus/#/home).

The Sentinel-2 scenes are Level-2A products which are already orthorectified and radiometrically corrected in Bottom of Atmosphere (BOA) reflectance, provided in UTM/WGS84 projection.

Table 1. Sentinel 2 spectral bands used in this study with their radiometric characteristics and spatial resolutions

Spectral Band	Wavelength (µm)	Spatial resolution (m)
Blue (B2)	0.46–0.52	10
Green (B3)	0.54–0.58	10
Red (B4)	0.65–0.68	10
Near Infrared (B8)	0.784–0.9	10
Short Wave Infrared (B11)	1.565–1.655	20
Short Wave Infrared (B12)	2.1–2.28	20

The further pre-processing operations consist of mosaicking of all four scenes into a single one (SNAP 6 software) and the sharpening of the SWIR bands (ENVI 5.1 software). We downscaled the 20-m resolution SWIR band to 10 m based on pan-sharpening for preserving the detailed information available at the 10-m resolution in the normalized indexes computed from SWIR bands (Du et al., 2016). The SPEAR pan-sharpening algorithm implemented in ENVI software was used. Instead of the Panchromatic band, which is not provided by Sentinel-2 sensors, we used the NIR band (B8) (Du et al., 2016).

The computing of the Normalized Indexes used for water surface detection (Table 2) was done in SNAP 6 software. The Land and Water Mask (LWM) and Brightness were computed in eCognition software.

Table 2. The normalized indices derived from Sentinel-2 bands used for water surface detection.

Table 2. The normalized indices derived from Sentinel-2 bands used for water surface detection

Data	Equation/Description	Reference/data source
Normalized Difference Water Index (NDWI)	NDWI = (GREEN-NIR) / (GREEN+NIR) It detects the surface waters in wetland environments	McFeeters (2007)
Modified Normalized Difference Water Index (MNDWI)	MNDWI = (GREEN - SWIR 2) / (GREEN+SWIR 2) It enhances open water features while efficiently suppressing built-up areas, vegetation and soil noises.	Xu (2007)
Normalized Difference Ponds Index (NDPI)	NDPI = (SWIR 1 – GREEN) / (SWIR 1+ GREEN) It distinguishes small ponds and water bodies (down to 0.01 ha) and differentiates vegetation inside ponds from that in their surroundings	Lacaux et al. (2007)
Normalized Difference Vegetation Index (NDVI)	NDVI = (NIR – RED) / (NIR + RED) It distinguishes water from vegetation	(Rouse et al., 1974)
Land and Water Mask (LWM)	LWM = NIR/(Green+0.0001)*100 It distinguishes water from non-water areas	(Gilani et al., 2015)
Mean Brightness	It is calculated only for image objects, post-segmentation, using image layers with positive values (specific for eCognition software).	Reference Book eCognition Developer https://geospatial.trimble.com/products-and-solutions/ecognition

GREEN = green band ; RED = red band; NIR = near-infrared band; SWIR1= short wave infrared 1; SWIR2= short wave infrared 2

The spectral bands and normalized indexes were further used as input bands in the image classification process conducted in an object-based image environment in eCognition 9.1 software. The Multiresolution

Segmentation algorithm (Baatz & Schape, 2000) implemented in the software eCogniton was used to subdivide the entire image and to obtain the image primitives. The algorithm relies on the scale parameter to subdivide the image into image objects. The scale parameter determines both the spectral heterogeneity and the average size of the image objects (Baatz & Schape, 2000) and also heavily impacts the classification accuracy (Gao et al., 2011). For enabling objectivity in choosing the scale parameter we used the Automated Estimation of Scale Parameter (ESP2) tool implemented in eCognition (Dragut et al., 2014). The tool estimates the appropriate scales for segmentation, based on the concept of local variance (Woodcock & Strahler, 1987) and works on multiple layers simultaneously. ESP2 was performed on the NIR band, NDWI MNDWI, and NDPI layers. We selected two values for scale parameters, 136 and 20 (shape = 0.1 and compactness= 0.5), from the local variance computed graph, related to the dimension of the water bodies. Compatibility and significance assessment of boundaries of the delineated objects was done by visual comparison.

The first segmentation, at a scale parameter of 136, had, as a result, bigger image objects used for the classification of the large water bodies. The second segmentation was computed on the unclassified pixels at scale 20 and generated smaller image objects which were used for the classification of the small water surfaces. Because of the great diversity of the water bodies and the high heterogeneity of the land cover, the delineation of the image objects in "water" and "no-water" classes, according to objects features, was made by a rule-based classification in three steps: first, we classified the well-highlighted larger and deeper water areas, like big lakes and reservoirs or large rivers sectors, based on threshold values for the NIR band and Brightness; second, we classified shallower waters based on thresholds values for NIR, MNDWI, LWM and Brightness and third, small eutrophic waters, sometimes surrounded by vegetation or included in wetlands, which were classified based on threshold values for the NDVI, NDPI, and Brightness. The few shadows areas in the proximity of the tall buildings in Timișoara misclassified as "water" were corrected using manually classification. In the final step, all three classes were merged into a single water class. The result was exported as shapefile for the integration and analysis in ArcGIS software.

Ancillary data

Ancillary GIS vector data were used for spatial analysis, zonal statistics and cartographic representation: the limits of Natura 2000 SPAs (http://www.mmediu.ro/articol/date-gis/434), the limit of the Banat Plain (Badea et al., 2011) and the map of the settlements from the study area.

Although some global water body datasets were developed, we used for the comparison only the available scale-similar inland water maps (Table 3).

Table 3. The global/continental inland water datasets and their characteristics

Water body dataset	Data used for the dataset building	SMWB (ha)	Reference/source
Global Lakes and Wetlands Database (**GLWD**) (vector dataset)	digitized inventories, archives, and remote sensing data from various sensor types	1	Lehner and Döll (2004)
GLCF global inland surface water dataset (**GLCF_GIW**) (30 m resolution)	Landsat	0.09	Feng et al. (2015)
Global Surface Water (**GSW**) (30 m resolution)	Landsat 5, 7 and 8	0.09	Pekel et al. (2016)
Water and Wetness 2015 (**WW 2015**) (20 m resolution)	Sentinel-1 and Sentinel-2	0.04	https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness
EU-Hydro* (vector dataset)	Various EO data; EU-DEM for drainage model	1	https://land.copernicus.eu/imagery-in-situ/eu-hydro
CORINE Land Cover inventory 2018 (**CLC 2018**) (vector dataset)	Various satellite data: Landsat 5, 7 and 8, SPOT 4 and 5, IRS P6 LISS III, RapidEye and Sentinel-2	25	https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

SMWB = the smallest mapped water body; when this information was missing we considered that SWMB is equivalent to a one-pixel area in hectares

Ground-Truth Data and accuracy assessment

Very high resolution (VHR) Pléiades images, 0.5 m resolution color orthophoto, VHR images in GoogleEarth, GIS layers and GPS data collected in 2004 – 2016-time interval was used for the accuracy assessment. The 1500 sample points were randomly generated in a stratified random scheme, half of them in the water areas. The confusion matrix, the Kappa index and the overall accuracy (OA), producer's accuracy (PA) and user's accuracy (UA) (Congalton, 1991) were computed for the assessment of the results of the classification.

Results and discussion

A rule-based classification algorithm developed in an object-based image analysis environment was applied to Sentinel-2 Level-2A images over one of the largest plains in Romania, well known for its waterbird species richness (Kiss, 1999; Stănescu, 2005), in order to realize the first inland water bodies inventory at the 10-m resolution for this area.

The satellite images were deliberately selected at the end of the autumn season, after a long rainless time interval in an extremely droughty year, because we aimed to map the permanent water bodies. At the moment of the satellite images acquisition, after more than three months of water scarcity, the entire Banat Plain was affected by extreme agricultural and hydrological drought, according to Romanian National Meteorological Administration (http://www.meteoromania.ro), so the detected water areas represent the stable water habitat that water birds could rely on the whole year.

The inventory summarized 2396 inland water bodies (rivers, lakes, reservoirs, ponds, low-order streams, and ditches) with areas between 0.01 ha and 621 ha. The total area of detected open water surfaces is 3293.5 ha. The main rivers summarized almost 60% of the total open water area.

Qualitative analysis

Figure 2 illustrates the resulted image objects after the running of the two segmentation algorithms. Both the bigger image objects resulting after the first segmentation, using a scale parameter of 136 and the smallest ones resulting after the second segmentation, at scale parameter of 20, are significant and meaningful, their boundaries fitting well the water bodies.

A visual inspection of the classification results was first made by comparing it with VHR images and orthophotos (Fig.3). Special attention was accorded to the long-time monitoring areas where the seasonality of the water bodies was well known (Török-Oance & Török-Oance, 2016).

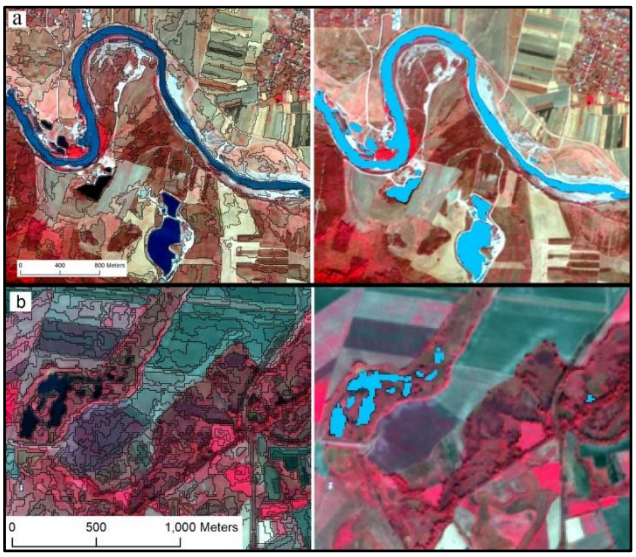

Fig. 2: Segmentation (black outlines) and classification results (light blue polygons) draped on NIR false-color image: (a) bigger image objects used for the classification of the big rivers and lakes (mixed agricultural and forest area along the Mureș River); (b) smaller image objects used for the classification of the small waters (mixed agricultural and swamps area in the Mlaștinile de la Satchinez SPA)

Fig. 3: Visual comparison of the detected water (blue polygons) with Pléiades 2-meters resolution image (Beregsău Mare village)

We have to mention that our inventory has some limitations like any other map derived from remote sensing data. The detected water surface is slightly underestimated because the water detection was limited by the spatial resolution of the satellite images which is 10 m. All water surfaces with an area below 0.01 ha or narrower than 10 m could not be detected. Another issue was the riparian vegetation because in many cases, the trees canopy masked the water surface mainly along the small rivers and ditches (Fig 4).

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Fig. 4: Small ditches south of Bârzava River (light blue pixels) which could not be mapped because of their width smaller than a Sentinel-2 pixel

The quantitative assessment

The OA recorded an excellent value, more than 95% of the detected water areas were correctly classified from the total number of validation areas (Congalton, 1991). At the water class level, the commission error (UA) was 0.96 and the omission error (PA) was 0.94. The Kappa Index of Agreement (KIA) was 0.91. The very high level of the classification accuracy sustained that the resulting 10-m resolution dataset derived from Sentinel-2 imagery could be used as an inventory and a reference map for the Banat Plain. A similar higher accuracy of the classification was obtained using object-based image analysis methods (Blaschke, 2010; Cheţan et al., 2018; G. Kaplan & U. Avdan, 2017).

Comparison with previous global and European water datasets and national statistics

Both visual and quantitative comparison was made between our water inventory and other similar scales water datasets (Table 5). Even if the smallest mapped water body has a surface between 0.04 ha and 25 ha, none of the above-mentioned datasets were able to accurately map the inland waters from the Banat Plain (Fig. 5). In the area presented in this figure, there are many lakes with areas between 3 and 6 ha which are not present in any of the datasets. On the GLCF_GIW dataset, only a few water areas are mapped along the river, smaller than the lakes in the nearby area which are not mapped. GSW dataset mapped both river segments and some lakes located in the floodplain. Both datasets are greatly underestimating the real water surface. The WW 2015 dataset mapped well the river and many of the lakes but there are still many missed lakes, even their areas are similar to the mapped ones. On the CLC 2018 vector dataset appears only the river which is highly overestimated; the area of each of the lakes is below the minimum mapping unit which is 25 ha so they could not be mapped. The maximum width of the Timiș River in this area, measured on VHR satellite images is 101 m, but on the CLC 2018 map it is above 400 m. In the Eu-Hydro vector dataset, the river was well mapped but almost all the lakes are missing.

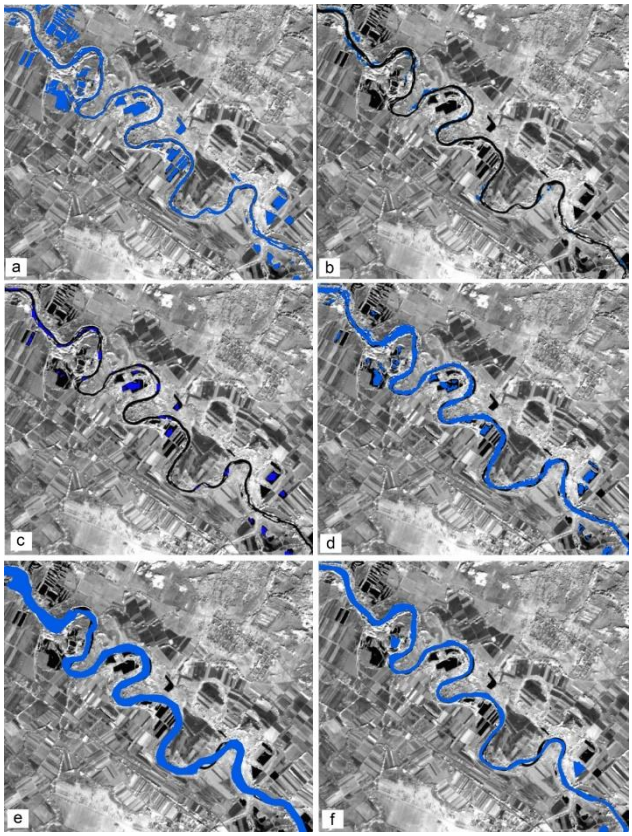

Fig. 5: The comparison of the water bodies detected in this study (a) with other global or continental water bodies datasets: (b) GLCF_GIW at 30 m resolution; (c) GSW at 30-m resolution; (d) WW 2015 at 20-m resolution; (e) CLC 2018 vector dataset; (f) EU-Hydro vector dataset. The area in the image is located along the Timiș River, south to Lugoj City.

The abbreviations are according to Table 3

There are also great differences in the total water area in hectares computed from each dataset for the study area (Table 4). The vector datasets are greatly overestimating the area of water mainly because of the dataset building methodology (https://land.copernicus.eu/pan-european/). Not a single water body was mapped in the GLWD dataset for the study area. Both 30-m resolution datasets, GLCF_GIW and GSW present lower water areas, below 2000 ha.

Table 4. The total water area in the Banat Plain computed from different water datasets

Water body dataset	Area (ha)
GLWD	0
GLCF_GIW	1935.7
GSW	1561.5
WW 2015	2750
CLC 2018	10741.4
EU-Hydro	4698.76
10-m resolution dataset derived from Sentinel-2 images	**3293.50**

The National Institute of Statistics (INS) provided through the TEMPUS Online portal (http://statistici.insse.ro:8077/tempo-online/#/pages/tables/insse-table) statistical data regarding the terrain land cover. Since the data are provided at an administrative unit level and not for physical-geographical units, we could only use the data for the Timiș County. This county contains more than 85% of the Banat Plain area. The total area occupied by waters in Timiș County was, for the 2014 year (the most recent year in the database) 15275 ha which represents an area 6 times larger than the one we found in this study and also larger than CLC 2018. This difference could be explained by the fact that the INS data are based on old 1992 topographical surveys and in the class "Land covered with water, ponds" are included also the wetlands, so these data could not provide useful information about open water surfaces.

The maps derived from remote sensing data, at an appropriate spatial resolution, remain the best alternative in areas with high seasonal water dynamic and an increasing anthropic impact and where the official data are inconsistent and not updated.

Waterbody inventory at SPA sites level

In these 11 SPA sites from Banat Plain, there have been recorded 26 species of waterbirds (European Environment Agency) which are included in annex 1 of the Birds DIRECTIVE 2009/147/EC. The species belong to six orders (Gaviiformes, Pelecaniformes, Ciconiiformes, Anseriformes, Gruiformes, and Charadriiformes) and are representatives of eleven families (Gaviidae, Phalacrocoracidae, Ardeidae, Ciconiidae, Threskiornithidae, Anatidae, Gruidae, Rallidae, Recurvirostridae, Scolopacidae, Sternidae). The most numerous waterbird species are recorded for Lunca Mureșului Inferior and Mlaștinile Satchinez.

Regarding conservation status, all aquatic and semiaquatic bird species reported for the 11 protected areas and included in annex 1 are classed at least concern (LC) according to the European Red List of Birds (BirdLifeInternational, 2015). In Romania though, encountered species as Phalacrocorax pygmeus, Nycticorax nycticorax, Ardeola ralloides, Ciconia nigra, Ciconia ciconia, Plegadis falcinellus, Aythya nyroca, Crex crex, Recurvirostra avosetta, are considered vulnerabile species and Ardea purpurea, Platalea leucorodia, Egretta garzetta, Himantopus himantopus are considered threatened species (Botnariuc & Tatole, 2005).

Beside these species corresponding to annex 1 of the Birds Directive, which need special conservation measures, many other present species also depend on the existence of water and contribute to existing avian biodiversity. Thus, in Mlaștinile Satchinez SPA have been identified over the years 167 bird species (Stănescu, 2005) and in the Banat Plain 114 waterbirds species (Kiss, 1999).

The present analysis reveals that, according to official data from 2007, the total area of the 11 SPA sites is 63328.40 ha, from which water occupies an area of 1669.19 ha (Table 5), which represents 2.6%. The water area detected in this study is even smaller, only 2.25%, most probably due both to the extreme drought in the summer of 2019 and the anthropic impact during the last 12 years. The most significant open water area, above 870 ha, was detected in Lunca Mureșului Inferior SPA, but it is significantly smaller than the official reported water area. The Mureș River summarize 98% of the total detected open water area in this SPA and sustained the greatest number of protected waterbird species (21 species) from all protected areas in the Banat Plain.

There are two SPA sites where we detected almost no water surfaces. In the first one, Hunedoara Timișană SPA, are reported only two waterbird species that are sustained by the existing wetlands. In the second one, Mlaștinile Satchinez, there are 66% waterbirds (21 species) from the total of protected birds in this SPA which rely on the extended wetlands included in the SPA area and mostly on the nearby open water surfaces, outside the protected area (Kiss, 1999; Stănescu, 2005; Török-Oance & Török-Oance, 2016). A special situation, most probably a data omission, is recorded in Lunca Timișului SPA, where, in the official data, are not mentioned water surfaces but 39% of the reported protected birds are waterbirds. We detected over 246 ha of open water, represented mainly by the Timiș River which is crossing the site on its entire length.

Table 5. The Natura 2000 SPA in the Banat Plain – relevant data

Site Code	Site Name	Total area (ha)*	Area of open water (ha)*	Area of the detected open water (ha)	Number of protected birds' species**	Water-birds species (%)
ROSPA0047	Hunedoara Timișană	1537	0.00	0.00	14	14
ROSPA0069	Lunca Mureșului Inferior	17428	1391.79	873.73	46	46
ROSPA0078	Mlaștina Satchinez	268.3	0.00	0.11	32	66
ROSPA0079	Mlaștinile Murani	301.9	75.86	55.02	4	75
ROSPA0095	Pădurea Macedonia	4625.3	0.00	67.08	17	53
ROSPA0126	Livezile - Dolaț	6564.6	0.00	0.00	10	30
ROSPA0127	Lunca Bârzavei	2393.3	71.62	109.22	11	64
ROSPA0128	Lunca Timișului	13404.1	0.00	246.78	28	39
ROSPA0142	Teremia Mare - Tomnatic	6627.7	0.00	3.34	8	38
ROSPA0144	Uivar - Diniaș	10043.3	0.00	25.37	17	47
ROSPA0164	Pescaria Nadlac	134.9	129.91	71.72	11	82
TOTAL		**63328.4**	**1669.19**	**1425.37**		

** Official data from the European Environment Agency (EEA) site (https://www.eea.europa.eu/).*
*** According to Annex 1of the Birds Directive*

The total area of open water surfaces we detected for the entire protected areas is lower than in the official records. It represents the permanent water bodies that remain even after a long drought period. Open waters are used by birds for feeding, resting, and breeding. It has been suggested that between the most important environmental factors to which birds respond is the open water area and the ratio between emergent vegetation and open water (Pyrovetsi & Crivelli, 1988). Many studies showed that for the study area the open water decreased in the last 50 years and the clogging of the wetlands is the synchronous process in some areas (Kiss, 1999; Stănescu, 2005; Torok-Oance & Torok-Oance, 2005). For waterbirds, open water surfaces have great importance, both in launching to flight and landing from flight. In this regard, the reduction of open water spaces has a negative effect on waterbirds, especially geese and ducks (Stănescu, 2005). When landing on water surfaces, larger water birds need greater braking distances (Hart et al., 2013).

Water bodies are also important stopovers for wetlands migrant birds (Gyurácz et al., 2011; Pocewicz et al., 2013), so efforts for the maintaining or restoring of the water surfaces were made. It was shown that the restoration of water surface could restore migrant bird populations (Gyurácz et al., 2011) or, even when the restoration succeeded only partially, the waterbirds feeding area was extended (Török-Oance & Török-Oance, 2016). The small waters are also important, many of them could be refuges for species which have disappeared from larger, more damaged, waterbodies (Biggs et al., 2016).

Conclusion

As open water is of great importance for waterbirds, an accurate assessment of the water surface offers the information which may serve to further better protection of birds. The existing official data regarding the water bodies in the Banat Plain, where the seasonality of the water is high and the anthropic impact is increasing, are not consistent enough and are not proper to support applications for waterbirds and biodiversity conservation. In this situation, the water body maps derived from appropriate spatial resolution remote sensing data represent a suitable solution.

We produced the first permanent water body inventory at a 10-m resolution at a regional-scale, for the Banat Plain. Given the great diversity of the water bodies and the high heterogeneity of the land cover, the object-based image analysis allowed us a multiscale classification approach which led to a better result. The very good performance of the classification algorithm (overall accuracy of 95% and a Kappa coefficient of 0.91) sustained that the resulting dataset could be used as an inventory and a reference map for the open water areas from the Banat Plain. Also in our dataset, the small water bodies were mapped more accurately than in the other six water bodies datasets at global or European

scale we compared with. It may represent the starting point for better aquatic management and elaboration of ecological strategies to support bird necessities and to counteract the increasing vulnerability and environmental threatening of waterbird species. Since we mapped the permanent water bodies, the dataset could be also used further as a feasible, stable, training data set for the development of machine learning classifiers for mapping complex water.

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Aridity risk in the west of the Oltenia Plain: natural factors and human impacts on land degradation

Cristian RĂDUCĂ [1,*], Lavinia CRIŞU[1], Sandu BOENGIU[1]

[1] Department of Geography, Faculty of Sciences, University of Craiova, A.I. Cuza St., No.13, Romania
* *Corresponding author*: c_raduca@yahoo.com

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Abstract

The lands of southern Oltenia had different evolution stages in the last century being influenced by the climatic factor but especially by the anthropic factor. From the extensive areas of ponds and marshes in the pre-war period to drainage, embankments, irrigation systems and planting of the windbreakers and shelterbelts in the 50s - 60s (reflected in the agricultural peak of the 70s – 80s) and to the present day, we are witnessing the aridization of the lands and the extension of the predominantly sandy areas, impracticable to the current type of agriculture.
After 1990, agriculture in the southern part of the Oltenia Plain had an accelerated decline caused by the destruction of the irrigation systems, the deforestation of the windbreakers and shelterbelts, the situation of land ownership and the failure of the adaptation of the crops to the soil types. In 2012 the percentages of irrigated areas reached 0% capacity used out of 76,820 ha in the Blahnița Plain and 1% capacity used out of 299,621 ha in the Oltenia Plain. All these have led to land degradation and amplification of geomorphological processes, especially on sandy surfaces, where the lack of vegetal layer together with the wind process lead to destabilization and movement of sand dunes.
This article aims to conduct a spatial-temporal analysis of several types of lands exposed to drying, whose surface has increased considerably to almost 50,000 hectares. Another 50,000 hectares are predisposed to this phenomenon in the Oltenia Plain, on the western part of Jiu. An environmental management strategy for a sustainable development could be made for the protection of the lands against the winds by planting windbreakers and shelterbelts of fast growing species (acacia, hybrid poplar, wild pine, walnut tree).
The research methodology involved the processing of the annual average data on temperature, precipitation and wind direction from the weather stations in south-west Oltenia, the processing of the data from the Landsat, Corine maps, as well as the analysis of the data provided by the examination reports on the occupation of land offered by the Ministry of Regional Development and Public Administration.
In the analysis of land degradation as a result of the aridization process, the situation of the current vegetation layer was taken into consideration using the NDVI (Normalized Difference Vegetation Index) and data taken from Corine Land Cover between 1990 and 2006 regarding the change of the land use in the Oltenia Plain.

Keywords: *aridity, sandy lands, land management, windbreakers trees, Corine Land Cover, South-West Oltenia*

Rezumat. Pericolul aridizării în vestul Câmpiei Olteniei: impactul factorilor naturali și antropici asupra degradării terenurilor

Terenurile din sudul Olteniei au cunoscut în ultimul secol etape de evoluţie diferite sub influenţa factorului climatic dar mai ales a factorului antropic. De la suprafeţele extinse de bălţi şi mlaştini din perioada postbelică la desecări, indiguiri, sisteme de irigaţii şi plantări de perdele de protecţie din anii 50-60 (reflectate în apogeul agricol din anii 70-80) şi până în zilele noastre când, asistăm la aridizarea terenurilor şi extinderea suprafeţelor, predominant nisipoase, impracticabile tipului de agricultură actuală.
După 1990 agricultura din sudul Câmpiei Olteniei a cunoscut o decădere accelarată datorată distrugerii sistemelor de irigaţii, defrişării perdelelor de protecţie, situaţiei proprietăţii terenurilor şi neadaptării culturilor la tipurile de sol. În 2012 s-a ajuns la procente de suprafeţe irigate de 0% capacitate utilizată din 76820 ha amenajate în Câmpia Blahniţei şi de 1% capacitate utilizată din 299621 ha amenajate în Câmpia Olteniei. Toate acestea au dus la degradarea terenurilor şi amplificarea proceselor geomorfologice în special pe suprafeţele nisipoase, acolo unde lipsa stratului vegetal coroborat cu procesul eolian duce la destabilizarea şi miscarea dunelor de nisip.
Acest articolul propune analiza spaţio-temporală a câtorva tipuri de terenuri expuse aridizării, a căror suprafaţă a crescut considerabil la aproape 50.000 de hectare, alte 50.000 de hectare predispuse acestui fenomen în Câmpia Olteniei la vest de Jiu şi observă că o strategie de management de mediu pentru o dezvoltare durabilă ar putea fi protejarea terenurilor împotriva vânturilor prin plantarea de perdele de păduri din specii rapid crescătoare (salcâmul, plopul hibrid, pinul silvestru, nucul).
Metodologia cercetării a implicat prelucrarea datelor medii anuale de temperatură, precipitaţii şi direcţia vântului de la staţiile metorologice din SV Olteniei, prelucrarea datelor din hărţile Landsat, Corine precum şi analiza datelor oferite de rapoartele de expertiză privind ocuparea terenurilor oferite de Ministerul Dezvoltării Regionale şi Administraţiei Publice.
În analiza degradării terenurilor ca urmare a procesului de aridizare s-a luat în considerare situaţia stratului vegetal actual folosind indexul NDVI (Normalized Difference Vegetation Index) şi date preluate de la Corine Land Cover între anii 1990 şi 2006 privind schimbarea destinaţiei terenurilor din Câmpia Olteniei.

Cuvinte-cheie: *ariditate, terenuri nisipoase, managementul teritoriului, perdele forestiere, Corine Land Cover, Sud-Vest Oltenia*

Introduction

The southern part of the Oltenia Plain is one of the most problematic and fragile ecological territories of Romania. Since the beginning of the 19th century, these sandy areas with dry climate have been subject to an intense human factor intervention whose purpose was to obtain as much agricultural production as possible.

In 1904 Rusescu claimed that the balance between the three types of land culture (arable, pasture and forest) has been deteriorating since the

middle of the 19th century and that the deterioration of the land will accentuate if there is no intervention against overcrowding with animals on the pastures and on sands, against the massive deforestation after the 1864 land reform and the lack of concern for the adaptation of crops for the purpose of efficient use and stabilization of the sandy lands (Chiriță & Bălănică, 1938). There were movements of the sands in the form of dunes, even 150 m/year, threatening the villages near the Danube in some areas of the southern part of the Oltenia Plain, on the western side of Jiu, between 1830 and 1880. This phenomenon determined a movement of the Ciuperceni, Desa, Tunari, Piscu, Bistreţ and Nedeia villages further north-east (Ionescu Şişeşti, Staicu Ir. 1958) at the beginning of the 20th century.

The accentuated process of aridization of land and the advance of sands toward the villages in the south of the Oltenia Plain alarmed the population and the officials and as a consequence they began to take measures to restore the natural balance.

Drăcea (1942) asserted that the windbreakers and shelterbelts are the cheapest and most efficient way for water retention in the soil and the planting of forests is the only means of fighting against winds and dust storms. In 1958, Ionescu Sisesti and Staicu showed that the reduction of wind speed to less than 5 m/s is essential in combating wind erosion and advancing sand dunes. During the 70s – 80s there were over 10,000 ha of forests in the area located in the south of the Jiana Plain (Jiana -Burila – Izvoarele), in the south of Băileștilor Plain, in the Ciuperceni - Desa area and in the Bistreţ - Nedeia area. There is also an exemplary exploitation of agricultural land in accordance with the system of forests for protection and stabilization of the land as well as with the irrigation system, obtaining high yields of agricultural products. After 1990, the evolution of the efficient use of agricultural land experienced a steep decline. This area has not only experienced a worrying depopulation and economic decline, but also an intensification of the destructive processes of the environment. Some studies on the drying and drought phenomena in the Oltenia Plain were conducted in 2013 and 2014 by Remus Prăvălie as well as by Irina Onțel, 2018 and Iosef Verovencii, 2014.

This paper aims to illustrate the dynamics of several types of land exposed to the aridization of the western Oltenia Plain and their evolution from the early 80s to the present days.

The study area

The study area of this paper is represented by the southern part of the Oltenia Plain between the Danube, Jiu and the Getic Piedmont in the north. The landscape has an north/north-west to east/south-east orientation, being shaped mostly by the Danube, by Jiu and to a small extent by Blahniţa, Drincea and Desnăţui (Fig.1). The local climate is influenced by the circulation of air masses from the Mediterranean area, from the east of Europe and from the Atlantic (Fig.2). In such conditions, the climate has strong Mediterranean characteristics, with more consistent precipitations in the cold and spring seasons (Ielenicz, 2007) (Fig.3). Also, this area is under the influence of the climatic variations generated by the particularities of the Carpathian and the Balkan mountains (Fig.4).

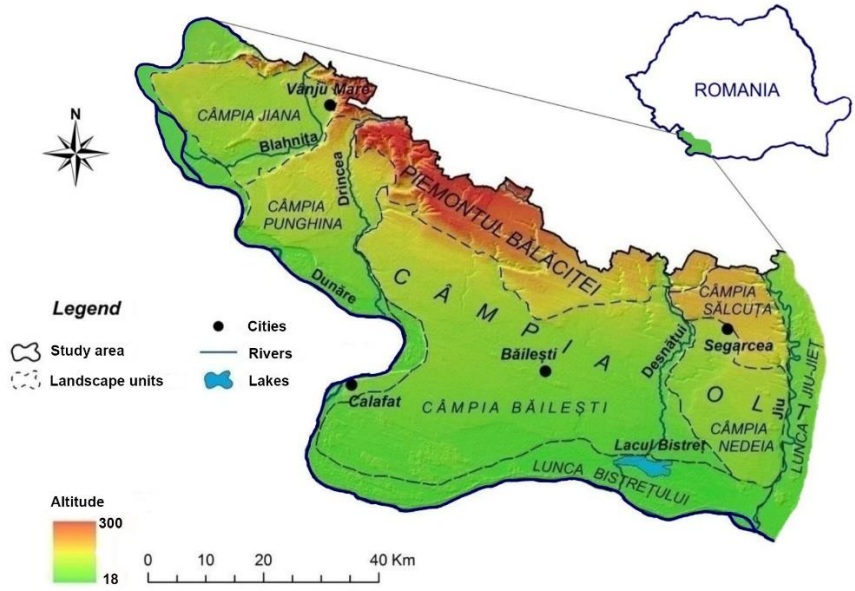

Fig. 1: The Oltenia Plain in the western part of Jiu – hypsometry (GIS processing)

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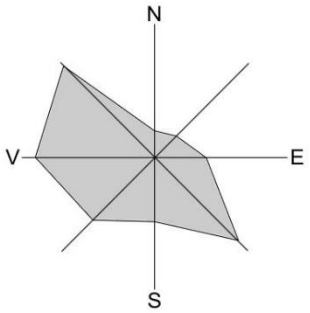

Fig. 2: The general wind direction in the Oltenia Plain - Vânju Mare weather station, 1998

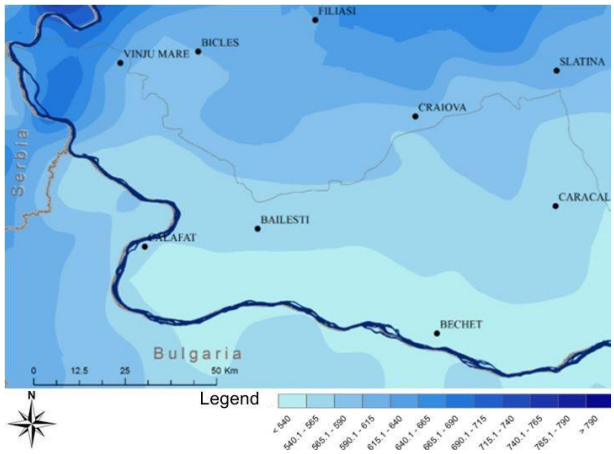

Fig. 3: The multiannual rainfall values in the Oltenia Plain, 1961-2013 (Romanian Climate Dataset)

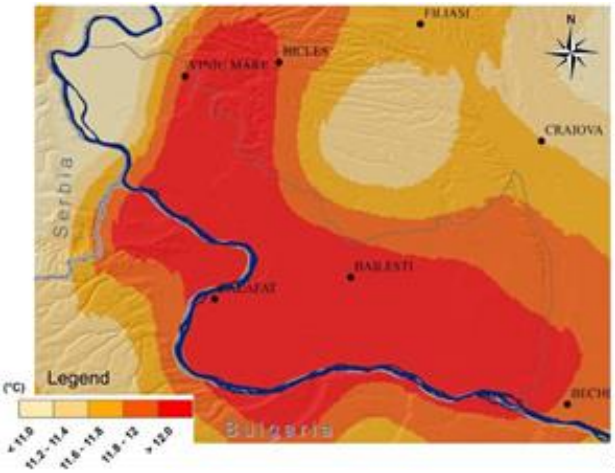

Fig. 4: The multiannual temperature values in the Oltenia Plain, 1961-2013 (Romanian Climate Dataset)

The Oltenia plain is the result of the evolution of the hydrographic network formed by the Danube, Jiu, Blahniţa, Drincea and Desnăţui and to a small extent of the wind and anthropic factor.

The hydrographic network consists of two categories of rivers: those with permanent flow (Danube, Jiu) and those with intermittent flow (Blahniţa, Drincea and Desnăţui). The three intermittent rivers have low flows and often dry completely in summer and autumn (Ielenicz, 2007).

For this reason, the influence of the hydrographic network on the evolution of agricultural land is minor, although the potential is considerable if the planning of large hydrotechnical works would be taken into consideration (Fig.5).

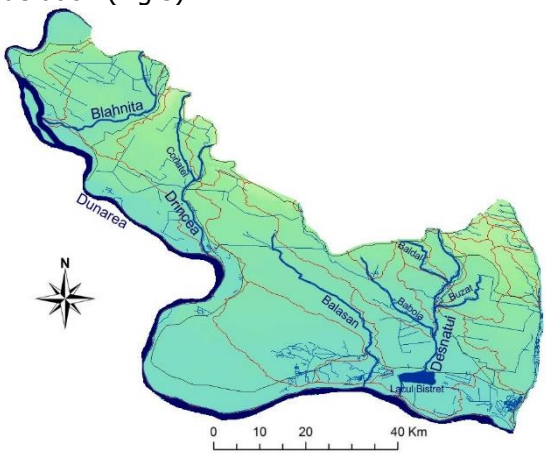

Fig. 5: The hydrographic network from the west of the Oltenia Plain (GIS processing)

The west of the Oltenia Plain is characterized by a rich and diversified range of soils, starting from the typical reddish brown ones at the base of the Piedmont, to the typical chernozemic soils in the center of the Băileștilor Plain and in the IV and V terrace of the Blahnița Plain, to the moorlands, the marshes and the glacial chernozems in the south-central part of the Jiana Plain and south of Poiana Mare - Bistrita - Nedeia. The characteristic of the soils in this area is the presence of a consistent sandy bed below the A layer of the soil profile, this texture influences directly the capacity of these soils (Oprea, 2009) (Fig. 6). This makes the landscape balance very fragile and any change can contribute to the dryness of this area.

Materials and methods

The study of the effects of the aridization on the lands in the south of the Oltenia Plain and in the west of Jiu required a careful research by field observations.

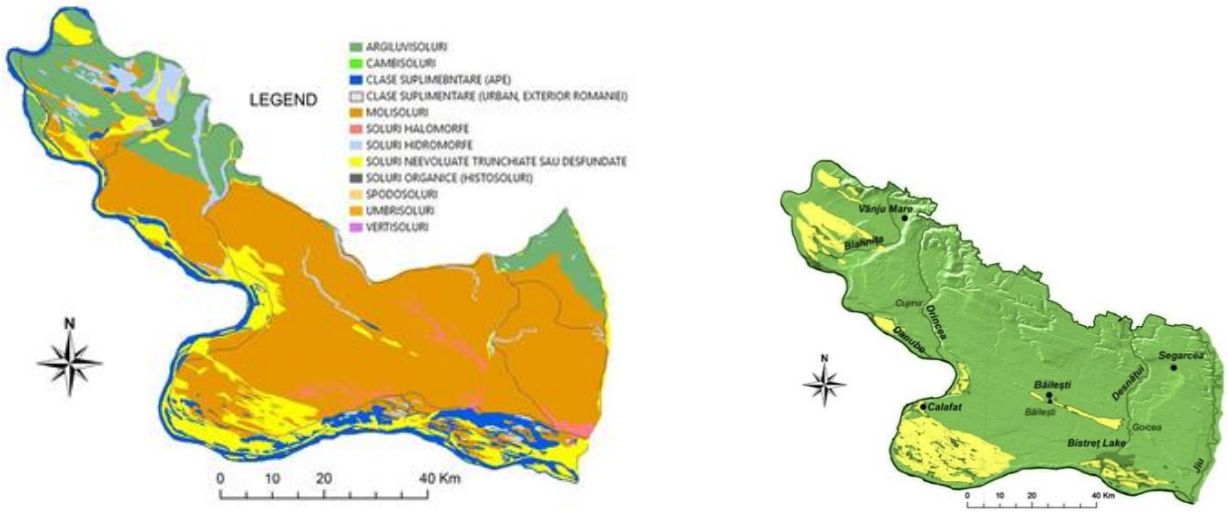

Fig. 6: The soils of Oltenia Plain in the west of Jiu (Processing after CLC, 2006, for natural ecosystems, respectively according to the Institute of Pedological and Agrochemical Research, in the case of sandy soils)

The study was based on the comparative analysis of numerous maps: administrative map of Romania 1993, topographic map (rastel dataset - ro25k16.ecw), road map, geological map (Institute of Geology, 1978, scale 1:1,000,000), soil map, ABA Jiu map, maps with climate values (National Meteorological Administration), population distribution map, etc. It focused on areas where landscape changes were detected in terms of forest surfaces, water-covered surfaces, lack of crops or lack of vegetation layer in general.

By comparing the topographic maps from 1979, the CorineLandCover maps 1990, 2000, 2006 and 2018 Global Mapper - World imagery 2009, Google Earth 2012, 2016 and observations from August 2018 - May 2019, some evolutionary changes could be highlighted along the last 40 years, from the climax of the exploitation and stabilization of the lands in the communist period to the period of decline after the 1990s and to the easy rehabilitation after the entry into the European Union. The satellite data Corine Land Cover 1990, 2000 and 2006 provided by the European Environment Agency were of major importance. Corine Land Cover is based on three different satellites and different spatial resolutions: Landsat 5TM and Landsat 7TM for CLC 1990 respectively 2000 (both at 30m resolution) and IRS P6 LISS-III (23.5m resolution), respectively SPOT 4XI (20m resolution) for CLC 2006 (EEA 2007).

Results and discussions

The dynamics of vegetation

The analysis of the forest surfaces shows a decrease of the forests by 28% between 1981 and 2006, which results from the comparative analysis of the topo map from 1981 and CorineLandCover 2006. In order to capture the most important differences between the two years, they were delimited in two areas: Ciupercenii Noi - Rast (in the south of the studied region) and Jiana - Pătulele (in the western part). The analysis of the dynamics of forests in these areas is very important considering the correlation between deforestation and the existence of sandy surfaces on large areas in these sectors. The disappearance of forests has caused the considerably expansion of the sandy areas and the dunes by about 50%, from 223 ha (Ciuperceni-Rast 152 ha; Jiana-Pătulele 71 ha) in 1981 to 446 ha (Ciuperceni-Rast 310 ha; Jiana-Pătulele 136 ha) in 2008 (Prăvălie, 2013).

The Ciupercenii Noi - Rast area shows a remarkable decrease in forest areas by 18.78% (2,240 ha) over 25 years, from 11,924 ha in 1981 to 9,684 ha in 2006. Notable in this area is the forest loss especially of acacia and poplar (about 3,300 ha) at the expense of agricultural areas, the extension of agricultural areas being the most important cause of local deforestation.

It should be mentioned that in parallel with the deforestation, the climatic pressures (prolonged droughts of the last decades, the local thermal stress) were an important cause in the disappearance of the forests, through drying and, later, by the cutting down made by the local forest department. There are other causes indirectly that are responsible for the diminishing of forest areas. For example, in the case of poplars located in the area of interdunes, the decrease of the water level and the withdrawal of the Danube from the old courses of the Rast extremities represents another important cause in the drying and, later, in their natural or anthropic disappearance (deforestation) (Prăvălie, 2013).

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Based on the comparative analysis between the topographic maps, the current Google images and the CORINE Land Cover database, a reduction of forest areas by 37% (1,666 ha) in 2006, compared to 1979 was observed in the Jiana - Pătulele area (Fig. 7).

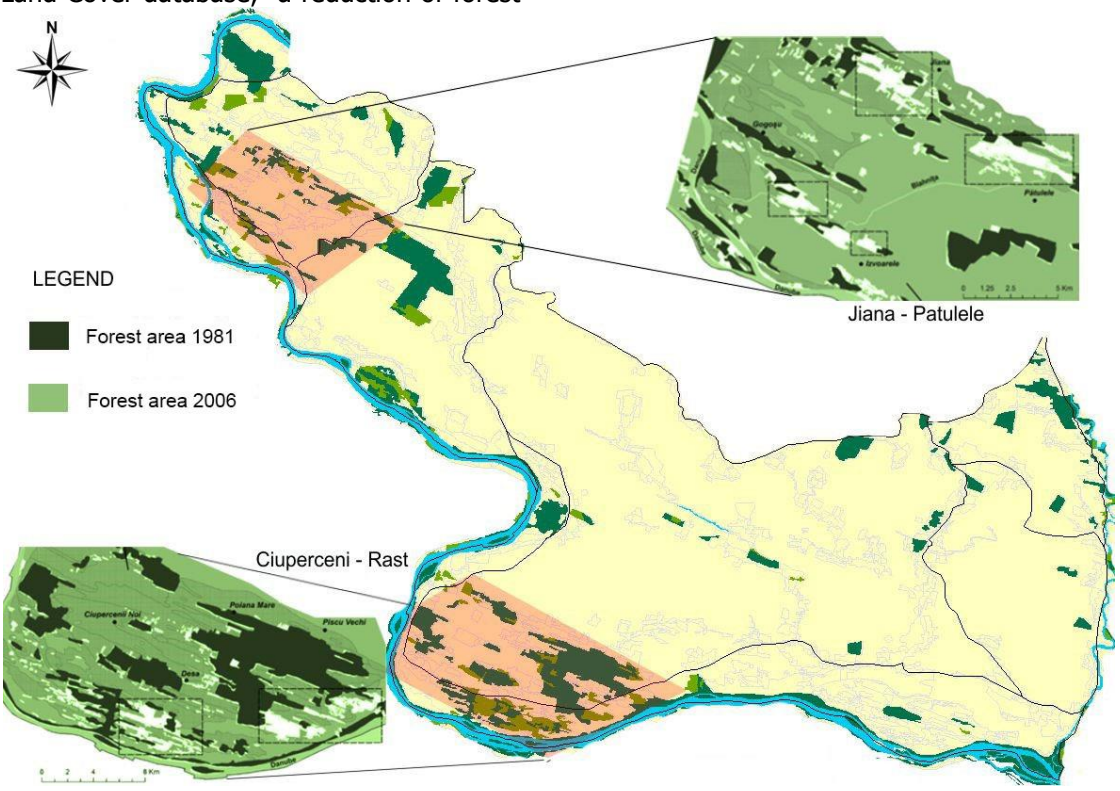

Fig. 7: The dynamics of the forest areas in the Ciupercenii Noi - Rast and Jiana Pătulele areas between 1979-2006 (comparative analysis of topo.79.rastel.sid and Corine Land Cover 2006)

The main cause of the disappearance of the forest layer in the western part of the study area is mainly anthropic caused by deforestation carried out by the owners. A secondary cause is represented by the unfavourable climatic context, determined by the prolonged droughts of the last three decades that had direct consequences on the sanitation works far beyond the provisions of the local forest department.

A hypothesis regarding the modification of the local water balance (the decrease of the groundwater level downstream Izvoarele - Gruia) could be the construction of the dam of Portile de Fier II hydrotechnical area. This has led to an amplification of the drying phenomenon among the poplar forest areas, especially in the area of the sand dunes.

An accelerated negative dynamic is noticed in the case of Jiana (663 ha lost forest areas), Pătulele (540 ha), Vrața (463 ha), Desa (462 ha), Gogoșu (361 ha) and Piscu Vechi (350 ha), the causes being related to the irrational cutting down of trees. The situation is even more complicated in the context in which the mentioned villages generally overlap with the sandy areas of the southern Oltenia (Prăvălie, 2013).

Vineyards

The data provided by CORINE Land Cover show that the vineyards recorded considerable losses at national level. The 1981-2006 period is interesting to be studied given the significant spatial transformations of land use in southern Oltenia, triggered by the change of the political system since 1990 (Bălteanu et al, 2013). As a result of the application of the 18/1991 land law it was noticed a poor management of the vineyards by the new owners, either by abandonment or by clearing. The vineyards can play a key role in the ecological stability of this territory by stabilization of sandy soils, similar to the role of forest surfaces (Prăvălie, Peptenatu and Sîrodoev, 2013).

The analysis of the spatial-temporal dynamics observed on the basis of the topographic maps of 1981 (scale 1: 700,000) and of the CORINE base 2006, shows that during the 25 years this category has reduced by about 60% (11,000 ha), respectively from almost 18,400 ha in 1981 to almost 7,400 ha in 2006. Thus, one can discuss about a substantial spatial constraint of this permanent culture, in a relatively short period of time. In contrast to the

forest surfaces, the vines recorded relatively uniform spatial losses throughout the analyzed area (Fig.8).

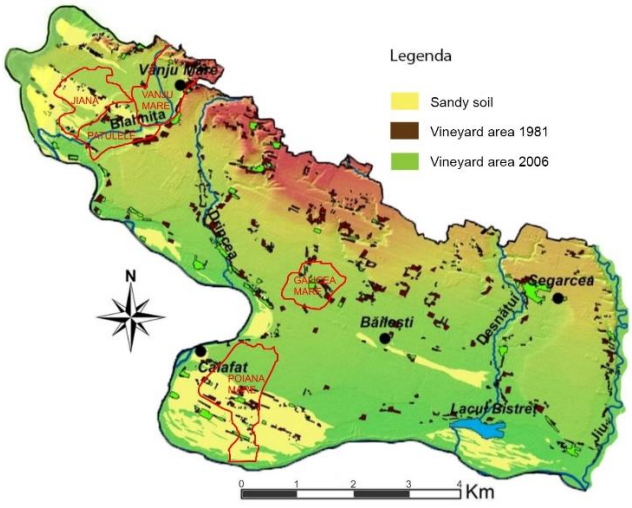

Fig. 8: The dynamics of vineyards in the west of the Oltenia Plain in the 1981-2006 period (after Prăvălie, 2013 and GIS processing)

Large losses of vineyards were recorded mainly in the central-western part of the study area, but a significant extent was also noticed in the area of sandy soils. If in 1981 the sandy soils were stabilized with vineyards in a proportion of 7% of the area (20,063,360 ha), in 2006 the percentage decreased to about 5% (≈ 2,400 ha). At the level of landscape units, the largest losses occurred in the central-northern part of the Băilești Plain and in the Vânju Mare area (Prăvălie, 2013).

The areas with the largest losses of vineyards are Vânju Mare (616 ha, 70% losses in 2006, compared to 1981), Pătulele (585 ha, 100%), Poiana Mare (550 ha, 75%), Galicea Mare (531 ha, 99%) and Jiana (500 ha, 100%).

The dynamics of wetlands

Swamps are ecosystems that are part of the wetland category, being considered among the most productive terrestrial ecosystems (Gibbs 2000). They are essential due to the habitat function. They are developing a specific biota, but they also play a major role in stabilizing the environment by mitigating climate change, controlling pollution, water purification, flood mitigation or nutrient retention at ground level (Wright & Reddy 2001); Gâştescu and Ţuchiu, 2012).

In the south of Oltenia, wetlands play a fundamental role in improving the restrictive climatic conditions, by regulating the humidity balance and the thermal regime. At the same time, they are very important in terms of biodiversity, considering that there are three sites of wetlands of international importance (Bistrița, Blahnița and Calafat - Ciuperceni - Danube), which have a variety of species of flora and fauna. However, it seems that a large part of these ecosystems have disappeared in this area during the last decades, because of the draining generated in order to expand agriculture (Dumitraşcu, 2006). The cartographic analysis shows that the marshy areas decreased in the 1981-2008 period by 52%, respectively from almost 11,200 ha in 1981 to 5,400 ha in 2008 (Fig.9).

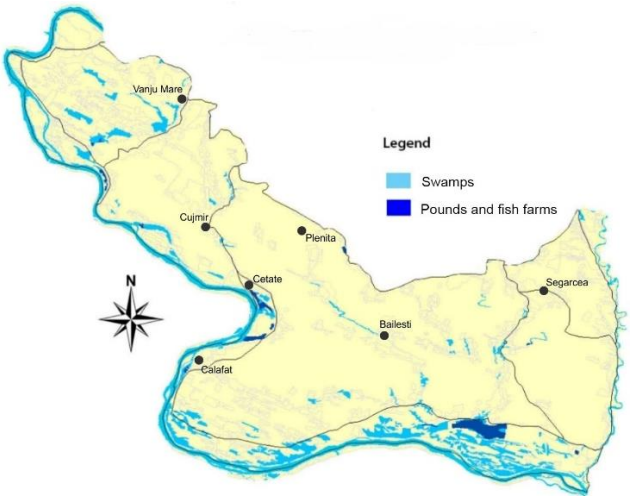

Fig. 9: The current location of the swamps and pounds in the Oltenia Plain, in the west of Jiu

In the Ciupercenii Noi - Rast area, the marshy areas suffered initial losses in favour of the agricultural field of 1,248 ha. It is also interesting to note that in the case of water bodies (aquatic surfaces), there are area losses in favor of marshy areas. In this case, the transformation of the natural aquatic areas into marshes (considered as lands with lower humidity compared to the proper aquatic surfaces) are caused by the climatic changes, i.e. the accentuation of the climatic aridization of the region.

The situation is similar in Jiana - Pătulele area. In this area, it is noted that the marshy areas in the 1981-2008 period lost a total of 3,600 ha, of which 98% (3,524 ha) in favour of the extension of agricultural land.

The highest losses were recorded in the Devesel (1,241 ha), Gogoșu (976 ha), Jiana (852 ha), Desa (432 ha), Vânju Mare (360 ha), Cârna (348 ha) and Ciupercenii Noi (340 ha) administrative units located in the west and south of the studied region (Fig.10).

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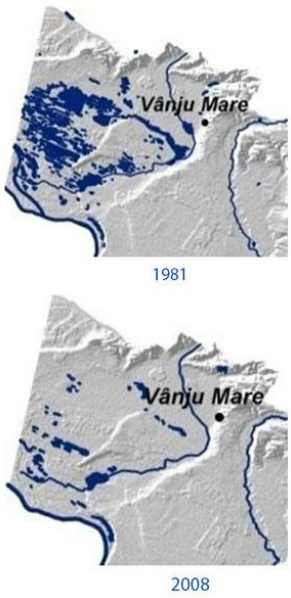

Fig. 10: The dynamics of the areas with marshes in the Jiana Plain in the 1981-2006 period (Global Mapper and GIS processing)

Irrigation

The greatest achievements of the irrigation system in the Oltenia Plain were made after the 1970s, when large agricultural areas began to be irrigated. In the context of lack of investments, technical maintenance problems, non-technologization and numerous thefts, this system, vital for local agriculture, disappeared almost entirely after 1990.

In the western area of the Oltenia Plain, corresponding to Mehedinți county, no irrigation has been carried out since 2007, the irrigation systems Crivina - Vânju Mare and Izvoare - Cujmir being totally abandoned (Prăvălie, 2013). At the same time, the analysis of the year-on-year data from Dolj county showed that the irrigated areas have decreased dramatically since 1991. It was recorded that the irrigated lands reduced on average to 12% in the 1991-2008 period, compared to 1990 (412,502 ha). Thus, we can discuss an average of 88% collapse during the 18 years after 1990, even though there were some optimistic fluctuations during this period.

A close look at topographic maps (1979), Land Cover (1990, 2000 and 2006), World Imagery Esri (2009), Google Earth and Google Street View images (2012-2016) and field photos (2019) show some changes on the land use and the effects of the changes produced during this period. The analysis of these changes considered the correlation between:

- the evolution of forest areas, crops (especially those of vineyard and rice with an important role in stabilizing the sands of dunes and swamps), areas with marshes and ponds, anthropic constructions and
- their impact on the geomorphology of the area and on the management and sustainable development policies that need to be adapted.

Wind factor and sand dunes

In the western extremity of the Jiana Plain, the lack of forests for a long period of time led to the maturation of some dunes which reached a relative stabilization or low advance. The slow advance of dunes can be observed in the west of Burila Mare - Ţiganaşi where the lack of forests for a long period of time led to the leveling of the land, the erosion processes having a minor dynamic (Fig.11).

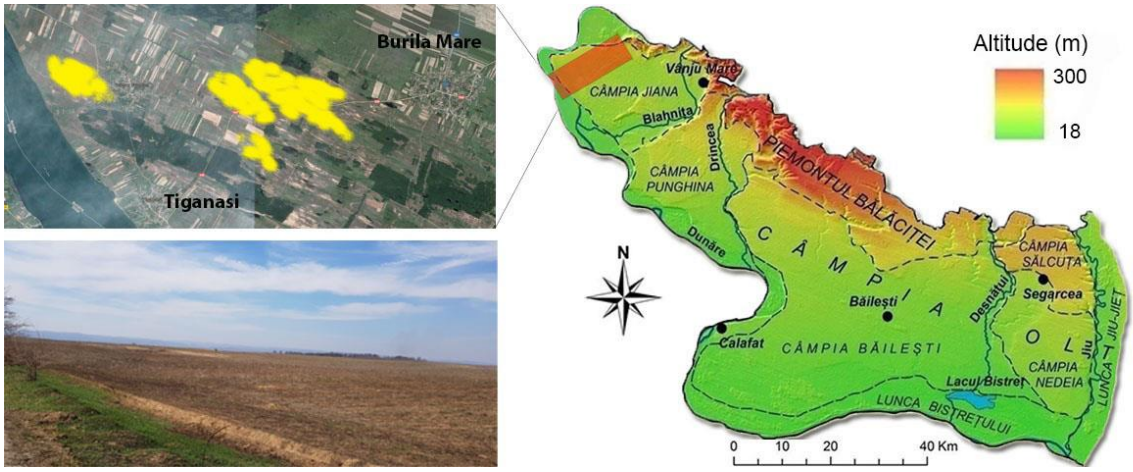

Fig. 11: Mature dunes stabilized in the Burila Mare - Ţigănaşi area (Cristian Răducă, April 2019)

This can be deduced from the analysis on the erosion witness of the dune in the south of Burila Mare, represented on the topographic map of 1979, on the World Imagery 2009 map (Global Mapper), on the Google Street View image from 2012 and on the photos from the present days. The analysis showed a decrease, gradually and slowly from a width of 100 m in 1979 to 10 m currently on the 100 m isohypse map (Fig.12).

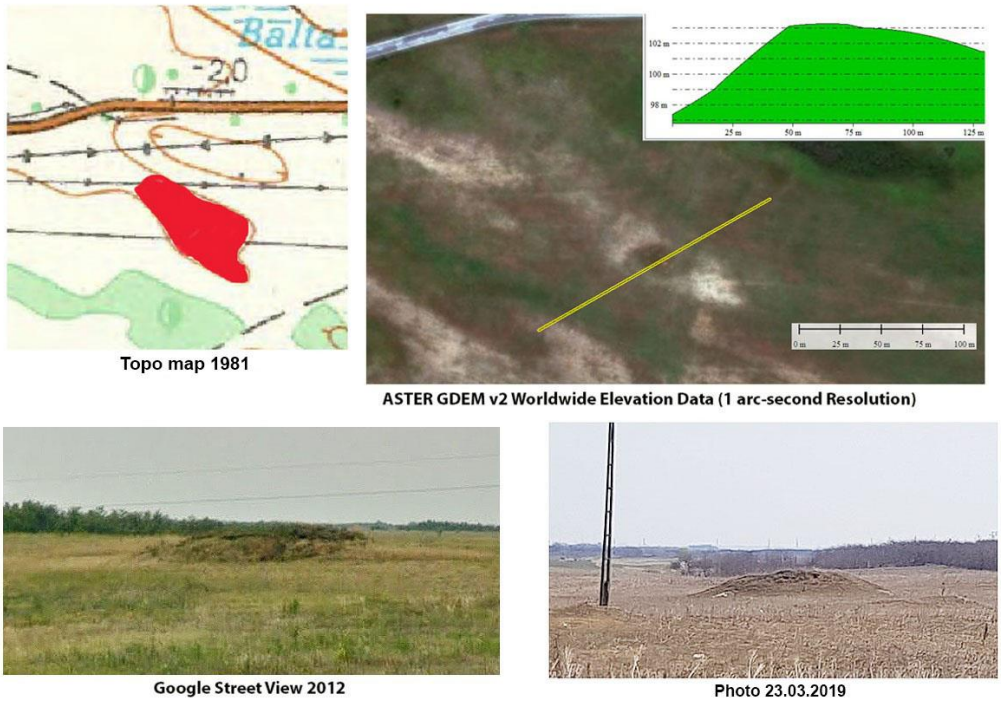

Fig. 12: The evolution of the dune ridge from the south of Burila Mare

In the same area we have the confirmation of the land evolution under the influence of the wind factor during the last 40 years in the Ţigănaşi - Burila inter-forest where the forest edge is up to 2 meters higher than the uncovered area nearby (Fig.13).

Fig. 13: The different evolution of the sandy lands uncovered between the forests in the north of Ţigănaşi town (Cristian Răducă - 04.2019)

Another confirmation of the evolution and intensity of the land degradation process under the influence of the wind factor is the elevation of the base of the electric tower fixed on the sandy lands in the south of the Jiana plain. Compared with the electric towers in the areas with stable land, their base was uncovered up to 2 m as it can be seen at the entrance of Burila Mică from Bistriţa (Fig.14).

Fig. 14: The effects of different wind erosion in the Blahniţa Plain a) sandy land (Burila Mică), b) Chernozem stable soil (Gruia) (Cristian Răducă, 04.2019)

The quantities of sand carried by the winds from west/north-west to east/south-east were settled and stabilized in the forests and in the agricultural crops between Burila Mică, Jiana and Pătulele as well as within the villages of this area. Another part was carried with the sand from the uncultivated or deforested areas during the last two decades and determined the advance and reactivation of some dunes such as the ones from Ţigănaşi forest, in the south of Jiana Veche, in the east of Pătulele and in the north of Izvoarele (Fig.15).

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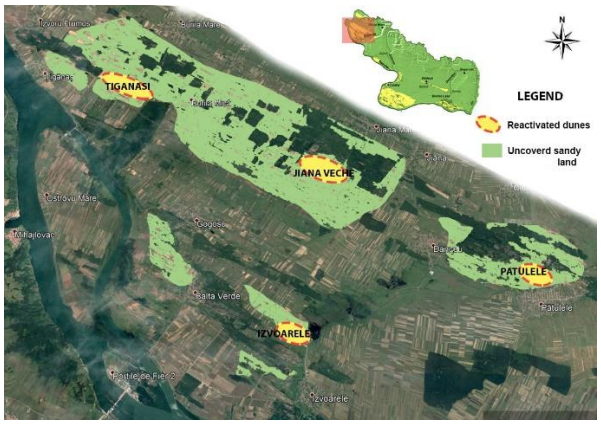

Fig. 15: The location of the reactivated dunes within the uncultivated sandy lands or covered with temporary mild vegetation (Correlation between Google Earth maps and field observations, August 2018)

A certain sample of dune reactivation is in the east of Pătulele (Fig.16) and in the north of Izvoarele, in the east of the Rotunda Lake (Fig.17)

Fig. 16: The altimetric difference between the western and eastern riverbank of Blahnița near Pătulele (Cristian Răducă - 04.2019)

Fig. 17: The uncovered sandy lands and reactivated dunes in the north of Izvoarele (Cristian Răducă - 04.2019)

The tree cutting of the mulberry forest and the deforestation of the silkworm farm in Pătulele led to the reactivation of the dune from Pătulele, whose development is consistent, the western riverbank of Blahniţa rising almost 1 m in comparison to the eastern one. Fortunately, in this case, the advance is stopped by the Blahniţa river and Pătulele village.

The Blahnița meadow in the north of Izvoarele is the scene of the reactivation of a series of dunes due to the narrowing of the water surface of the Rotunda Lake and the intensification of the aridization process in this area during the last 4 decades (Fig.18). If in 1980, the Rotunda Lake had a water surface of 311 ha and in its north, the Ontolea Lake had 37.7 ha in 2019, the water surface of the Rotunda Lake is 50 ha and the Ontolea Lake has a water surface of 6.4 Ha.

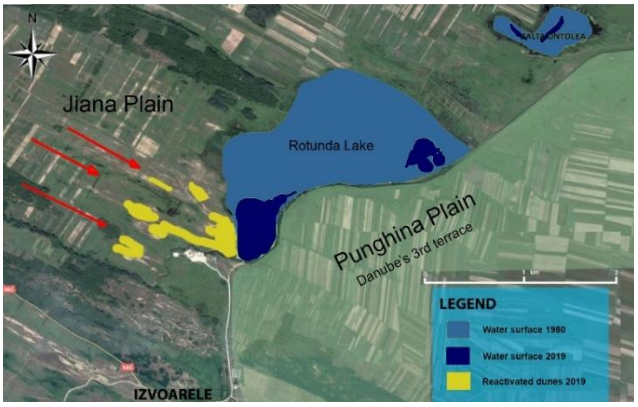

Fig. 18: The uncovered sandy lands and reactivated dunes in the north of Izvoarele

There is a fortunate case regarding the dune of Pătulele in terms of stopping the advance of these dunes, considering that their advancing front meets the Blahniţa valley and the high side of the 3rd Danube terrace.

The improper national strategies of rehabilitation and bad reforms are other major causes of the fast degradation of this sector of great national importance. The degradation of irrigation system in large areas in the south of Oltenia caused serious economic consequences (by decreasing agricultural productivity), but also ecological ones (by deepening the water level and thus inhibiting the overall biological productivity). The disappearance of irrigation amplifies the adverse effects of the climate aridization and, consequently, the general degradation of the land in the region.

Conclusions

This study aims at identifying the risk generated by the drying and drought phenomena on the sandy land in the west of the Oltenia Plain. Meteorological data have been analyzed since 1980 and these were correlated with the topographic and satellite data (after 1990), thus making possible the localization of

the phenomena that cause the aridization and the identification of the vulnerable areas.

The analysis of the dynamics of the vegetation, of the areas cultivated with vineyard, of the dynamics of the aquatic areas, of the irrigated areas in conjunction with the observations from the field, allowed the identification and mapping of the areas in which the aridization is accentuated; under the influence of the wind factor they are in danger in terms of the dynamics of sandy lands.

In the south-west area of the Oltenia Plain, especially in the rectangle located in the south of the Jiana Plain (Burila Mare - Ţigănaşi - Izvoarele - Pătulele), with an interruption in the area of the erosion witness of the 5th terrace from Dănceu - Jiana, the terrain dynamics is very sensitive, depending very much of the economic interest and involvement in this area with significant potential. A serious involvement in the valorization of the lands would mean the redesign of the irrigation systems and the planting of large areas, determining the stabilization and the efficient exploitation of the land. Conversely, an economic downturn would leave the lands to the winds, increasing the danger of drying and of the dunes advance towards the villages located in the south of the Oltenia Plain.

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Risk assessment of consuming aromatic hydrocarbons (The case study: Mesopotamichthys sharpeyi of Huralazim Wetland in Iran)

Mohammad BOSTANZADEH[1], Laleh ROMIYANI[2,*], Khoshnaz PAYANDEH[3], Sima SABZALIPOUR[1], Maryam Mohammadi ROOZBEHANI[1]

[1] Department of Environment, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran
[2] Department of Fisheries, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran
[3] Department of Soil Science, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

* *Corresponding author*: *

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Abstract

Background and goal: Aromatic hydrocarbons are one of the most important environmental pollutants in the environment. These compounds, even at very low concentrations, have carcinogenic and mutagenic properties and are quantitatively and qualitatively known as compounds that have entered all parts of the environment due to human activities. This research studies the concentration of aromatic hydrocarbons in the predominantly fish (Mesopotamichthys sharpeyi) in Huralazim wetland and calculates the risk of consuming this fish by a human.
Materials and Methods: In the spring of 2018, 210 fish were collected from 4 reservoirs (7 stations). The analysis of 16 hydrocarbon compounds was carried out using the GC-FID (Shimadzn-14A) equipped with a capillary column (RTX-5).
Results: The highest concentration of oil-based hydrocarbons was in fish of station 7 (43.93 ± 2.70 mg/kg) and its lowest concentration was at station 1 (9.52 ± 3.06 mg/kg). The highest carcinogenesis incidence rate was 1.13 at station 7 and the highest mutation rate was 23.49 at station 5. The gradual carcinogenesis rate of Benz [a] pyrene was 0.00003 to 0.0029 and n in general, through Huralazim Wetland it was 0.0027. The gradual mutation risk assessment for Benz [a] pyrene was estimated as 0.055 (which ranges from 0.034 to 0.061).
Conclusion: According to the standard of mutant and carcinogenic compounds [5], it can be said that the daily consumption of fish in this wetland increases the risk of cancer and mutagen in the consumer population. Measures have to be taken to reduce the consumption of caught fish which are exposed to pollution in Huralazim Wetland, in order to minimize the risk of gradual cancer or mutagen, especially in the natives of that area.

Keywords: *risk of consumption, aromatic hydrocarbons, Bani fish, Huralazim Wetland*

Rezumat. Evaluarea riscului consumului de hidrocarburi aromatice (studiu de caz: Mesopotamichthys sharpeyi din zona umedă Huralazim, Iran)

Scop: hidrocarburile aromatice reprezintă unul dintre cei mai importanți poluanți ai mediului. Acești compuși, chiar în concentrații foarte mici, au caracteristici cancerigene și sunt cunoscuți din punct de vedere cantitativ și calitativ drept compuși care afectează toate componentele mediului datorită activităților umane. Studiul de față analizează concentrația hidrocarburilor aromatice în ihtiofauna (Mesopotamichthys sharpeyi) din zona umedă Huralazim, calculând riscul la care se expune populația consumând acest pește.
Material și metodă. În toamna anului 2018, 210 pești au fost colectați din 4 rezervoare (7 stații). Analiza celor 16 compuși ai hidrocarburilor s-a făcut cu ajutorul GC-FID (Shimadzn-14A), echipat cu o coloană capilară (RTX-5).
Rezultate: Cea mai mare concentrație a hidrocarburilor pe bază de ulei a fost înregistrată la stația 7 (43.93 ± 2.70 mg/kg), iar cea mai mică concentrație la stația 1 (9.52 ± 3.06 mg/kg). Cea mai ridicată rată a incidenței cancerigene a fost de 1,13 la stația 7, iar cea mai mare rată de mutație, 23,49, la stația 5. Rata cancerigenă graduală a Benzo [a] pirenei a variat între 0,00003 and 0,0029 și n în general, pe tot cuprinsul zonei umede Huralazim fiind de 0,0027. Riscul mutației gradule pentru benzo [a] pirena a fost evaluat la 0,055 (variind între 0,034 și 0,061).
Concluzii. Conform standardelor compușilor cancerigeni și cu potențial pentru mutații genetice, se poate afirma că un consum zilnic de pește provenit din această zonă umedă crește riscul de cancer pentru populație. Trebuie luate măsuri pnetru a reduce consumul de pește pescuit aici, întrucât acesta este expus unei poluări considerabile din zona umedă Huralazim, astfel ncât să se limiteze riscul de îmbolnăviri în rândul populației autohtone.

Cuvinte-cheie: *risc de consum, hidrocarburi aromatice, peștele bani, zona umedă Huralazim*

Introduction

Wetlands and their related areas are special displays of water resources. A local wetland is a natural manifestation that, in the process of its formation, its soil is saturated with surface and underground water. Under normal and environmental conditions, wetlands are formed gradually and during a long period of time. They have biological sequences. Hence, the population growth, as well as the industrial and agricultural developments has quickly infected these valuable areas (Christensen and Bzdusek. 2005, Moon et al., 2006). Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds with two or more non-volatile or semi-volatile aromatic rings (Singh et al., 2016) that are produced naturally or by human activities. Polycyclic aromatic hydrocarbons are formed during incomplete combustion of organic materials and are found in oil

reserves in large amounts and are released during the extraction, transport, or processing of oil (Pampanin and Sydnes, 2013). These compounds have a very low solubility in water and are lipophilic so they are quickly stored in fat tissue (Veiga et al., 2014).

It is predicted that in 2030, the global demand for oil from 84.7 million barrels per day in 2008 reaches to more than 105 million barrels per day. As a result, most of these compounds will be found in nature (International Energy Outlook 2013). In aquatic environments, sediments of rivers are the main place of receiving and storing pollutants. Besides, they play an important role in the accumulation of petroleum and its derivatives in benthic macro-invertebrates (benthos) and transferring them to higher nutritional levels such as plants, invertebrate, and fish (Mendi and Uluozlii, 2006). Fish are one of the most important extracted material in the wetlands (Usydus et al., 2009), which due to exposure to petroleum in these environments as well as feeding on lower nutritional chains that have stored pollutants increase the risk of cancer in the consumers (Ohiozebau et al., 2017). Among the hydrocarbon compounds, some polycyclic aromatic hydrocarbons (PAHs) such as Benzo [a] pyrene, chrysene, indeno (1,2,3-c, d) pyrene and benzo (b) fluoranthene are known as the causes of cancer or mutation which have also genetic effects on laboratory animals (Deutsch-Wenzel 1983; Thyssen et al., 1981).

Conventional crude oil production method is not able to meet the increasing demand for oil- based hydrocarbons energy. This has led to the significant growth of oil extraction from the bed of wetlands and seas (Parajulee and Wania, 2014). This type of extraction can be seen in Khuzestan province and Huralazim wetland. In the oil-rich province of the Khuzestan, contamination with polycyclic aromatic hydrocarbons is one of the most common pollutions, which is increasing in Huralazim wetland due to extensive oil extraction from the fields (Jena'ale and Buazar, 2014). Huralazim wetland is vulnerable and has contamination since it was dried during the years of the war between Iran and Iraq as well as the oil extraction to a high level. It made it difficult to assess the level of pollution in the fish caught from these areas. In this research, the accumulation of polycyclic aromatic hydrocarbons (PAHs) in muscle tissue of mesopotamichthys sharpeyi, as one of the herbivorous and saprophagous predominant species, with a frequency of 24.6% in Huralazim wetland, and the degree of carcinogenesis and mutagenesis effect of this species are studied.

Methodology

Sampling was carried out in spring in 2018 and at the stations specified in the Penta-reservoirs of the Huralazim wetland (Figure 1 and in accordance with Table 1). With regard to the volume of water, the area and the rate of activity of exploration, extraction, and development of oilfields located in the wetland, the stations were selected as follows:

The reservoir 1, in which undeveloped oil reserves of Sohrab has located, includes two stations (station 1 and station 2). Reservoir 2 located in the North Azadegan oil field and it includes two stations (station 3 and station 4). Reservoir 3 located in the South Azadegan oil field and North Yaran oil field, and it includes two stations (station 5 and station 6). Reservoir 4 located in the South Azadegan oil field and it includes one station (station 7) and reservoir 5 located in the North Yaran oil field and includes one station (station 8) that this reservoir is eliminated due to dryness of reservoir 5.

Table 1: Sampling Stations

Station	X	Y
1	765730.75	3501747.01
2	765260.91	3501806.43
3	766565.51	3486920.11
4	766124.16	3477671.14
5	761845	3473681
6	764854	3468623
7	765441	3461467

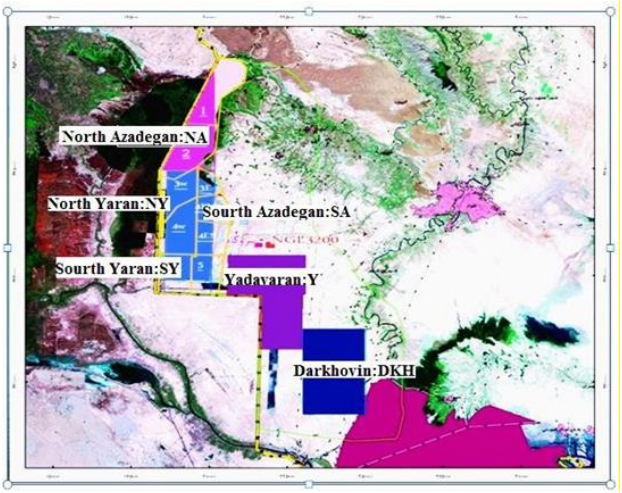

Fig. 1: The studied area in Huralazim wetland (Hawizeh Marshes)

Collection and preparation of sample

Gill fishing nets (with a 5cm source) were used to catch Binni (Mesopotamichthys sharpeyi) (Rezaei and Papahn, 2013) and this kind of fish was identified using code recognition keys (Coad, 2010) and Abdoli (2000). 210 fish were collected from seven stations. The samples were washed with the distilled water and then were transferred to the laboratory (Jazza et al., 2015). The muscular samples were separated from

the mid-back of the body of fish. Afterwards, it was placed in an aluminum foil, labeled, and then frozen at -18 ° C (Ohiozebau et al., 2017). In the preparation stage, the samples were completely dried, because aqueous compounds are intrusive in the PAHs analysis. To reach this stage, the samples were placed in a Freeze Dryer Model FD- 10V for a period of 72 hours at a temperature of -50 ° C and under vacuum conditions until the water was completely dried (Jazza et al., 2015). Fish samples were prepared for injection into gas chromatography using Pena method (2006). Therefore, 0.2 g of each dried specimen was poured into a Transform 600 Microwave Digestion, and 4 ml of potassium hydroxide saturated solution in alcohol and 10 ml N-hexane are added to the sample. After placing the cells inside the digestion system, extraction was carried out at 129 °C and in a period of 17 minutes. After cooling the solution, 6 ml of the organic phase contained in it was mixed in the centrifugal tube (DOMEL Centric 250IVD) with 3000 rpm for 3 minutes. The extract was evaporated and concentrated by a rotary evaporator (Senco RV 8-VC) until its volume reached to 0.5 ml. Then, the extracted solution was filtrated using silica sheets which had been activated with 4 ml of dichloromethane solution and then again with 4ml of dichloromethane-hexane (with a volume ratio 1:1). The material was washed with 4ml of dichloromethane hexane and again it was concentrated to 0.5 ml by the evaporator. 1 ml of acetonitrile was added to it and the mixture was again concentrated to reach a concentration of 0.5ml. The obtained extract was transferred to a volumetric flask with 2 ml volume, which includes 0.5 ml of ultra-pure water, and the solution was filtrated using a 0.22-micron mesh. Ultimately, 20 µl of the resulted solution was injected into a GC-FID (Shimadzn-14A) device equipped with Rtx-5 capillary columns. The concentration of 16 aromatic hydrocarbon derivatives was then calculated through a reference material (Certified Reference Material).

Toxicity factors

Two Toxic Equivalence Factors (TEFs) (Nisbet and LaGoy, 1992) (carcinogenesis) and the Mutagenic Equivalence Factor (MEF) (Durant et al., 1996; 1999) (mutagenesis) were used in order to express the relative toxicity of hydrocarbon compounds of fish for individuals. In these two formulas, the toxicity levels were calculated for the existing hydrocarbon coefficients and summed these coefficients from the toxicity equation (TEQ) and meta-genetic equation (MEQ).

$$TEQ = \sum(TEF_i \times C_i)\ MEQ = \sum(MEF_i \times C_i)$$

C_i is the measurement of the concentration of cyclic hydrocarbons

Assessing the gradual risk of carcinogenesis and mutagenesis

Maximum exposure of humans with a mean lifespan of 70 years with different doses of PAH in a diet ($mgkg^{-1}\ BWd^{-1}$) (carcinogenic and mutagenic) is calculated by the following formula:
carcinogenic (mutagenic)

$$PAH = \frac{(TEQ \text{ or } MEQ) \times IR \times CF}{BW}$$

This equation shows the maximum exposure level based on the EPA Guide (USEPA, 1993). In the equation, IR is the mean of fish consumption per year (Iranian Fisheries Statistical Yearbook, 2014), and the CF denotes carcinogenesis factor (0.001 mg μg^{-1}) and BW is the body weight, which was considered as an average of 70 kg.

Results

The results of the measurement of oil-based hydrocarbons in fish muscle in the reservoirs of Huralazin wetland are given in Table 2. The highest concentration of hydrocarbon was observed in station 7 (43.93 ± 2.70 mg/kg) and its lowest concentration at station 1 (9.52 ± 3.06 mg/kg). The highest concentration of PAH was related to Acenaphthene (30.67 mg/kg).

Table 2: The results of measurement for oil-based hydrocarbons of the fish muscle in reservoirs of Huralazin wetland (mg/kg)

Cycle	Compound	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Total
2	Naphthylene (Nap)	a 12.85 ±0.64	a 14.20 ±0.31	a 17.27 ±0.81	a 21.14 ±0.50	a 27.89 ±0.96	a 37.04 ±0.08	a 43.93 ±2.71	24.90
3	Acenaphthylene (Acel)	a 11.01 ±0.50	a 11.75 ±0.09	a 18.79 ±0.42	a 23.37 ±0.24	a 23.84 ±0.19	a 29.33 ±0.19	a 30.96 ±0.53	21.29

3	Acenaphthene (Ace)	a 15.43 ±0.21	a 16.56 ±0.18	a 22.39 ±0.24	a 26.10 ±0.06	a 39.68 ±2.28	a 47.24 ±0.06	a 47.33 ±0.72	30.67
3	Fluorene (Flu)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
3	Phenanthrene (Phe)	a 12.55 ±0.22	a 14.60 ±0.25	a 15.36 ±0.08	a 16.21 ±0.11	a 19.66 ±0.41	a 18.44 ±0.27	a 19.46 ±0.14	16.61
4	Anthracene (Ant)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
4	Fluoranthene (Flt)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
4	Pyrene (Pyr)	< 10	< 10	a 21.69 ±1.93	< 10	< 10	a 18.09 ±0.27	a 17.89 ±0.62	15.75
4	Benz[a]anthracene (BaA)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
4	Chrysene (Chr)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
5	Benzo[b]fluoranthene (BbF)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
5	Benzo[k]fluoranthene (BkF)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
5	Benz[a] pyrene (BaP)	a 14.28 ±0.12	a 13.31 ±0.11	a 17.61 ±0.21	a 18.38 ±0.26	a 23.49 ±2.24	a 19.46 ±0.19	a 19.32 ±0.59	17.98
6	Indeno[1,2,3-cd] pyrene (IcP)	< 10	< 10	< 10	< 10	< 10	a 10.45 ±0.22	a 11.17 ±0.04	10.23
5	Dibenzo[a,h]anthracene (DhA)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
6	Benzo[g,h,i]perylene (BgP)	< 10	< 10	< 10	< 10	< 10	< 10	< 10	-
	Total	a 9.52 ±3.06	a 14.20 ±0.31	a 17.27 ±0.81	a 21.14 ±0.50	a 27.89 ±0.96	a 37.04 ±0.08	a 43.93 ±2.70	-

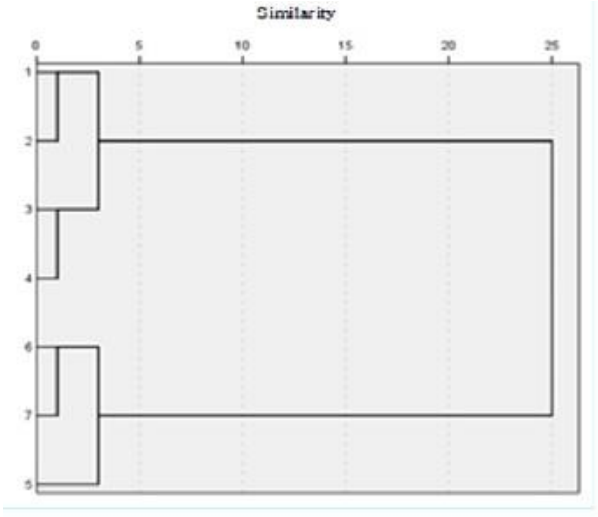

Fig. 2: Hierarchical cluster analysis (HCA) for categorizing the PAHs of the muscle in the fish- (1) Station 1, (2) Station 2, (3) Station 3, (4) Station 4, (5) Station 5, (6) Station 6 and (7) Station 7

According to the hierarchical cluster analysis (HCA), stations 6 and 7 had less similar in comparison to other stations. Stations 1 and 2, as well as 3 and 4 were each in a cluster or at least a distance in comparison (Fig. 1).

Comparison of hydrocarbons (2 and 3) showed that the concentration of this hydrocarbon group was higher in stations 4, 5, 6 and 7 as compared with the initial stations (P <0.05).

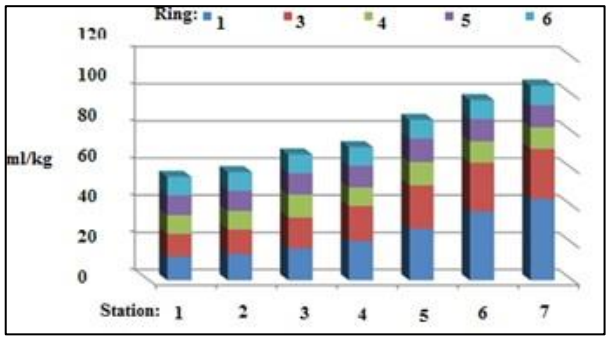

Fig. 3: Comparison of hydrocarbons based on the ring in the fish muscle of the studied stations

Two Toxic Equivalence Factors (TEFs) and Mutagenic Equivalence Factor (MEF), which indicate cancer and the cause of mutation, are shown in Table 3 for hydrocarbon compounds. According to the

values of the two TEFs and MEFs indicators, the rate of mutation caused by this wetland's fish consumption was higher than the rate of cancer formation. The highest mutation rate at station 5 and the highest carcinogenicity rate at station 7 were measured.

Table 3: The results of calculation for toxicity equivalence factors (TEFs) and Mutagenic Equivalence Factor (MEF)

Total	Station 7	Station 6	Station 5	Station 4	Station 3	Station 2	Station 1	Gradual risk assess-ment
1.04	1. 13	1.06	0.023	0.018	0.017	0.014	0.013	TEQ
21.15	22.78	22.69	23.49	18.38	17.61	14.28	13.31	MEQ

The gradual evaluation of carcinogenicity and mutation based on the values of two carcinogenicity indices and the occurrence of mutations based on the per capita consumption of fish recorded in the Iranian Fishery Statistical Journal is shown in Table 4. The highest incidence of cancer and mutation occurred at station 7.

Table 4: Carcinogenic Risk Assessment

Total	Station 7	Station 6	Station 5	Station 4	Station 3	Station 2	Station 1	Gradual risk assess-ment
0.0027	0.0027	0.0027	0.00005	0.00004	0.00004	0.00003	0.00003	Toxic
0.055	0.059	0.059	0.061	0.034	0.045	0.037	0.034	Mutagenic

Discussion

According to Table 1, the total concentration of hydrocarbon compounds in fish caught in the Huralazimm wetland shown for the range from 9.52 mg/kg (station 1) to 47.93 mg/kg (station 7). Tolosa et al. (2005) reported the concentrations of hydrocarbons in the fish tissues of "Epinepbelus coioides" and "Lethrinus nebulosus" on the shores of the United Arab Emirates 2.7µg/g and 3.40µg/g respectively. Moreover, Jazza et al. (2015) investigated the aromatic hydrocarbon concentrations in the tissues of the two species of "Liza abu" and "Carassius auratus" fish in Iraq, which were 161.61-2.03 ng/g and 0.95-1.875 ng/g of dry weight, respectively. In general, it indicated that the concentration of hydrocarbons in both studies is much lower, compared to the present study. This significant difference was due to the specific position of the Huralazimm wetland through the exploration, extraction and drilling of the well that contributed to the level of contamination in the food chain.

The caught fish from stations 1 (9.52 ppm) and 2 (14.20 ppm) showed lower hydrocarbon levels compared to other stations, especially station 7 (43.93 ppm). The Huralazimm wetland in the Iranian section consists of five main reservoirs, the reservoir 1 (two stations 1 and 2) has the most natural structure, ecologically. The level of extraction and exploration activities in this reservoir is very limited and this can be confirmed due to the low concentration of oil hydrocarbons in the fish tissue compared to other stations. In addition, the station 7 has the highest level of exploration and extraction activities and the level of hydrocarbons at this station is much higher than other stations. The hierarchical cluster analysis also showed the proximity of stations 6 and 7, which confirmed the findings.

The classification of identified ring hydrocarbons in fish in terms of number of rings showed that the two-and three-ring compounds had a higher frequency than the four –ring compounds (Fig. 2). Furthermore, the concentration of two-ring compounds or lightweight compounds of Naphthylene, Acenaphthylene and Acenaphthene were more abundant in fish caught compared to other hydrocarbon groups. Looking at the results of this study, it can be seen that at most stations, the compounds levels were 16 PAH below the detection limit (<10), which it is more likely due to the decomposition and conversion of these compounds to lower molecular weight compounds (Khairy et al., 2009). In this study, Mesopotamichthys sharpeyi, as an herbivorous and Saprophagous fish, provides a large portion of its nutritional needs from the invertebrate bestial beings. Given that by entering oil-based hydrocarbons into an aqueous medium, these materials are transported across the chain to various parts of planktons, invertebrates, and plants, and, then, they can be transferred to the body of fish and stored in it. Therefore, the amount of contamination in the tissue of Mesopotamichthys sharpeyi can indicate the contamination level in the lower levels of the food chain (Stolyhwo and Sikorski, 2005;

Echeveste et al., 2010; Yakan et al., 2017). In addition, this form of nutrition justifies the higher concentrations of oil- based hydrocarbons due to the higher accumulation of these substances in the body of the invertebrates (Yim et al., 2004).

Comparison of the values obtained by the average rate of compounds 16 PAHs in edible tissue of Binni fish based on the international standards. These standards include the U.S. environmental standard, EPA16PAH (µg/kg.dw 50), the world health organization (WHO) standard, 6 PAHs (µg/kg.dw 20) and the european standard, BaP (µg/kg.dw 8)(Sadatipour et al., 2001) and European commission (OJEU, 835/2011) (Hafez et al., 2017) (2ppb). They determined that the hydrocarbon values available in the tissue of wetland fish of Hawizeh Marshes (Houralazim) were much higher than the standards. IARC (1986) identified six combinations of benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benz[a] pyrene and dibenzo[a,h]anthracene, as mutagenic and carcinogenic compounds, which in the present study, except of benz[a]pyrene, the amount of other compounds were insignificant. Benz[a]pyrene as a known carcinogenic compound is usually used as an indicator for controlling hydrocarbon compounds in the environment. Hence, in the evaluation of carcinogenic risk or mutagenic risk, it is generally considered as the main combination (Kofi et al., 2018).

Therefore, this combination has the main part in the evaluation of carcinogenic risk or mutagenic risk in Hawizeh Marshes. Indeed, the equivalent toxicity factor (TEQ) and the equivalent mutagenesis factor (MEQ) is related to the toxicity rate B(a) P. TEQBap has a direct correlation with carcinogenicity of compounds and MEQBaP has a direct correlation with mutagenicity of compounds (Zeiger, 2001; Essumang et al., 2013). It means that these non-carcinogenic compounds have destructive effects such as pulmonary diseases, birth defects, sexual dysfunction and reduction of IQ (DeMarini et al., 2004; Essumang et al., 2013). According to the environmental protection agency and the European union, the two combination of indeno (1,2,3- cd)pyrene (IP) and benz[a]pyrene have positive mutagenicity and in terms of carcinogenicity, they have been categorized as a possible causing combination of cancer and carcinogenic composition, respectively. These compounds, alone or in combination with covalence compounds, attaches to the cellular macromolecules such as DNA and by making mistake in DNA replication, provide a background for mutation, so create a tumor and ultimately cause cancer (Orecchio et al., 2009). Other hydrocarbon compounds also have different degrees of carcinogenicity or mutagenicity, which according to the findings of the present study, contained minor amounts. The highest carcinogenicity rate was 13.1 at the station 7 and the highest mutagenicity rate was 23.49, which belonged to station 5. In the study of Kofi et al., (2018), the highest carcinogenicity rate was 3.05 and the highest mutagenicity rate was 4.40. In this study benz[a]pyrene was as the major causative compound of cancer and mutation, but in the study of Kofi et al., (2018), benz[a]anthracene was the most carcinogenic compound and Indeno[1,2,3- cd]pyrene was the most mutagenic compound.

The rate of gradual carcinogenicity for the combination of benz[a]pyrene with respect to the station was between 0.00003 to 0.0029 and generally in Hawizeh Marshes was 0.0027 (Table 4). This means that, due to the consumption of these fish during 70 years, out of every 10000, 29 people and out of every 100, 3 people, more likely will be affected by cancer. Compared to the study by Kofi et al., (2018), in the Ghana oysters the carcinogenicity rate was 45 people out of 10000000. Considering the value of threshold of the carcinogenesis intensity 1 × 10-5, which is announced by the USEPA (1993-2009), it represents the high carcinogenicity risk of this compound, especially at station 7.

The evaluation of gradual mutagenicity risk for the combination of benz[a]pyrene with the Per capita consumption rate of 9.2 kg (Fishery yearbook, 2015) was 0.055 (range 0.034 - 0.061). It means out of every 100 people, on average, 34 – 61 people are more likely to be exposed to non- cancer-related illnesses. Since the mentioned values are higher than 10-5 USEPA standard, so it can be said that daily consumption of these wetland fishes, increases the mutagenicity risk of the consumers with high consumption. In the study of Kofi et al., (2018), the mutagenicity level of benz[a]pyrene was 9 people out of 1000000 and 38 people out of 1000000 and they expressed that the high consumption of these oysters does not have good results and increases the mutagenicity risk in them. It should be noted that among the two-ring hydrocarbon compounds, naphthylene is a high-dose compound, which according to the American ATSDR, is considered as one of the causes of cancer in humans (US ATSDR, 2005), but it is not included in the calculations. This issue increases the risk of carcinogenicity and it necessitates the need of more attention to prevent from destruction and ruining of Hawizeh Marshes and reduction of human interventions.

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New application of fuzzy logic algorithm in GIS for land classification

Seyyed Hadi SADEGHI[1,*], Alireza EILDOROMI[1], Mohammad FARAMARZI[2]

[1] University of Malayer, Hamadan, Iran, Department of Watershed Management
[2] University of Malayer, Hamadan, Iran
* *Corresponding author*: Hadi.watershed@gmail.com

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Abstract

Population growth and disorganization of urban planning have led to unsuitable city development in the center of Iran. Suitable region recognition for urban land development is an important step towards future planning. In the present study, fuzzy logic algorithms (*OR, And, Sum, Product* and *Gamma*) were used within GIS in order to identify valuable land for appropriate residential development. Moreover, effective factors of urban land development (elevation, slope, aspect, geology, land use, drainage network, main and bypass roads, distribution of urban and rural areas, and fault line layer) were examined on fuzzy analyses to find the most effective ones. The results showed that, by considering the regional priorities and constraints, the best operator was Gamma, with a power of 0.9. According to this, 74 percent of the total regions are located between less and the least valuable lands and the remaining surfaces (i.e. 26% of the region) were classified from valuable to the most valuable lands. The sensitivity measurement of the layers used in the study showed that fault and distribution of urban and rural layers were the most and the least effective layers on region recognition (i.e. by 25.83% and 3.29%, respectively).

Keywords: *land classification, fuzzy logic, GIS*

Rezumat. O nouă aplicație SIG a algoritmului ce folosește logica fuzzy pentru clasificarea terenurilor

Creșterea populației și carențele planificării urbane au dus la o extindere inadecvată a orașelor în centrul Iranului. Recunoașterea regiunii adecvate pentru dezvoltarea arealelor urbane este un pas important în planificarea. În studiul de față au fost studiați algoritmi de logică fuzzy (*SAU, Și, Sumă, Produs* și *Gamma*) în SIG pentru a identifica terenuri valoroase pentru dezvoltarea rezidențială adecvată. Mai mult, au fost examinați factori efectivi ai dezvoltării terenurilor urbane (altitudine, pantă, aspect, geologie, utilizarea terenului, rețeaua de drenaj, drumurile principale și ocolitoare, distribuția zonelor urbane și rurale și faliile), folosind logica fuzzy, pentru a-i identifica pe cei mai importanți. Rezultatele au arătat că, luând în considerare prioritățile și constrângerile regionale, cel mai bun operator a fost Gamma, cu o putere de 0,9. Conform acestuia, 74% din totalul terenurilor sunt puțin și foarte puțin valoroase, iar suprafețele rămase (adică 26% din regiune) au fost clasificate de la cele valoroase la cele foarte valoroase. Măsurarea sensibilității straturilor utilizate în studiu a arătat că cele ce cuprind faliile și distribuția zonelor urbane și rurale au fost cele mai eficiente, respectiv cele mai puțin eficiente pentru recunoașterea regiunii (cu 25,83%, respectiv cu 3,29%).

Cuvinte-cheie: *clasificarea terenurilor, fuzzy logic, SIG*

Introduction

The purpose of this study is site selection for the appropriate development of urban settlements and identification of effective layers on region recognition (RR) using fuzzy analyses, in GIS. Recently, new urban centers have increased in order to balance the growth of large cities in Iran. During recent years, numerous cities, especially the large ones, have seen a city or new cities in their neighborhoods (Zaraby, 2009). In some cases, some geomorphologic factors (elevation, slope, etc.) have created obstacles to urban development, which caused several problems.

One of the most important questions regarding the manner of attracting population in these cities concerns the site selection techniques and development of cities over the time. In addition, the principles of urbanism should be known in order to determine the best location of urban development and population growth (Liu et al. 2014).

In recent years, urban planning has taken into account environmental hazards and natural processes. Different priorities such as topography, land use, land slope, climate, earthquakes, and distance from urban areas and main roads should also be considered for site selection (Dursun et al. 2011).

Geographical Information Systems (GIS) is a computer-based tool that can be used for different study purposes such as entry, storage, manipulation, analysis and display of geographical data. As GIS can manage a large amount of spatial data, it can serve as an ideal tool in the site selection studies (Isalou et al. 2013; Shahabi et al. 2014).

The fuzzy method helped the researchers to make better use of incomplete, inaccurate and ambiguous data (Salaski, 2002; Jamshidi-Zanjani & Rezaei, 2017). Numerous researches were conducted around the world in order to introduce physical development patterns of cities; for instance, in Nalos (west Azarbaijan province, Iran) affective factors of city development, including environmental and physical factors, were classified. These factors were overlapped in Arc GIS and the results showed that according to city conditions, environmental factors had the most important impact on city development (Naghibi & Shirmohammadi, 2008).

Bahram (2011) introduced natural factors, such as spatial and living limitation, as the main problems of Sanandaj city development based on constraints and environmental factors.

Gharakhlou et al. (2011) found two options for physical development of Babolsar city. The first concerned the inward development of the city, which was possible by allocating higher building and the second concerned the outward development of city, southwest of Babolsar, which was determined in GIS for future development according to city's limitation.

Rezaee and Melek Rudy (2010) investigated on physical development of Rudbar city. They found that numerous limiting factors induce effects on the development of the city; among them slope, landslides, faults, and the seismicity risk had the most important impact on RR.

Zoghi et al (2017) used fuzzy logic, weighted linear combination (WLC) and Multiple Criteria Decision Making (MCDM) in order to optimize site selection; they concluded that the combination of fuzzy logic, WLC and MCDM has a high accuracy and positioning in locating optimal solar sites.

In a different study, RR was done using fuzzy logic in GIS to determine appropriate areas for physical development in Divandareh, Iran. Hereby, ten layers were used based on priorities and restriction of the city and prone areas using the best-known fuzzy operator (Gamma) for city development (Hosseini et al. 2011).

The usefulness of fuzzy logic in GIS modelling for urban land evaluation was confirmed in different studies as well (Daniel, 1992; Chang Ni-Bin, 2008; Davidson et al. 1994; Khorram et al. 2015; Jamshidi-Zanjani & Rezaei, 2017).

The present study concerns a very extensive area located in the center of Iran. No study has been done in this regard and there is no development program for residential regions. Therefore, RR for urban land development is considered as one of the main objectives. Furthermore, the effects of layers are examined based on fuzzy analyses in GIS, in order to find their roles in RR.

Material and Methods

The region under study covers an area of 31,022 km², its coordinates being marked by 54°2' and 55°33' long. E and 31°25' and 33°56' lat. N.

From north and south, the area is connected to Isfahan, Semnan and Yazd, individually. The maximum altitude of the region is 3128 m above sea level (Figure 1).

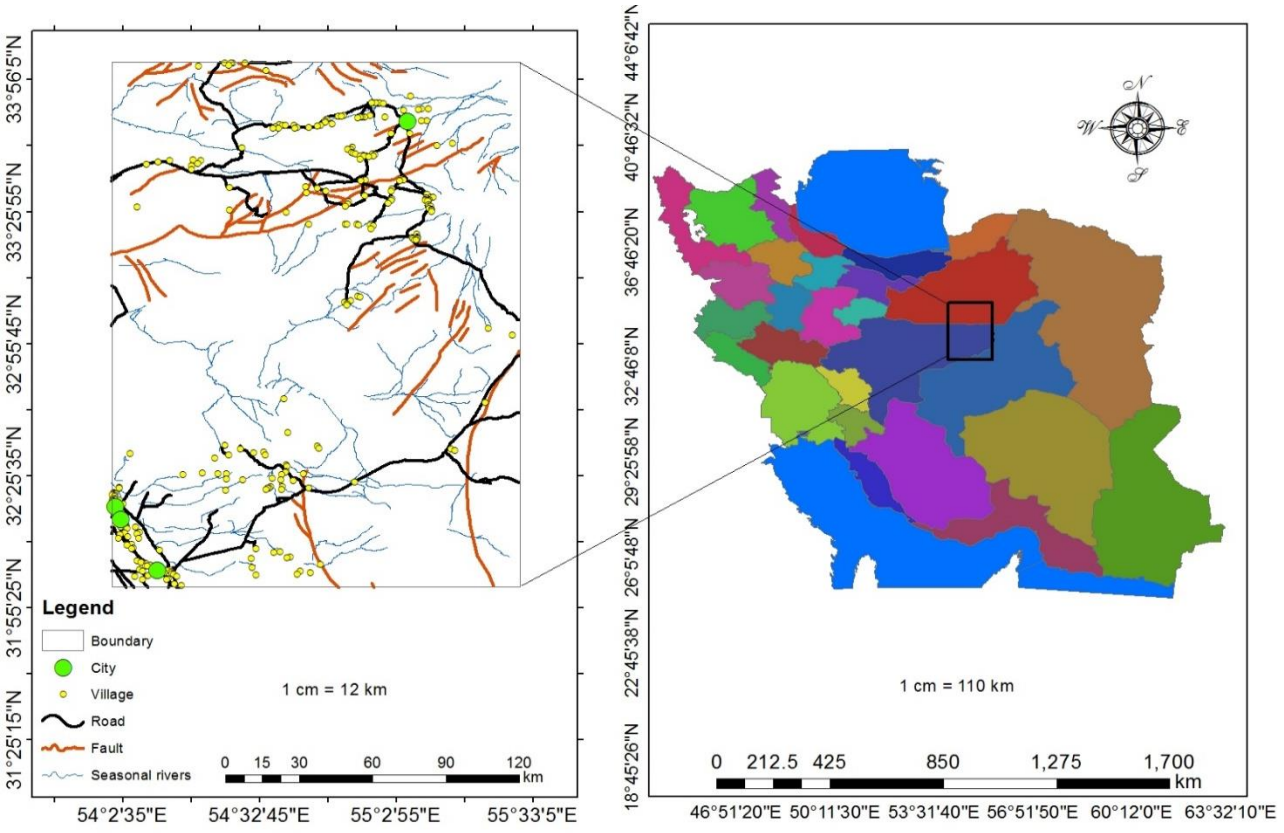

Fig. 1: Location of study area in Iran

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Fuzzy logic

Fuzzy membership values range between 0 and 1; however, there are no practical constraints on the choice of fuzzy membership values. Values are simply chosen to reflect the degree of membership of a set, based on subjective judgment. The fuzzy membership values must reflect the relative importance of each map, as well as the relative importance of each class of a single map (Hosseini, 2011).

Model inputs

Based on studies conducted on RR, many factors are involved in this regard. According to the view of experts and to the environmental and human characteristics, the most important factors that affect the region in terms of RR and physical development include elevation, slope, aspect, geology, distance from drainage network, land use, distance from the main and bypass roads, distribution of urban and rural areas, and distance from fault lines.

The data for these nine criteria for RR were obtained from governmental organizations and the information was examined by using the fuzzy method in GIS. At first, all layers were scaled, and their raster were prepared to implement fuzzy model in Arc GIS. The layers were weighted based on responses from groups of producers and researchers in Arc GIS (Pradhan et al. 2009).

Lesser height and slope, north and northwest direction (these directions receive the highest sun shine in the area), closeness to the main and bypass roads, closeness to urban services, resistance to erosion, significant distance from rivers and fault lines, and dense pasture lands received the highest weight. Each layer got the same total weight (0.111), to recognize their roles on RR by using fuzzy algorithm in GIS. Membership function for the layers was linear, which is derived from the deficiencies of the Boolean logic-based evaluation method (Daniel, 1992). For instance, in relation to the fault lines, any point located within a distance of less than 1 km was rated as the least valuable, 1 to 2 km was less valuable, 2 to 3 km was valuable, 3 to 4 km was very valuable, and above 4 km was the most valuable land. The sub-criteria was determined and weighted based on GIS classification for each criteria and the view of experts and environmental characteristics of Isfahan, Semnan and Yazd province (Table 1).

Table 1 Evaluation Criteria, Membership and Weights based on responses from groups of producers and researchers

Criteria	Sub-criteria	Weight	Total weight	Fuzzy Membership
Elevation	698-959m	0.81-1	0.111	Linear
	959-1287m	0.66-0.81		
	1287-1618m	0.47-0.66		
	1618-2000m	0.47-0.25		
	2000-3057m	0-0.25		
Slope	0-6 %	0.94-1	0.111	Linear
	6-11%	0.70-0.94		
	11-20%	0.50-0.70		
	20-40%	0.38-0.50		
	40-73%	0-0.38		
Aspect	South	0-0.25	0.111	Linear
	South-East	0.25-0.40		
	South-West	0.40-0.50		
	East	0.50-0.60		
	West	0.60-70		
	North-East	0.70-0.80		
	North-West	0.80-0.90		
	North	0.90-1		
Geology	Higher sensitivity to erosion	0-0.05	0.111	Linear
	Medium sensitivity to erosion	0.05-0.49		
	Low sensitivity to erosion	0.49-1		
Land use	Residential areas	0-0.02	0.111	Linear
	Bare and rock land	0.02-0.07		
	Saline land	0.07-0.15		
	Desert	0.15-0.49		
	Denser pasture lands	0.49-0.88		
	Dense pasture lands	0.88-1		
Drainage network	Distance to river	0-1	0.111	Linear
Main and bypass roads	Distance to road	0-1	0.111	Linear
Distribution of urban and rural areas	Distance to urban and rural area	0-1	0.111	Linear
Fault	Distance to fault line	0-1	0.111	Linear

The layers were named and the final estimation was conducted on them to determine whether the urban land is most valuable, very valuable, valuable, less valuable or least valuable using fuzzy operators including *And, OR, Product, Sum,* and *Gamma* (with different powers).

Fuzzy *AND*

This operator sets values of 0 and 1. It is defined as (eq. 1):

$$\mu_{combinatin} = MIN(\mu_A, \mu_B, \mu_C, \ldots) \quad (1)$$

where μA is the membership value for map A at a particular location, μB is the value for map B, and so on.

"Fuzzy AND results in a conservative estimation of set membership, which tend to produce small values".

Fuzzy *OR*

The output membership values are controlled by the maximum values of any of the input maps, for any particular location. The fuzzy OR is defined as:

$$\mu_{combinatin} = MAX(\mu_A, \mu_B, \mu_C, \ldots) \quad (2)$$

Fuzzy *Algebraic Product*

The product membership function is defined as:

$$\mu_{combinatin} = \prod_{i=1}^{n} \mu_i \quad (3)$$

where μ_i is the fuzzy membership function (i=1, 2... n).

"The Product fuzzy membership values tend to be very small with this operator due to the effect of multiplying several numbers less than 1".

Fuzzy *Algebraic Sum*

This operator is complementary to the fuzzy algebraic Product. "The result is always larger or equal to the largest contributing fuzzy membership value", being defined as:

$$\mu_{combinatin} = 1 - \prod_{i=1}^{n} (1 - \mu_i) \quad (4)$$

where μ_i is the fuzzy membership function for the i-th map and i=1, 2... n maps are to be combined.

Fuzzy *Gamma*

"This is defined in terms of the fuzzy algebraic Product and the fuzzy algebraic Sum by eq. 5":

$$\mu_{combinatin} = (FuzzyAlgebraic\ Sum)^{\gamma} * (FuzzyAlgebraicProduct)^{1-\gamma} \quad (5)$$

where γ is a parameter between 0 and 1 (Zimmermann and Zysno, 1980). When γ is 1, the combination is the same as the fuzzy algebraic Sum and when γ is 0, the combination equals the fuzzy algebraic Product. This operator was applied with 0.7, 0.8 and 0.9 powers.

Sensitivity measurement of layers

In order to understand the effective layers on fuzzy analyses, one of nine layers is removed at each step, and eight remaining layers are used for RR. Each layer is evaluated based on its impact on RR.

Results and Discussion

It was specified in evaluation of the fuzzy operators including And, OR, Product, and Sum that none of these operators were appropriate for physical development feasibility, because their results were far away from realistic (Mirnazari et al, 2015; Motevalli and Esmaili, 2013; Hosseini et al, 2011). Although these operators were confirmed as unsuitable methods for classification in different researches, testing these operators in relation to urban development would give a better understanding of the fuzzy logic technique.

The *Gamma* operator (with 0.7, 0.8, and 0.9 powers) was also tested in order to identify the best power applied, which depended on whether the identified areas are the regions with restriction or not. If the identified areas fall in the restricted regions, the operator would not be found as appropriate for RR.

Figure 2 illustrates the classification of RR using all operators. Five classes were categorized from the most to the least valuable land, based on priorities and restrictions in the study region. Findings indicated that fuzzy *OR* and *Sum* operators covered the highest valuable land for physical development, and the fuzzy *Product* and *And* operator expressed more different conditions of the region. They cover the least valuable lands for physical development of city. These operators including fuzzy *OR, Sum, Product* and *And* selected either all or none of region for city development which their selection were not suitable for our purposes. It means that these operators did not consider the criteria and limitation of the regions that were defined in Table 1. However, the *Gamma* operator, with different powers, indicated a sensible balance of RR (Pradhan et al. 2009).

Table 2 shows the proportion of RR using the operators. According to this table it can be concluded that fuzzy *OR* and *Sum* operators identify more than 99% of the study region as the most valuable land. This conclusion was opposed to fuzzy And and Product operators. These operators identified the highest region between less and least valuable land. This conclusion was different in the case of fuzzy *Gamma* with power of 0.7, 0.8 and 0.9 which more reasonable results based on priorities and limitations achieved for RR. Among the different powers (0.7, 0.8 and 0.9) of the Gamma operator, fuzzy Gamma with 0.9 power

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had better recognition of the region (Hosseiny et al. 2011; Yalcin, 2008; Lee, 2007).

Estimations of Gamma with power of 0.7 and 0.8 showed that these two operators did not include some of suitable areas for city development while their locations based on priorities and limitations (Table 1) are appropriate for new city development. This importance was grasped by examination of the constraints and priorities in the subject area, which were provided by used layers. Hereby, by means of Gamma operator (0.9) most valuable, very valuable, valuable, less valuable and least valuable lands included 2.26%, 7.5%, 16.22%, 29.30% and 44.70%, respectively.

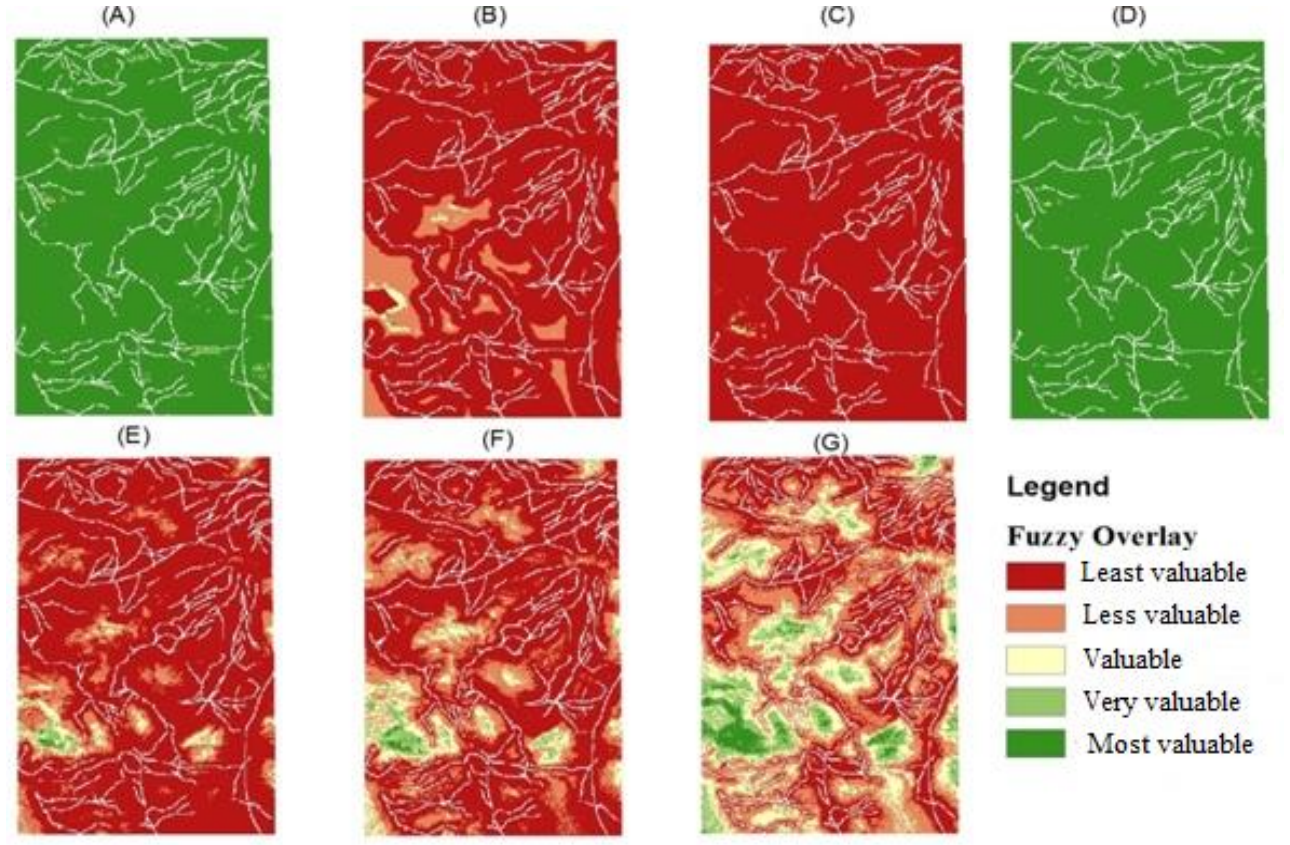

Fig. 2: Classification of RR with all operators including A: OR; B: And; C: Product; D: Sum; E: Gamma 0.7; F: Gamma 0.8; G: Gamma 0.9

Table 2 RR of subject area by all operators

	Gamma 0.9	Gamma 0.8	Gamma 0.7	Sum	Product	And	OR
Most valuable	2.26	0.28	0.1	99.9	0.0008	0.002	99.37
Very valuable	7.5	1.77	0.66	0.0004	0.003	0.006	0.47
Valuable	16.22	5.6	2.07	0.0002	0.003	0.7	0.009
Less valuable	29.30	17.62	9.37	0.00009	0.17	8.41	0.006
Least valuable	44.70	74.69	87.78	0.0001	99.74	90.79	0.0002

Figures 3-11 show the effect of layers on RR when using fuzzy analyses. The restrictions and the priorities of applied factors were used for RR verification (Meshginni et al. 2013; Shamsipour & Shikhi, 2010). Thus, the elevation factor was examined in the entire area and it was found that sections which were chosen as the most valuable and very valuable lands had no height restriction. This means that they are at an altitude lower than 2000 m, which are valuable for physical development. Figure 3 illustrates that elevation layer affect RR by 4.98%.

In the examination of slope restriction, it is founded that 90% of the total region are located between the slopes of 0 and 11 percent which is the most appropriate slope for residential development (Cowan, 2005). Out of the regions selected for development from valuable to the most valuable lands, none is out of this slope range. Figure 4 shows that slope layer affects RR by 5.23%.

With respect to the aspect, important areas were identified from valuable to the most valuable lands. In this regard, northern and north-eastern aspects were determined as the most appropriate directions for development because areas with these aspects receive the highest sun radiation in the region. Two suitable sections identified in the center of the region have south-eastern and south-western aspects. Figure 5 indicates that aspect layer affects RR by 3.82%.

The geology investigation of the region showed that more than half of the area under study combine marl, chalk, and sandstone, which have average resistance to erosion (Tavfigh, 1991, Zoghi et al., 2017). Valuable lands located in the southern part of the study region have soils that are more resistant to erosion; this area mainly comprises sandstone and conglomerates. Figure 6 shows that geology layer affects RR by 5.05%.

The low-density vegetation within the areas suitable for development represents an important part of the regions' cover. The main part of the valuable lands is located in the southeast and southwest of the study region in desert. Figure 7 illustrates that land use layer affects RR by 7.63%.

The river element has always been an effective factor for RR. This element is considered a possible potential of dry and extreme dry region, which has the potential of flood. The total length of the rivers in the region is 2,542 km. None of the identified regions is in the flooded area (Shirzadi et al. 2011, Jamshidi-Zanjani and Rezaei, 2017). Figure 8 shows that river layer affected RR by 22.45%.

The most of suitable regions, ranging from valuable to the most valuable plots, are appropriate for development based on the evaluation of the main and bypass roads. The total length of main and bypass roads is 1,165 km. These circulation axes connect cities such as Khor Biabanak to Ardekan, Meibod, and Yazd. Moreover, being near or far from urban and rural areas is always considered as one of the determinant factors for RR due to they will provide better condition for other regions. Figure 9 indicates that the main and bypass roads layer affect RR by 17.27%.

The distribution of urban and rural areas indicates that the highest distribution is in the south, southwest, north, and northwest. Being near the city was the priority of evaluation the urban and rural areas distribution for RR (Mohammady et al. 2009). According to figure 10, urban and rural areas distribution layer affects RR by 3.29%.

The length of the faults in the region is 1,060 km. Despite this fact, the important element is that none of the areas suitable for urban development and identified from valuable to the most valuable are on the fault line (Ercanoglu and Candan, 2004; Jamshidi-Zanjani and Rezaei, 2017; Zoghi et al., 2017). Figure 11 shows that fault layer affects RR by 25.83%.

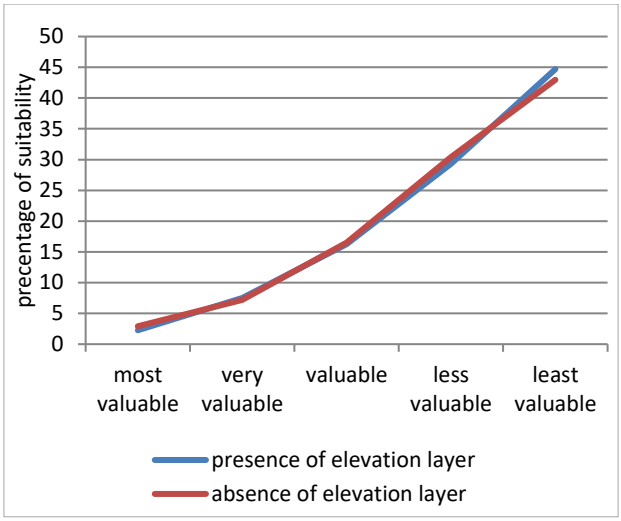

Fig. 3: RR in the presence and absence of elevation layer

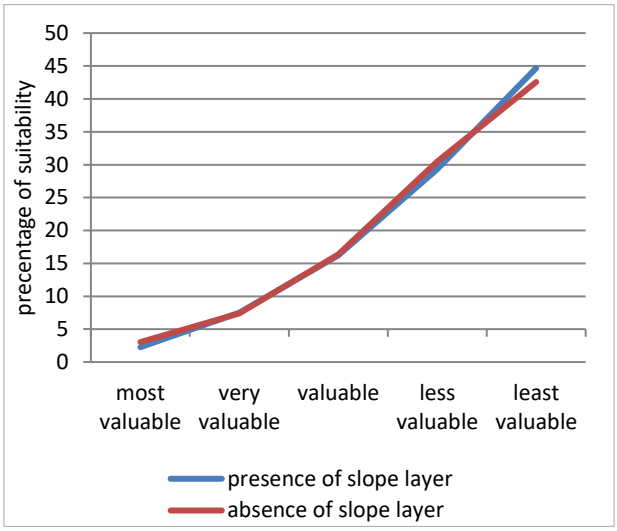

Fig. 4: RR in the presence and absence of slope layer

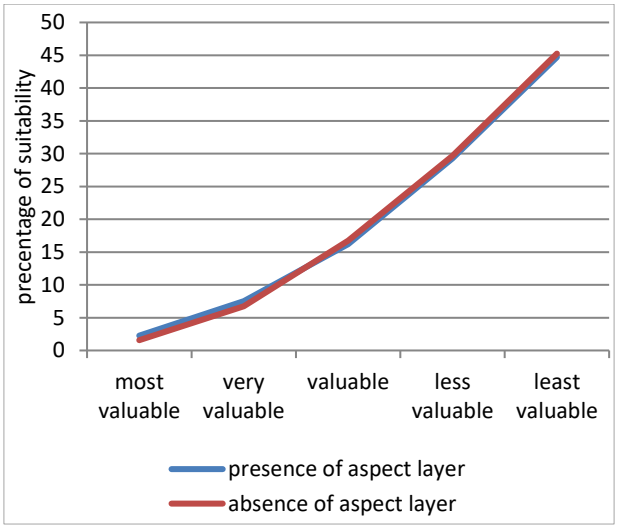

Fig. 5: RR in the presence and absence of aspect layer

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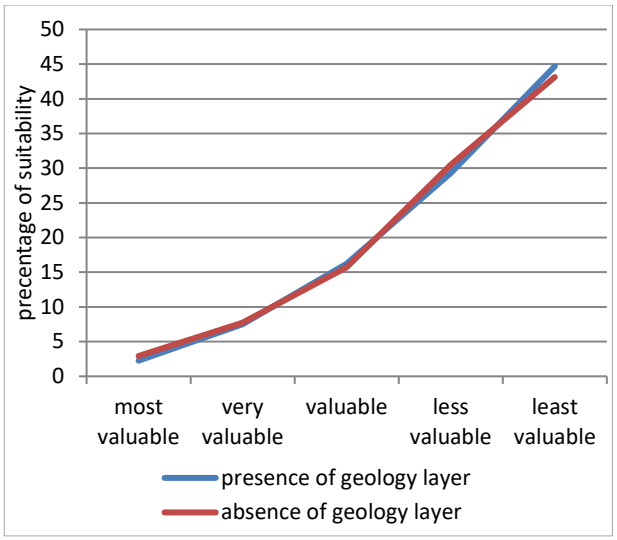

Fig. 6: RR in the presence and absence of geology layer

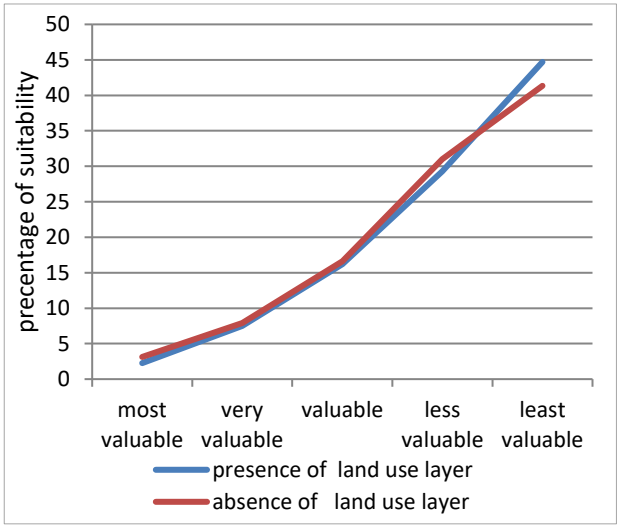

Fig. 7: RR in the presence and absence of land use layer

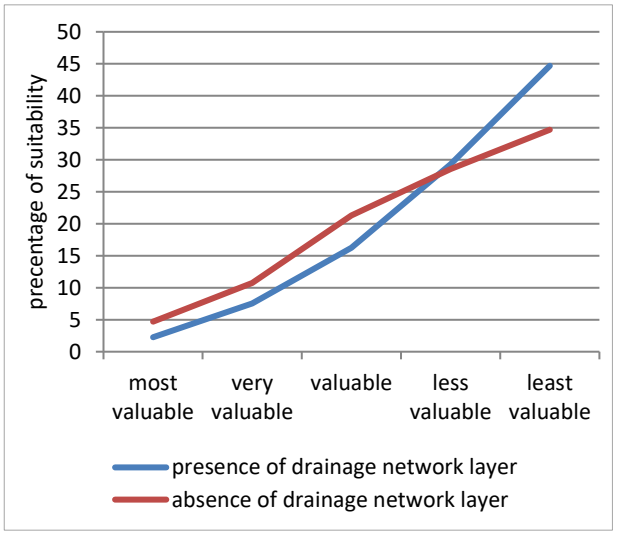

Fig. 8: RR in the presence and absence of river layer

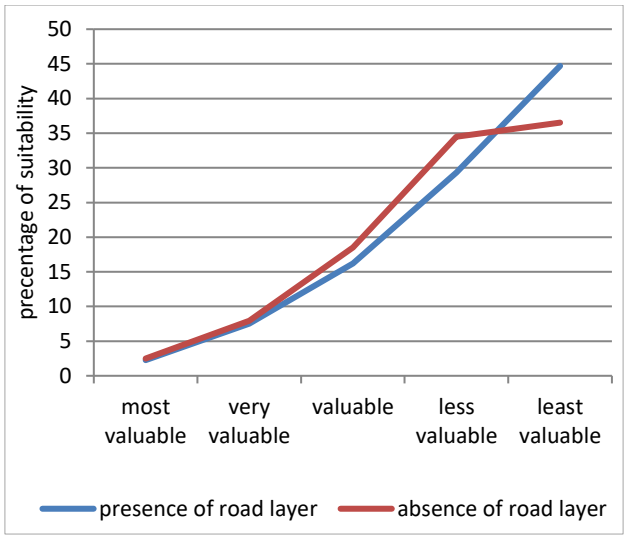

Fig. 9. RR in the presence and absence of main and bypass roads layer

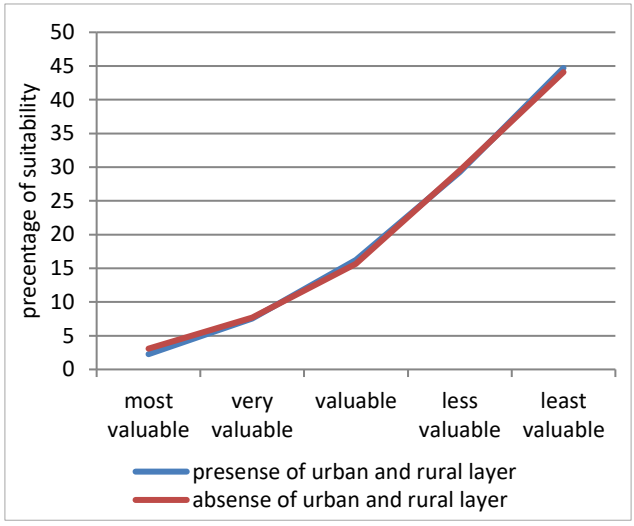

Fig. 10. RR in the presence and absence of urban and rural areas layer

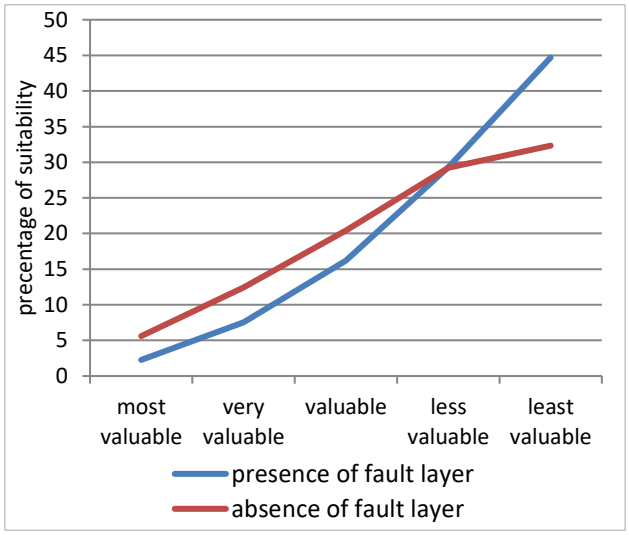

Fig. 11. RR in the presence and absence of fault layer

Conclusion

Site selection is an important strategy towards city planning. This importance is much sensible in areas where city development plans lack. This research was conducted in order to suggest prone areas for urban land development in the center of Iran. The effective layers that are important for determining RR were used and their impacts were examined to find the most influential layer on RR, by using fuzzy algorithm in GIS. According to the findings, *Gamma* (0.9) was the best operator among all operators that had either very less or a lot more RR based on priorities and restrictions. The most valuable, very valuable, valuable, less valuable, and least valuable lands were including 2.26, 7.5, 16.22, 29.30, and 44.70 percent, respectively. The analyses of the nine factors showed that the fault line layer (by 25.83 %) and the distribution of urban and rural layers (by 3.29 %) represented the most effective and, respectively, least effective layers on RR. Other effective layers on RR included the drainage network, the main and bypass roads, the land use, the slope, the geology, the elevation, and the aspect layer, individually.

It appears that one of the drawbacks of fuzzy algorithm is that this technique is much influenced by polyline feature (fault line, drainage network) when applying for site selection, rather than polygon (land use, geology) and point (distribution of urban and rural) features. By this, some effective factors such as land use, geology, elevation etc. were less considered, while they are highly important in residential area development. Overall, the *Gamma* operator is suggested for site selection, and the other fuzzy methods should not be tested for this kind of purposes. Moreover, other layers like groundwater level should be used for site selection study in order to find the best site for city development. Watershed operations on its seasonal rivers are suggested before any city development in the selected areas.

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Post-Communist Urban Ecologies of Romanian Medium-Sized Towns

Ioan Sebastian JUCU[1], Sorin PAVEL[1,*]

[1] West University of Timisoara, Department of Geography, Romania
* *Corresponding author*: sorin.pavel@e-uvt.ro

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Abstract

The post-communist policies on urban restructuring were the driving force in redundant and marginalized spaces' reproduction in all Romanian cities and towns. The paper investigates post-communist urban ecologies and derelict urban environments in Romanian small-sized municipalities, since these issues remain peripheral in the contemporary research on post-communist urban identity formation of the cities. The research was conducted in the town of Lugoj of Romania, from 2012 to 2016. It bases on empirical data provided by ethnographic analysis, quantitative approach and qualitative investigation. The results unveil a massive decline of some urban areas managed by post-communist policies on urban regeneration, with negative consequences, risk potential and derelict landscapes threatening the local urban welfare. Therefore, these marginal places request further enhancement urban policies to reduce their negative results claiming for more attention by the side of local governments.

Keywords: *post-communism, urban ecologies, derelict sites, urban environments, Romania*

Rezumat. Ecologiile urbane post-comuniste în cadrul oraşelor mijlocii din România

Politicile şi intervenţiile post-comuniste, aplicate şi desfăşurate în procesul de restructurare urbană la nivel local au reprezentat factorii determinanţi în apariţia şi reproducerea spaţiilor urbane marginalizate în toate oraşele mici şi mijlocii ale României. Lucrarea analizează ecologiile urbane post-comuniste, în strânsă legătură cu mediile urbane derelicte, în contextul în care, deşi de mare interes în cercetările actuale, la nivelul României, acestea ocupă un loc periferic. Spaţiul laborator îl reprezintă municipiul Lugoj, cercetarea fiind realizată între anii 2012 şi 2016. Designul metodologic este bazat pe date empirice şi informaţii rezultate prin aplicarea analizei etnografice, a observaţiei participative, a cercetării cantitative şi a metodelor calitative de investigare a spaţiului urban. Rezultatele studiului evidenţiază un declin masiv al unor spaţii urbane, cu consecinţe negative, cu elemente de risc şi insecuritate urbană şi cu implicaţii majore în imaginea oraşului şi a peisajului urban. Mai mult decât atât, aceste aspecte îşi pun amprenta asupra calităţii mediului urban şi al modului de viaţă al oamenilor la nivel local. Spaţiile marginalizate, identificate prin studiul de faţă solicită noi intervenţii de regenerare în vederea reducerii aspectelor negative ale mediului urban şi intervenţii adecvate din partea tuturor actorilor implicaţi în procesul dezvoltării urbane, din perspectiva sustenabilităţii la nivel local.

Cuvinte-cheie: *post-comunism, ecologii urbane, situri abandonate, medii urbane, România*

Introduction

A recent statement on urban transformations governed by political and economic changes unveils that 'cities throughout the world contain spaces that are run-down and neglected. They are abandoned sites, decayed buildings boarded-up shop fronts, public facilities in disrepair and blighted neighborhoods' affecting the cities' viability as a whole' Turok (2015: 74). Against such a background, framed by post-communist economic changes and by the negligence in unfinished urban transition of the cities (see Svetlozar, 2009; Paddison and Hutton, 2015), their urban ecologies have to be (re)considered to manage proper policies on urban marginalized places' remaking, since the built urban environment remain 'an integral part of the economic and social life of the city' (Turok, 2015: 91) managed by the current globalization and de-industrialization. Therefore, cities appear as places where 'the work of globalization gets done' (Keivani et al, 2001: 6) whether they are large urban agglomerations or smaller towns where environmental side effects are often opaque, exclusive and unaccountable (Keivani, 2010). They have to be fashioned in the frame of the current urban ecologies ensuring the local urban sustainability through realistic policies agendas on urban planning (see Turok, 2015). These new political agendas on cities' remaking would render urban ecology more inclusive in local urban development and in the political framework on urban regeneration. Consequently, the issues of urban ecologies are key features in the contemporary geographical research with multiple implications in the local urban communities. As McDonnell (2015: 1) states 'human settlements are unique ecosystems consisting of human-made structures and natural elements, including people, which are maintained and transformed by a complex set of interactions within and between ecological and social systems.' Today, cities and towns face with multiple environmental economic and social challenges (McDonnell, 2015) provided by the residual places, by the shifts in local

cultural values, by the social spatial cohesion (Thiagarajah et al, 2015; van Tran, 2015) and by the urban habitats' degradation at the local scale (Mcdonald et al, 2008; Seto et al, 2012), especially in small and medium-sized towns of developing countries (Elmqvist et al, 2013). These ongoing processes fits to post-transitional states due to the economic political and economic changes in urban areas (Kiss, 2007; Smith and Timár, 2010; Paddison and Hutton, 2015; Hutton, 2015), threatening the local urban welfare and the urban quality of life (see UN-Habitat, 2011). Against such a background, socio-economic processes and urban planning practices related to urban landscape design, local planning and sustainability decisions are important issues in the present environmental impacts in urban areas (Kennedy et al, 2012; Desouza and Flanery, 2013; Pickett et al, 2013; Childers et al, 2014; Wu, 2014; Gagné et al, 2015). They are mandatory tailor-made interventions considering the main post-communist urban shifts in the inner-urban spatial patterns with abandoned, derelict and ruined sites left behind in the face of the present global capitalism.

On the scene of political and economic changes during post-communist period, the Romanian cities and towns faced with multiple challenges fashioned by divergent interventions producing important ruined sites often neglected. They argue contrasting, divergent and antagonist interventions of the state in the local urban regeneration (Chelcea, 2012; Ianoş et al, 2015; Jucu et al., 2016) with their multiple spatial, social and economic consequences in local communities arguing the unfinished political and socio-economic transformation (Svetlozar, 2009) in post-communist Romanian cities and especially in all those small or medium-sized urbanities. Consequently, post-industrial ecologies in urban areas remain as proofs of post-communist economic shifts with marginalized spaces, derelict urban environments, ruined sites and post-industrial landscapes being spaces of limited representation in the local collective perception (Chelcea, 2015). In this regard, industrial ruins and urban derelict places are ubiquitous scenes in the Romanian urban landscapes. Their production launched by the expansion of capitalist economy and globalization (Edensor, 2005; Mah, 2010, 2012; Keivani, 2010; DeSilvey and Edensor, 2013) is a common feature in all former state-socialist countries and in Romania as well. The transition to a new capitalist regulation generated multiple and dramatic changes and uneven development (Kiss, 2007; Smith and Timár, 2010) at local, regional and national scales. The main driving producer of these left-behind urban spaces as derelict environments and ruined sites was the rapid process of deindustrialization (Keivani, 2010). After 1990, the Romanian industry faced a major decline (Stanilov, 2007; Hirt and Stanilov, 2009; Voiculescu and Jucu, 2016; Gavrilidis et al, 2015; Ianoş et al, 2015; Jucu, 2015) with the formerly industrial sites turning to unproductive and redundant places. These ruined sites are presently subject to degradation, influencing their neighborhoods' welfare, the urban landscapes and the local environment (Chelcea, 2015).

The main question in this study relates the post-communist policies on urban restructuring to the urban derelict places production at the local scale. Furthermore, it concerns on how post-communist urban transformation altered the local urban patterns under the shifted umbrella of the new capitalist development in formerly state-socialist spaces through a particular case-study in-depth analyzed. In addition, the question of how urban dereliction appeared and their multiple consequences in urban area are investigated to highlight the (re)production of the urban ruined sites and their related marginal ecologies. Likewise, how urban dereliction appeared producing local spatial consequences in local community and how local authorities managed these hybrid urban ecosystems are important topics with merit in this analysis. The study brings to the fore the connections between local policies in urban restructuring, urban ecology, derelict landscapes and ruined environments with these issues considered as spaces of perception and representation in local community.

Theoretical framework on urban ecologies and derelict environments

The post-communist Romanian transition from the centrally planned economy to an oriented-market one was dramatic with uneven impacts on the local urban communities (Kiss, 2002; 2007). These dramatic changes of social and economic urban environments with rapid deindustrialization being the main factor generated contradictory and divergent patterns in Romanian urban space (Keivani, 2010; Chelcea, 2012; Marcińczak et al, 2014; Ianoş et al, 2015). Furthermore, uneven spatial development in urban areas has a central position in the present urban identity formation (Stanilov, 2007; Kiss, 2007; Ianoş et al, 2010) as there are important difficulties of national democratization related to hesitant and discretionary interventions in Romanian post-communist policies on economic restructuring (Mihuţ, 1994; Bojkov, 2004; Nenovsky et al., 2013). Against such a background framed by the urban environmental justice (Keivani, 2010) as crucial feature in the present urban sustainability demands, urban ecologies of marginal groups and spaces appeared (Chelcea, 2015), with derelict urban environments remaining the most important features of post-communist urban shifts. Consequently, they generated fragile environments at micro-scale level (Ianoş et al, 2009; 2011; 2012). The rapid suc-

cession of events in Romanian post-communist restructuring in terms of political and economic remaking (Ilieş et al, 2012) related to industrial decline, deindustrialization, relocation of the local industrial activities (Peptenatu et al 2012; Gavrilidiş et al 2015; Hutton 2015), the links between national identity and Europeanization, diffused levels of political support and political tensions in national government (Dragoman, 2008; Cernat, 2010; Stan, 2015) are the main contributors in the appearance of the contemporary urban ecologies of local urban areas of the Romanian towns. They are framed by a poor management on local risk environment and by slippery interventions, corruption and speculations in local economic restructuring (see Kideckel, 2008) with multiple consequences in local urban communities. Improper interventions as a particularly striking feature for the political elites that managed the processes of economic restructuring (Svetlozar, 2009) remain responsible for the marginalized urban areas production.

Considering the brutal changes in the urban spatial formation of the former state-socialist towns since transition started and new capitalist order has been implemented, urban ecology became an important floor of analysis that could provide critical thoughts that has to be (re)considered in local authorities' agendas concerning local urban development. Incorporating human perception on urban ecology and its derelict environments, the increasing role of the citizens and public participation in local urban regeneration, the information in local decisions guiding and gathering new social and ecological knowledge in local policies of governments agendas represent the main perspectives of current urban ecology (Cooper et al, 2007; Wilkinson et al, 2013; Douglas, 2014; McDonnell, 2015). Thus, urban ruins and local dereliction related to the local way of life of the inhabitants and their negative results in urban areas represent a central issue of the urban settlements, in their transition to the present capitalist regulation. The state of the art of ruins' emergence and derelict places appearance acknowledge this statement. It is complex and challengeable with multiple difficulties in local urban management. Economic restructuring through the lens of post-communist policies in urban management are the main contributors in the production of derelict environments (Jucu, 2015). Furthermore, since deindustrialization started, close aboard to the reforms in the national political system in all economic fields as well as in the housing capital, important derelict places appeared, with their presence threatening the local communities.

Therefore, ruins are ubiquitous scenes in many urban settlements (Mah, 2010; 2012) conceptualized as 'debris of global capitalism' (Martin, 2014: 1037) and as collapsed, dead, loose, null, vacant and underused spaces in urban areas due to the economic shifts (Edensor, 2005; Bagaeen, 2006; Nefs, 2006; Jogensen and Tylecote, 2007; Chelcea, 2008; Kideckel, 2008; Barndt, 2010; Puşcă, 2010; Mah, 2012; Armstrong, 2011; Jucu 2011, 2015; DeSilvey and Edensor, 2013; Voiculescu and Jucu, 2016; Jigoria and Popa 2016). Urban ruins as left-behind places of representation illustrate indifference, ignorance and social stagnation (Edensor, 2005; DeSilvey and Edensor, 2013), thus producing inner-urban derelict environments and repulsive landscapes with particular usage by marginal human groups (Chelcea, 2015). These marginalized places and their related individuals belong to the present urban ecologies whether they are located in the cities' outskirts or in the urban central areas. However, beside the industrial areas (see Mah, 2012) ruined sites and their associated derelict environments appeared in vacant military sites (Davis, 2008), in rail areas (Qviström, 2012) and in residential districts. Regardless of their origins and placements in urban areas, ruined sites appear as places with repulsive landscapes, risk potential and unsafely feelings in individuals' perceptions, with human and non-human marginal groups being the main beneficiaries (Chelcea, 2015). These fit especially for post-communist industrial ruined sites in urban areas but they are not limited to them. The post-industrial emergent ecologies of ex-industrial places could be translated in other types of ruined sites, as there are all those of rail-ruined areas and of residential districts. However, all these derelict urban environments are sites in which activities are developed. Chelcea (2015) identifies four important perspectives: as urban mining; as playgrounds for children; as refuges for urban marginals (humans and non-humans) and as struggles to construct signification by the cultural bourgeoisie. Whether these activities have been identified for metropolitan areas, they are more present in the small-sized municipalities that have to be more considered as ethnographic case studies in the current research (Roose et al, 2013; Iaţu and Eva, 2016). The issue of ruined and urban derelict environment distribution throughout Romanian space confirms the hypothesis of a general assessment that ruined sites and urban derelict environments present the same background for locals, regardless of their geographic scale. Furthermore, beyond their presence, urban derelict environments unveil divergent patterns spatial stress, contradiction and incoherence related to important environmental tensions in urban areas (Iojă et al, 2014; Ianoş et al, 2015; Onose at al, 2015). In the absence of real urban development strategies, and related to un-participatory planning in urban regeneration by the locals and to the community's voice missing in local urban post-communist (re)formation (Voiculescu and Jucu, 2016), derelict environments still stand as proofs of present municipalities indifference. Their related urban ecologies remain key issues in the contemporary scientific dialogues in order to promote new sustainable visions of

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local urban development agendas. Thus, research on the spatial perception and representation of post-communist derelict environments and their related urban ecologies could provide critical thoughts on how the urban left-behind places have to be further managed in the short run. Urban ruined sites, their local perception and representation frame the present patterns of local urban ecologies and derelict urban environments produced by the post-communist economic transition to a market economy. All through the study, these theoretical issues are in-depth applied in the following sections. Of these, the next one highlights the study area, the methodological design and the empirical data used in the research.

Study area, data and methods

Located in the western Romania, (Figure 1) the municipality of Lugoj assumed in the past an important position in the national industry, with industrial activities remaining the main economic activity (Ianoş, 1987; Voiculescu, 2004; Jucu, 2011, 2015). The post-communist economic spatial shifts in the local urban restructuring generated divergent patterns (Ianoş et al, 2015; Jucu, 2015; Jucu et al., 2016), with derelict environments remaining important features of the local urban changes under transition and post-transitional time. This post-industrial urban ecology of the town translates in the appearance of urban ruined sites since the actions of urban land use and environmental development shifted under the new capitalist umbrella (Zeng et al, 2014; Iaţu and Eva, 2016). Due to the Romanian post-communist industrial decline (Gavrilidiş et al, 2015), associated with relocation of industrial activities with the investors being interested in new locations for their industrial investments (Peptenatu et al, 2012), mismanagement in urban industrial privatization, urban land-use disputes and conflicts, personal and competing interests at the local scale (Kideckel, 2008; Hersperger et al, 2015), derelict urban environments appeared with a myriad of complex challenges on the study of local derelict environments. Consequently, urban ruins are the most important spatial result of post-communist urban restructuring. Even though avoidance of derelict urban environments and brownfield sites in urban areas are suggested (see Gavrilidiş et al, 2015), these sites with particular urban ecologies still prevail, generating peculiar environments at the local scale. Against such a background, the municipality of Lugoj, a medium-sized municipality, faces multiple problems, due to the local urban derelict environments' production. This is the case study sampled in this attempt to investigate the local urban ecology with particular local sites in-depth approached. The present approach is in line with the case-studies relevance in the contemporary academic debates, especially concerned on non-metropolitan areas (Roose et al, 2013; Gavrilidiş et al, 2015; Iaţu and Eva, 2016). Accordingly, nine derelict sites in local area have been considered, their spatial distribution being highlighted in Figure 1.

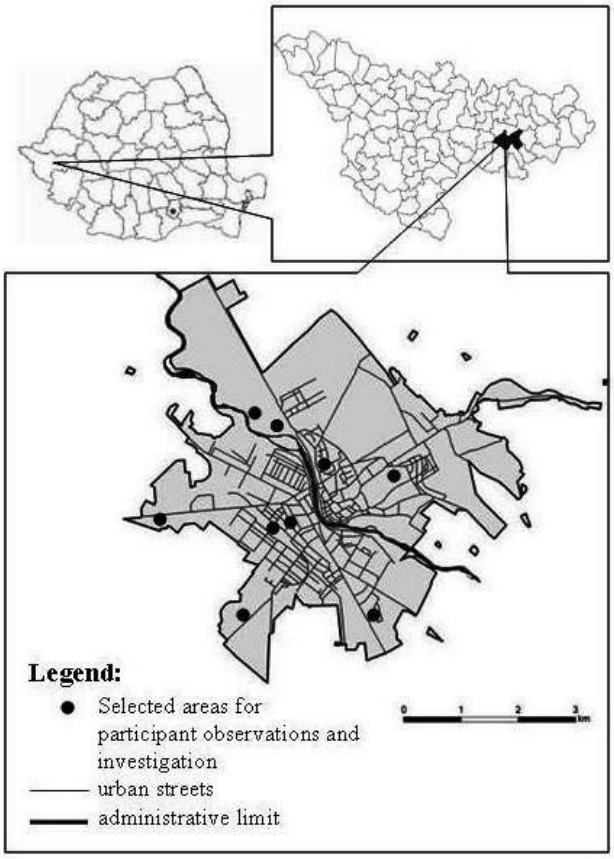

Fig. 1: The study area: the position of Lugoj municipality in Romania and Timiş County, and the distribution of selected sites for in-depth investigation

The focus on the local urban ecology concerns on various sites of dereliction, from industrial debris to military, rail transport and residential ruined places. They were considered as local derelict urban environments with direct consequences in local community. The analysis follows the methodological design recommended by recent research on urban derelict places (see Edensor, 2005; Mah, 2012; DeSilvey and Edensor, 2013; McDonnell, 2015). To assess the local urban ecology issues, the analysis of various plenty of texts on this topic (McDonnell, 2015) has been considered framing a mix-method and a multi-criteria analysis (Lee et al, 2014; McDonnell, 2015). The starting point of the research was ethnographic observation with participatory in-field analyses being the main source in collecting empirical data on urban ruined sites. As table 1 highlights the mix-method, analysis was used all through the study including quantitative and qualitative approaches framed by extensive repeatedly and continuous in-field observation.

The (re)production of local urban dereliction and the emerging processes of derelict environments and their related urban ecologies have been directly perceived. The self-experience of the authors in onsite urban ecologies investigation (see Chelcea, 2015) was helpful in gaining an understanding on the present processes of local urban derelict environments and their related consequences in local community. The research bases on two sets of data provided by the voice of local residents and by public participation in contemporary urban planning (see Cooper et al, 2007; Hersperger et al, 2015; McDonnell, 2015). To decipher these questions, in line with the statements of confirmed generalizations of urban ecologies approaches (Borer et al, 2014), the study focuses on a case study considering the municipality of Lugoj as a sample town in-depth analyzed. The case study brings to the fore the fact that these urban areas are relevant in the contemporary academic debates, since research on the local scales provide important accounts in sustainable urban planning and further political decisions. Based on ethnographic observation related to quantitative and qualitative approaches, important empirical data were achieved, collected, processed and interpreted to unveil the local perception and representation of local derelict environments and their ecologies. This framework rises since extensive field-surveys are important in assessing different groups' perception on environmental issues (Iojă et al, 2014). Consequently, a particular attention concerned on nine areas of Lugoj. Of these, one is located in residential urban core, whilst eight zones are industrial neighborhoods. Table 1 highlights the methodological framework of the research, following the research flow on urban ruined environments acknowledged by different scholars as Edensor (2005), Loures et al. (2006), Loures and Panagopoulos (2007), Krieger (2011), Mah (2012), Bernstein (2013) and DeSilvey and Edensor (2013).

Tabel 1 The main characteristics of the methodological flow

Methods	Characteristics	Specific features
Ethnographic observation	9 urban sites investigated	Industrial and rail derelict sites, derelict sites in residential areas
Personal conversation	40 in each site	Local residents in investigated areas
Oral histories of inhabitants (ex-workers, neighbors)	20 in each site	Former workers in abandoned factories, neighbors living in investigated areas
Photographs taken	at least 100 in each site/year	Photographs continuous taken yearly in the last four years Repeated visits between 2012 and 2016
Visits in investigates sites	15 in each site	Old residents and new residents have been
Interviews with residents	20 in each district	personal approached
Interviews with key actors	1 interview	Key actor in local municipality institutions
Self-author experience	more than 200 hours – time spent in investigated sites a wide range of local, regional and national	The self-experience of the author has been useful in gaining a real understanding on the local realities generated by the production and the presence of derelict sites and their associated marginalities.
Media channels analysis	newspapers and TV documentaries critically examined.	Newspapers and magazines as Redesteptarea, Monitorul de Lugoj, Cetateanul, Actualitatea etc have been considered as critical resources portraying the issues of local dereliction and the reproduction of urban marginalized places at the local scale.

Accordingly, repeated ethnographic in-field observation (2012-2016) followed by quantitative and qualitative approach (through statistical data usage, surveys, questionnaires, oral histories, talks and personal conversations conducted in sampled urban areas), media analysis framed by repeatedly taken photographs triangulate the hypothesis, that urban derelict environments stand as proof of post-communist urban changes. Urban dereliction is still an ongoing process with ruined sites being stagnant places. In 2016, we re-visited all those investigated areas and we found out that there nothing happened in this regard. Since ruined urban environments and ruins analysis remain a slippery topic (DeSilvey and Edensor, 2013), I encountered difficulties at every step of the research. From the authorities' silence to the locals' talking reticence, there were drags in gaining some information. During

the field-analysis, in spite of the simple usage of photographs taken, as an important method suggested by Bernstein (2013), often times, my attempts to find out opinions on the local derelict environments were banished and blamed. Contrariwise, we faced with multiple occasions when questioned people showed their openness and honesty in stating their opinions. They considered that beyond their all-clamoring actions, research could remain the sole action in sustainable regenerating process of the urban derelict sites. The research findings are revealed in the next section concerned on local perception and representation of the urban derelict environments.

Findings and Results

Through the post-communist transition to a market economy, under the recent umbrella of new capitalist regulation in local urban management and their related processes in Lugoj important derelict areas appeared. They were determined by privatization, deindustrialization, reindustrialization, housing regeneration, local decentralization management, tensioned relationship between centralized state-governance and local authorities' power, divergent policies in national, regional and local urban planning (Chelcea, 2008, 2012; Voiculescu and Jucu, 2016; Jucu, 2015). Ruined areas had important consequences in the local urban environments and significant costs for local community, framing urban ecologies fitting not only to this sample case but to all Romanian cities and towns. These issues, in terms of their spatial distribution, local consequences and related processes in their perception and representation, are developed below.

Local (re)production and spatial distribution of urban derelict environments

As it was previously stated the main contributor in urban ruined place creation and derelict environments with peculiar ecologies was economic restructuring and privatization of various real estates, from industrial units to their related sites and to the urban housing stock. Consequently, the main derelict areas produced in the industrial areas engaging in their decline and failure their residential neighborhoods. The local ruined places, with urban derelict environments, appeared all through the urban space from the towns' outskirts to the central area. The largest amount of derelict areas, about 500000 sqm, appears in the northern part of the town, where the most important formerly state-socialist industrial area was designed. The post-communist industrial restructuring partly restored this area with many plants turned to industrial ruins (Jucu, 2015). These post-communist industrial shifts at the local scale generated new urban environments with industrial ruins remaining the most important objects in this area. Aside from one entirely restructured plant through Foreign Direct Investments (FDIs), the other factories of the area have been partly restored whilst other emblematic plants were completely closed turning to ruins. In such circumstances, emblematic industries disappeared with significant industrial buildings with cultural value being ruined (Jucu 2015).

In-field participatory observation revealed that behind collapsed buildings their yards host now only waste, residual scrap left behind vandalized actions, ruderal vegetation embracing both the ruins and the olden industrial equipment. These spaces generate particular environments that appear as places of abandonment and failure raising regrets from the side of the former ex-workers that blame the local ignorance on these ruined places. Against such a background, these sites continuously reproduced increased the repulsiveness of these urban post-communist environments. The same evolution fits to other industrial areas of the town. The districts' analysis emphasized important derelict areas in I.C. Drăgan, Mondialul Bocşei and Ţesătorilor districts. Of these, the first two areas, emblematic in the past, are completely derelict, with their environments attracting in a continuous decline their neighborhoods. These districts are the most disadvantaged areas of the town with their inhabitants being social supported by the local service of social assistance (Jucu, 2015). Beside the local poverty of the districts, the ruined sites include industrial ruins with waste, ruderal vegetation and residual materials being common features in the factories convention halls. Furthermore, stray dogs and homelessness found here proper environments for their daily lives.

This spatial alteration translates not only to the local neighborhoods but also in the cultural capital of the town, the mentioned sites hosting two emblematic plants of the earlier local capitalism under Austo-Hungarian domination. They are about Muschong Briks Factory and Textile Industry. Whereas these factories turned to derelict urban environments with major industrial ruins, in Ţesătorilor area a slow-go process of regeneration started. However, this area includes important ruins of the former state-socialist industry. A specific case is for the Rail Station Area (Cartierul Gării). Whether previous areas are located in the towns' outskirts, this area is close to the city center. Against such a background, marginalized urban spaces with derelict environments appeared in the inner-core of the town. This issue argues that marginalized spaces with related marginal groups are a common feature not for peripheries, fitting also to the central area of Lugoj municipality. The latter is more complex, due to the composite derelict urban environment fueled by industrial, rail transport and stor-

age facilities. Its reproduction was engendered because the local industrial decline entailed the rail transportation decline and the storage activities as well owing to their close economic relation under state-socialism. Considering the present post-industrial shifts, this area turned to ruins, with repulsive derelict environments close to the city center. Although the local municipality considers this area as an outskirt (according to cadastral register) it is located about 500 meters away from the center of the town. In the northern part of the town, Hezeris–Cartierul Nou District has derelict areas produced through the process of cities' demilitarization with ruins being in formerly military area. Because of the specific status of this area is difficult to provide details on these ruined sites but repeated in-field observation unveils the traces of the post-communist process of urban environmental dereliction.

As much, considering residential districts, small derelict environments are visible through the failure of the districts' heating plants. They compose repulsive sites and derelict environments in residential areas with important consequences or, eventually, advantages for residents. In all, a glance on the spatial distribution of the local dereliction show that all urban districts have in different extents ruined sites with derelict environments produced by post-communist changes in the town and ongoing reproduced by the local indifference of local government. In this regard, 93% out of the questioned persons, 98% out of the personal conversations and talks, and 94% out from the conducted oral histories with locals blame the local indifference of decision-makers, stakeholders and different other involved actors in local urban regeneration. Furthermore, the results disclose the major consequences of derelict environments for local communities. The next sections reveal these consequences, sampling with particular evidences from the investigated sites.

Ruins, ruderal vegetation, stray dogs and repulsive environments

Data provided by oral histories of the residents, personal conversation conducted with different individuals related to the processed survey information collected through questionnaires and ethnographic observation emphasized important results concerning the intimate features of local derelict environments. First, ruins of the former bankrupted state-socialist plants compose the general background of derelict environments. As Chelcea (2015) states, they are particular places where human and non-human marginal groups expressed their existence. This issue fits to the small-sized municipalities and to the present investigated sites. Urban ruins produce repulsive and distressing places acknowledged by 94% of the questioned persons living in their neighborhoods. In addition, obsolete and repugnant landscapes of the ruined sites are enriched by non-human components often maintained (un)willingly by the locals (from indifference to consciously actions). On one hand, they are expressed by wild ruderal vegetation and, on the other, by stray dogs. The first, embrace the ruins and their related facilities and features, both in their neglected precincts and in the outward places surrounding them. Hence, repulsive places rose, fueling the local indignation of the locals towards all those that have to regenerate these repellent places.

Fig. 2: Ruderal vegetation and waste in abandoned rail transport area with clogged rail lines (photo: Jucu, 2015)

Fig. 3: Images of local derelict environments: abandoned features, thrown out residual waste and ruderal vegetation from bushes to moss (photos: Jucu, 2015)

Figures 2 and 3 show the presence of ruderal vegetation and residual waste in derelict, abandoned and ruined places of the town close to the city center. Furthermore, these places host residual waste and extempore shelters for stray dogs.

As the above pictures portray, these local environments are repulsive and obsolete. Concerning the animal marginal groups in such derelict places, stray dogs are the main specie populating these urban environments. The issue of stray dogs appears as a

complex, continuum, tensioned and unsolved problem with few opportunities for further dispatching in Romanian urban settlements (see Creţan, 2015). A wide range of media channels from press, TV news and documentaries raise this question that fits to the sampled investigated sites of this case in point. Being in the care of anyone but at the same time in the care of local community, urban derelict places offer proper conditions for non-human marginal groups in terms of the stray dogs' presence.

Fig. 4: The image of six stray dogs sleeping through bushes and residual waste in a small area within a derelict place close to the towns' center (photo: Jucu, 2015)

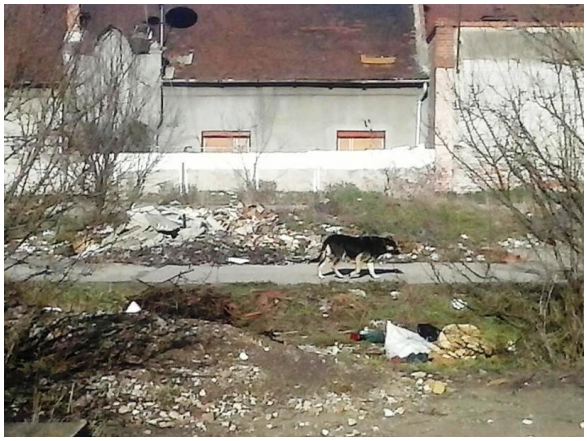

Fig. 5: A stray dog in the same area walking in a derelict place through ruderal vegetation, residual waste debris and rubbish (photo: Jucu, 2015)

Figures 4 and 5 show this particular habitat for stray dogs while in upper left inset of the latter image a shelter of stray dogs in an abandoned derelict building can be observed.

Concerning the issue of stray dogs in derelict places, according to the voice of questioned residents, the neighbors maintain the dog presence feeding them and taking care of these animals. They state that the dog presence is not fortunate but they not share the view on their culling. Of course, their place is not welcomed in these derelict areas since the failure of these formerly productive sites started. The people repeatedly grasp the local authorities but this problem remains in these derelict environments. Accordingly, this place turned to a peculiar derelict environment where non-human marginal features (stray dogs, ruderal vegetation, ruins, rubbish and residual waste) remain as peculiar components of these environments. According to residents' voice, the local authorities were repeatedly notified without any positive outcomes or interventions in these derelict areas.

Sites of scavenge for human marginals

In line with Chelceas' (2015) conceptualization on urban mining, post-industrial urban derelict spaces are sites of scavenges. All objects remaining abandoned in these sites drew attention of different marginal human groups in purchasing scraps for selling for money. In this regard, often times through stock-theft important amounts of metal scrap, iron bars, iron-concrete, steel materials, metal from dismantling buildings, related facilities, rail infrastructure and others were removed by new owners, poor people and, eventually, gypsies. The latter groups are omnipresent in these derelict areas with preoccupation in scrap scavenging.

Accordingly, these actions left behind vandalized landscapes and environments. In addition, there are outlined the usage of dry wild vegetation of these areas in ensuring domestic heating by the poor people living in derelict areas' vicinities. Therefore, derelict places turned to mutilated and destroyed environments with repulsive and obsolete backgrounds. Figure 6 and 7 show the cruelty destruction of these sites. While the first present the inner-devastation of the in-ward part of a formerly functional district heating plant, the second one unveils what's' left from a rail freight car, dismantled with parts of it eventually stolen and sold as scrap. This is only a simple sample of large devastation of these derelict places. A resident living in this area stated that there were hundreds rail freight cars that disappeared during post-90 period. In this area, only three remnants of the rail cars remained, with their vandalized bodies embraced with ruderal bushes and surrounded by throw out residual waste.

Fig. 6: An image of the vandalized inner part of a formerly heating plant in District Micro III (photo: Jucu, 2016)

Fig. 7: What's left from a former rail freight car in a derelict industrial area close to the railway station (photo Jucu, 2016)

Data collected through qualitative approach argue that the voice of local community blame all those responsible for the reproduction of these sites disagreeing their environments and advocating for immediate interventions in cleaning all these urban repulsive environments.

Derelict sites as playgrounds, urban marginal environmental art and other usages

In spite of their repulsiveness, obsolesces and disagreeable sites, derelict urban environments are improper playgrounds for children and teenagers. This issue revealed by Chelcea (2015) in large metropolitan areas translates to lower levels, being present in derelict environments of the small-sized municipalities. It is also a common issue for the municipality of Lugoj. In-field participatory observation associated with personal conversations and talks with children, teenagers and their parents revealed important results in this type of derelict environments usage. Firstly, children are attracted by these sites for different games from those peculiar in common childhood to different types of exploration and gaming with residual objects found in these areas. Industrial derelict places with their ruined buildings and disused facilities, abandoned rail transportation areas with deserted rail freight wagons, ruined heating plants in the inner districts are often times used in the children play and recreation. Secondly, children and teenagers play football or other ball sports in derelict areas ambushed by dangers and risk at every step on their play. Thirdly, ruined walls of derelict buildings within abandon landscapes are interesting attraction for 'urban marginal art' with graffiti being the main pictures all around the ruined, walls, the abandoned facilities and disused rail freight wagons. Figure 8 emphasizes the latter activity developed by local teenagers. Approaching some of them, they stated that drawing the ruined walls represent an interesting activity for different urban groups of teenagers in the local districts of the municipality.

On the other hand, visiting derelict sites I found out an interesting usage of these places. Becoming redundant after the year of 2000, the heating plants of the districts turned to dereliction with all its equipment removed. Now they appear as abandoned places that often times host homeless people. A specific case of different usage appears in Micro I District where the former heating plant changed in an improvised manner in off-hand parking for the cars of neighbors (Figure 9).

Fig. 8: Graffiti and drawing urban art on ruined walls (photo: Jucu, 2016)

Fig. 9: Off-hand parking improvised in a former heating plant in Micro I District (photo: Jucu, 2016)

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In other words, this initiative solves an acute problem for the local residents of the district in gaining more space for parking. However, this shift in the formerly heating plant generates repulsive a landscape nearby the collective housing stock with blocks of flats. Furthermore, according to personal talks and conversations with the residents, this site remains a shelter for both homeless people and stray dogs confirming the hypothesis of the human and non-human marginal groups presence even in the central residential area of the town. All these actions developed by the local people (children, teenagers, residents, and homeless people) in derelict areas evolve without any knowledge on the potential danger and possible risks that these sites could generated. This issue of related risk of derelict urban environments fuels the following section.

Derelict environments and their related ongoing risks in local communities

As it was stated, the local urban derelict environments are places that often times present high-risk potential for local residents. Data collected during the present research, emphasizes that issues on this perspective are multiple and complex. Firstly, ruined buildings, regardless of their former functionality, extents or related facilities presents possible risk to crash and collapse. An example in this regard is the former rail freight deposits with its roof crashing (Fig. 10).

Fig. 10: A crashed roof of a rail freight deposit (photo: Jucu, 2015)

Besides, as empty spaces with broken windows since the glasses are not removed, in the time of storms and violent winds the glass is blown with risk to hit the people that passing by this building. In spite of its dereliction, during my in-field participatory observation I observed, especially in the morning, many people passing by this building in their way to work, railway station or to the district kindergarten. In some cases, little children joined them, so their exposure to danger is clear. The same fits for all those that use to play in this area or for residents living in this district.

Analyzing derelict area in Railway District, the open sewers generate an additional risk source. In field, repeated and participatory observation developed during the last three years, demonstrated the high-risk potential of these features. Figure 11 reveal this finding. As we can observe, all these sewers are open with no caps on them. To avoid some dangers, local residents living in this area marked the sewer's presence and made them visible through improvised materials from scrap metals pieces, to plastic objects and dry vegetal branches.

Fig. 11: Open sewers with improvised marks as caution signals for residents (photo Jucu, 2013-2015)

The issue of these sewers status was repeatedly notified to the local authorities. As a response, often times the sewers were covered with steel caps that further (continually) disappeared. Regarding this situation, the questioned residents in the area suppose that the caps are stolen and sold as scrap metal at the steel collection point located nearby this area. Personal conversations conducted with residents in this area reveal that the theft of the caps is supposed to be assumed by gypsies and scrap-metal scavengers but this statement cannot be demonstrated. Other sources for risk in local communities are generated by the presence of the stray-dogs often times in the care of local residents. In addition, residual waste throws out represent another risk in terms of microbes and virus spread since in summer it gone putrefied. Accordingly, derelict environments are sources for various diseases threatening the residents' health at the local scale. Further, open sewers and putrefied waste are also the main sources and contributors in virus spreading in local derelict urban environments and its surrounded residential areas. The local risk potential of derelict areas amplifies especially in the evening and night since the public lighting is definitely missing. These issues have to be con-

sidered by the local authorities in improving the community's welfare and reducing the urban risk potential in these areas through a proper management on urban derelict environments. In spite of the above-mentioned issues, derelict urban environments at the local scale continue to appear. The participatory in-field observation conducted as a final visit in investigating local derelict sites emphasized that the production of ruined and derelict environments is an ongoing process. Against such a background, a new derelict area appeared. This is the case of the former state-socialist IURT plant that now is being demolished (Figure 12).

Fig. 12: IURT Plant in demolishment process with a new ruined site appearing (photo: Jucu, 2016)

Accordingly, this ruined site turns to a derelict area eventually fuelling attention for peculiar actions as urban mining through removing those materials that could provide certain gains both for involved actors in this sites' restructuring (Niţoiu 2015; Ghinea 2016) or for individual scavengers. At this time, through IURT demolishment is considered that this site would further turn to service activities (Tîrziu 2015). The same statements recently fitted to other ruined factory (the milk manufacture) considered through their new owner, in 2013, that it would turn to services, regenerating its place (Niţoiu 2014). However, there nothing happened, with ruins still standing as proof of only theoretical projects. Therefore, derelict urban environments remain an important topic for further research on the scene of the ongoing process of urban restructuring at the local scale. Witnessing IURT demolition, according to the final visit of ethnographic observation a group of workers watching IURT ravage expressed their regrets both for this important plant failure as well as for those previous ruined plants with important cultural capital in Romania turned to urban derelict environments.

Perception and representation of urban derelict environments and their related ecologies

According to the conducted field-survey during the ethnographic research and considering the item on personal involvement of the residents in the cleaning actions of these areas, there were provided no answers in 82%, while 11% considered that these actions should be included in the local government agenda. Out of 7% from questioned persons responded that they do not know the reason of their un-involvement in the local cleaning area. Accordingly, the indifference of the residents living in these areas cross the municipality ignorance on these derelict environments with these spaces remaining places that host residual waste, wild ruderal vegetation, thus producing repulsive and neglected environments in urban areas. In all, more than 89% out of the questioned subjects express their repulsion and indignation towards local urban derelict sites with risk potential (more than 88%) and displeasure (more than 89%) being the main topics in the individual perception and representation on derelict environments. More than 82% shared their feelings of fear, with an average of 9,55% providing no interest on the applied survey on urban derelict environments being indifferent towards these marginalized environments. Considering particular investigated sites, the results of the conducted survey fashioned similar patterns regarding the applied items focused on the local perception of urban individuals towards repulsion, fear, un-safety, displeasure and indifference (Figure 13).

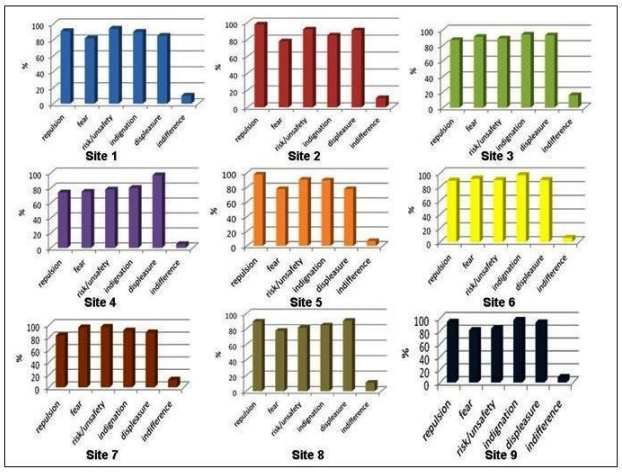

Fig. 13: Perception, representation and individual feelings on derelict urban environments (processed data, according to field survey on particular sites, 2015)

A global glance on the findings resulted from each investigated ruined place illustrate important results that would be critically examined to designed further urban policies in local urban development considering the voice of the residents as well as their opinions and participatory actions towards local derelict urban environments that continue to alter the local way of life.

Thus, as figure 13, shows for the first five items considered in the research the data are quite similar

regardless of the particular investigated sites. The same is for the last item related to the indifference feelings of the residents towards the local marginalized places and local derelict environments. Furthermore, next on the items analyzed in local perception and representation of these urban marginalized places other feelings as regrets, nostalgia appear for what was at once in these productive and functioning sites now left behind places. In addition, a huge blame for the presence of these derelict environments is assumed by the post-socialist processes of local economic restructuring, local deindustrialization and by wrong interventions in local urban planning in the local urban regeneration process during post-socialist period. Whereas the survey portrays lower rates of indifference and ignorance of the residents towards investigated derelict places their presence unveils a huge ignorant attitude and little interest from the side of the local authorities as well as of the present owners of these ruined sites left as abandoned places.

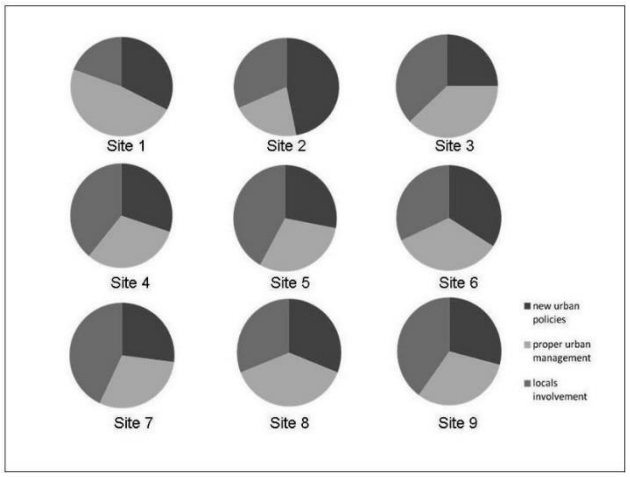

Fig. 14: The local perception in the investigated sites on the future interventions on local derelict and marginalized sites restoration processes (processed data, according to field survey on particular sites, 2015)

Against such a background new urban policy in local urban regeneration process are mandatory to recuperate these derelict sites and to reintegrate them in the present urban functionality. Considering the interventions that have to be done a first step is a new political agenda for local urban development. Thus, out of the total questioned residents in the selected sites, an average of 31.44% claims for new decentralized policies on the restoration processes of these derelict and marginalized sites with repulsive environments. This total average presents low deviations from one site to another from 25% in site 3 to 46% in site 2 (Figure 14). These variation correlates with the impact degree of particular derelict sites on their investigated neighborhoods.

A new proper urban management on the local planning is mandatory in line with the current international European policies on urban remaking and regeneration. This statement was provided by 33,33 of the questioned residents. Next on the involvement of the local authorities and local decision-making actors the involvement of the locals in urban regeneration through their voice claiming their needs and through their implication in local strategies on urban development represent a key action expressed by 35,33% of the questioned people in the sampled of this investigation. Hence, new public-private interventions crossing the actions managed by the local authorities with locals' involvement in new local agenda on urban policies would turn local post-socialist restructuring and regeneration to new visions that could reconsider the local urban derelict environments turning them to productive sites and attractive urban places for local residents and for further investments whether they are financial or simply spiritual emphasizing the place attachment for the local urban cultural heritage.

Conclusion

Through the lens of post-communist political changes and urban ecologies perspective, this article investigated the presence and the consequences of urban derelict environments in small-sized Romanian municipalities framed by their related urban ruins and marginal places that alter the inner-landscapes and the local community's welfare. In line with Chelceas' statements (2015) applied on large Romanian urban habitats and following the methodological flow, recently recommended by experts on urban ecology and ruins analysis (Edensor 2005; Mah 2012; DeSilvey and Edensor 2013; McDonnell 2015), the paper unveiled the production of the urban derelict environments, their spatial consequences and the attitude of the locals towards these marginal places, with repulsive landscapes. The core argument of these issues evolved into the post-communist economic, social and political restructuring processes in the small-sized towns, when urban derelict environments, ruined and marginal places intensely mushroomed. This fitted to the local scale of Lugoj municipality, the sample case study, in-depth analyzed in this paper. Urban ruined sites and their related derelict environments appeared all through the urban area of the town. In line with their approaches as places of perception and representation, they appeared as sites of indifference and marginal attitudes especially in the face of the local authorities and in a smaller extent in the face of local residents. Blaming the ongoing process of local urban identity formation under post-communist

political and economic umbrella their approach as sites of perception and representation, unveil them as spaces of indifference and marginal attitudes from the side of local government. Alongside, places for human and non-human marginal groups, these places alter the local urban landscape layout providing spaces for major risks, failure and abandonment. Repulsion, fear, risk, unsafe, indignation and displeasure are the main issues emphasized by the local residents towards these derelict and marginalized places. Furthermore, regrets, nostalgia, sorrow and sadness are feelings that frame the local residents' perception towards the local ruined sites once flourishing and productive places.

Under post-communist restructuring processes in local urban economies these sites are left-over spaces in continual deterioration being abandoned and marginalized. They not only destroy themselves but alter their neighborhoods and the quality of life of the residents and affect the town as a whole. Consequently, major regeneration interventions are required in order to reduce the present intensity of urban derelict environments, their cruelty destruction that harm both the present investigated town and the Romanian post-industrial small-sized urban municipalities that had a similar destiny during post-communist period. As much, the findings of the study provide important accounts and critical thought for local government in further decisions on local political agenda on post-communist urban regeneration. Acknowledging the seriousness impact of derelict environments, further fertile research and fruitful dialogues between researchers of various backgrounds and different actors involved in local urban planning and regeneration are required. As much, the findings of the study provide important accounts and critical thoughts for local governments in further decision on local policies concerned on present urban regeneration interventions.

Note

The authors have developed an equal contribution in this research and in the article production.

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