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DEPARTMENT OF GEOGRAPHY, TOURISM AND HOTEL MANAGEMENT

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Precipitation Spatial Patterns in Cities with Different Urbanisation Types: Case Study of Novi Sad (Serbia) as a Medium-sized City

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Abstract

A direct outcome of the global climate change is the modification of seasonal precipitation patterns, apparent on a monthly temporal scale. In Central Europe, it includes more frequent high-intensity rainfalls, occurring mostly during spring and summer. These heavy rainfalls induce pluvial floods in urban areas due to a high percentage of impervious surfaces and limited drainage systems. This hazard affects Central European cities and impacts many receptors, including lives, infrastructures, private properties or the functioning of cities. This study focuses on the monitoring of precipitation events with the aim of revealing precipitation patterns across two different types of land cover: urban and suburban/rural areas of Novi Sad (Serbia). Measurements from seven rain gauge stations were used as input data, covering the 2015–2018 period. The precipitation data were analysed using 12 precipitation indices, nine of which were defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), while three additional were designed specifically for this study. Based on their locations, the stations were classified into the 'urbanized' and 'non-urbanised' group.

The concept of the Local Climate Zone (LCZ) was used to classify urbanised areas LCZ1-8, non-urbanised areas LCZ9 and the land cover zones (LCZ A-G). A statistical analysis based on the ANOVA F-test was conducted, defining the significance threshold at 90% for $\alpha = 0.01$ and at 95% for $\alpha = 0.05$. The obtained results revealed one relation for the CDD index at 95% and two relations at 90% for CDD and Rp95 indices, showing a relation between heavy rainfall and the type of land cover. Statistical results underline the need for a denser station network and longer monitoring periods in order to proceed to stronger statistical tests and make it possible to establish other relations with the climate indices.

Keywords: urban climate; heavy rainfall; monitoring network; precipitation indices; pluvial flood; Novi Sad

Introduction

Human civilisations have shown important transformations over the past several decades, in terms of organisation and development. The growing human demography and urbanization are important factors shaping the current functioning of our urban systems. The world's population already hit seven billion in 2011; 75% of the European population live in cities today (Richard, 2002; Swart et al., 2012) and it is expected that around 80% of the world's population will live in cities by 2025 (UNFPA, 1999; WMO, 2008). Cities

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and towns are getting denser with the constant extension of urban limits, in parallel with the intensive conversion of natural land into agricultural or industrial areas. These trends are often unsustainable and they induce deep perturbations in various parts of natural macrosystems, such as climate, biotopes, or resources.

In parallel, the recent crisis related to climate change is becoming more severe. Changes on Earth and the place for human settlements arise as new issues. The current climate change is associated with a significant temperature increase at a global scale, due to human activities, especially since the early industrial period in the previous century (Allen et al., 2018). It has been identified as one of the main drivers of climatic perturbation, by changing the existing pattern of hydrological functioning (IPCC, 2007; Jiang et al., 2018).

Rainfall and extreme rainfall precipitations are recurring natural climatic events, with different return periods and magnitudes (Neppel et al., 1997). They are impacted by the global climate change and they occur more intensively, revealing new climate forcing (Gaume et al., 2009). They may be responsible for pluvial flooding due to the great amount of water carried by them and the small spatial and temporal scale of their occurrence (Collier, 2007; Gaume et al., 2009), which make these hazards very difficult to forecast.

Nowadays, a significant rise of heavy precipitation at continental (Groisman et al., 2004) and global scales (Groisman et al., 2005) has already been observed worldwide in different climate contexts. It inevitably leads to a more frequent occurrence of urban pluvial flooding, also known as flash flood. Furthermore, certain seasonality and geographical variability of flash flood have been detected at the European scale (Trobec, 2017; Prokić et al., 2019). This hazard is the most recurrent in the Mediterranean region, mostly in autumn, and in continental climate, especially in spring or summer months (Gaume et al. 2009; Marchi et al., 2010; Swart et al., 2012; Guerreiro et al., 2017).

Keeping in mind the new scale and intensity of these phenomena, and the consequent rise of receptors exposed to flash flood risks, it is necessary to understand better extreme rainfall generation and its place in the environment. Thousands of additional people are likely to be exposed to the risk of pluvial flooding in the coming decades (Ciscar et al., 2011; EEA, 2012). Intensive research is being conducted, especially in Europe, Asia and USA, because the monitoring and analysis of such events is a cornerstone of flash flood analysis and forecasting (Borga et al., 2002).

Accordingly, this study analyzes possible urban land cover/surface factors impacting the variability of extreme precipitation events by establishing climatic (precipitation) indices (Zhang et al., 2011), suggesting that it should be brought into relationship with the pluvial flood hazard according to the historical events occurring in the region. Climatic measurements have been carried out in Novi Sad (Serbia), using a set of meteorological station sensors which recorded precipitation data over several years.

The research on extreme precipitation events and pluvial floods, as well as meteorological studies, plays an important role in gaining knowledge and understanding new climatic events and their impact on human societies. Thy seeks to find an adaptive way to face natural hazards, by adopting a holistic approach focused on reaching sustainability (Xia et al., 2017; Jiang et al., 2018). This gives rise to new concepts, e.g. sponge cities, or an integrated framework and policy implementation. The territorial development of human settlements and the evolution of human societies should adapt to the environment by increasing the resilience of our civilization.

Description of the urban area, used data and statistical methods

Novi Sad is the second largest city in Serbia. It has approximately 332,000 inhabitants who are living in a built-up area reaching102 km2 in size (Statistical Office of the Republic of Serbia, http://www.stat.gov.rs). This urban area is located in Central Europe, in the Carpathian plain. Its northern part is located on an elevation ranging between 72 and 80 m in height, while the elevations in its southern part range between 80 and 200 m (Petrovaradin and Sremska Kamenica suburban towns). The Danube River flows along the east-west axis in the southern part of Novi Sad (260–680 m wide), and the narrow Danube–Tisza–Danube Canal runs through the city along the northwest-southeast axis, flowing into the Danube.

The areas surrounding the urban core of Novi Sad to the north, east and west mainly include agricultural land. The main feature of the southern section is the Fruška Gora National Park, natural area with low mountains covered with a deciduous forest. According to the Köppen-Geiger climate classification (Kottek et al., 2006), the Novi Sad region has a Cfb climate (temperate climate, fully humid, warm summers, with at least four Tmon ≥ +10 °C). The mean monthly air temperature ranges from -0.3 °C in January to 21.8 °C in July. The mean annual precipitation is 623 mm (based on data collected between 1949 and 2015). Furthemore, the research of Milošević and Savić (2013) shows positive precipitation trends dur-

ing all seasons (except winter), as well as on the annual level, for Novi Sad, in the 1949–2010 period. The temperature and precipitation data were provided by the Meteorological Yearbooks of the Republic Hydrometeorological Service of Serbia.

Novi Sad's urban area is marked by districts of different urban types and sizes. The central area is densely built-up. It consists of mid-rise blocks (usually four to eight floors high), and only a few of them reach 16–18 floors. The surroundings parts of the city are mainly composed of residential areas. There is an electrical production plant in the northern suburban area and much of the city's warehousing can be found there, intermixed with low-rise residential housing. The main avenues and boulevards link various districts, whereas moderately wide streets serve as communications within the built-up area. A number of parks act as open spaces in the downtown, while mature trees (more than 30 years old) form the green infrastructure along several main avenues of Novi Sad (Geletič et al., 2019). In addition, the Danube and its densely vegetated river banks provide a valuable ecological corridor inside the urban area. More open vegetated areas and natural places can be found on the outskirts.

The landscape classification used for Novi Sad's urban area consists of 17 standard Local Climate Zones (LCZs), developed by Stewart and Oke (2012). The standard set is divided into ten built-up types (from 1 to 10) and seven land cover types (from A to G). Two different GIS-based LCZ mapping methods were applied for the city of Novi Sad in previous research: the Lelovics-Gál method (Lelovics et al., 2016) and the Geletič and Lehnert method (Geletič & Lehnert, 2016). Thirteen LCZs were defined and delineated in Novi Sad and its surroundings using the two methods: seven built-up and six land cover types. The delineated built-up LCZs are: compact mid-rise (LCZ 2), compact low-rise (LCZ 3), open mid-rise (LCZ 5), open low-rise (LCZ 6), large low-rise (LCZ 8), sparsely built (LCZ 9) and heavy industry (LCZ 10) (Figure 1). The delineated land cover LCZs are: dense trees (LCZ A), scattered trees (LCZ B), low plants (LCZ D), bare rock or paved (LCZ E), bare soil or sand (LCZ F) and water (LCZ G).

In this study, data collected at seven precipitation stations, located inside the urban area or in the suburban/rural part, have been used for the analysis. All precipitation stations are equipped with an OTT Pluvio2 L weighing rain gauge, with the accuracy of ±0.1 mm; intensity of ±0.1 mm/min; measurement intervals of 1 min, etc. All the stations are installed 1 m above the ground. The stations have been divided into two distinct categories based on their locations: the 'urbanised' group – stations located in dense urban areas (from LCZ1 to LCZ10, except LCZ9), and the 'non-urbanised' group – stations located in rural and green areas (LCZ9 and LCZ from A to G). The precipitation measurements were analysed with one-minute precision, during a research period lasting from January 2015 to December 2018. The precipitation stations are part of the monitoring system of the PUC Water and Sewage Utility Novi

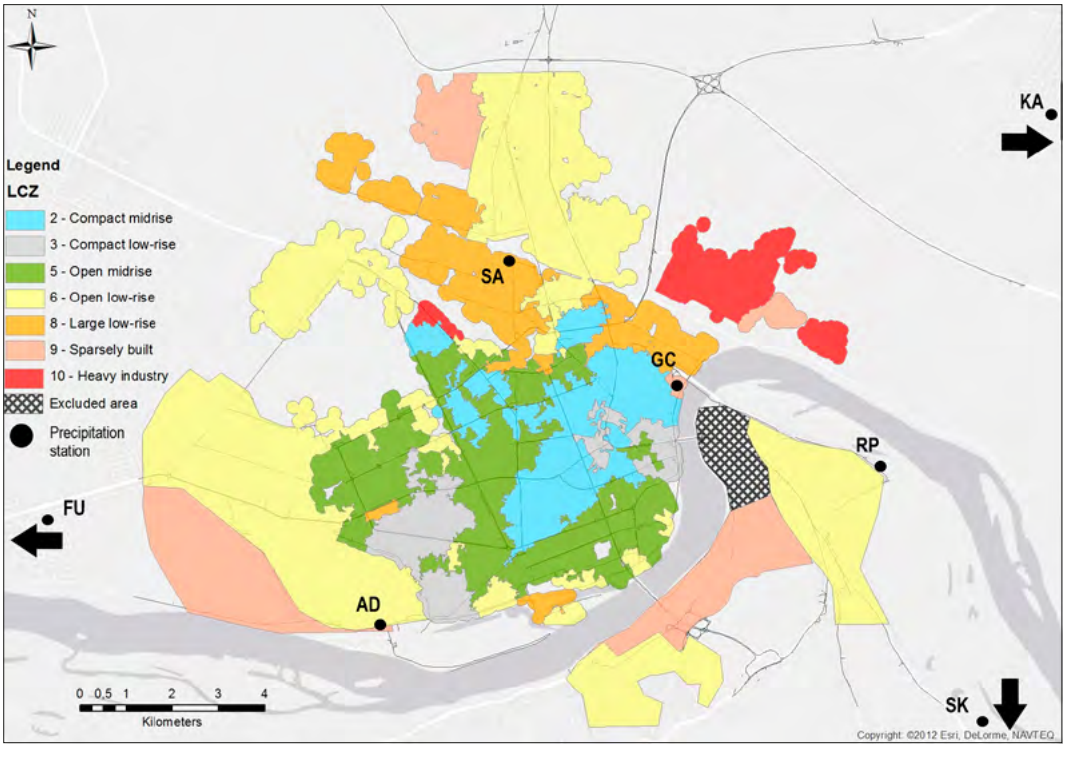

Figure 1. Urban area of Novi Sad with defined built-up LCZs and the locations of the analysed precipitation stations

Sad (JKP Vodovod i kanalizacija Novi Sad), which provided precipitation data for the city of Novi Sad. Table 1 lists the main characteristics of the analysed stations.

In order to define precipitation characteristics and differences between 'urbanised' and 'non-urbanised' areas, 12 precipitation indices were used. The precipitation indices are recommended by the ETCCDI (Expert Team on Climate Change Detection and Indices) (Karl et al., 1999; Zhang et al., 2011), and three additional indices have been designed in this study for further analysis. Table 2 shows the selected precipitation indices used in the analysis. Detailed and precise definitions can be found on the ETCCDI/CRD Climate Change Indices website (http://etccdi.pacificclimate.org/list_27_indices.shtml). Furthermore, an ANOVA F-test was performed to investigate the relations between climatic events (climatic indices) and land cover (urbanised and non-urbanised groups). The Fisher-Snedecor tables were used with a significance threshold of 90% and 95% corresponding to an α of 0.1 and 0.05, respectively. The value F calculated by testing statistically each climatic index was compared to the value of F' provided in the table, with the probability α to be exceeded. The degrees of freedom were established according to the number of groups and the number of samples used. All extreme precipitation indices were calculated for the entire research period (2015–2018), as well as for each year, respectively.

Table 1. Precipitation stations and their basic geographic information. Notes: Abb – Abbreviation; Lat. – latitude; Long. – longitude; Alt. – altitude in metres; * - GC2 stands for the sewage treatment plant where the precipitation station is installed

№	Station name	Abb.	Lat.	Long.	Alt.	Urbanisation type
1	GC2*	GC	45°15′	19°51′	79	urbanised
2	Adice	AD	45°13′	19°47′	75	urbanised
3	Rokov Potok	RP	45°14′	19°53′	77	non-urbanised
4	Sajlovo	SA	45°17′	19°48′	83	urbanised
5	Futog	FU	45°14′	19°42′	79	urbanised
6	Kać	KA	45°18′	19°55′	73	non-urbanised
7	Sremski Karlovci	SK	45°12′	19°55′	148	non-urbanised

Table 2. Selected extreme precipitation indices recommended by the ETCCDI (Karl et al., 1999; Zhang et al., 2011) and additional indices used in this study (marked with an asterisk)

№	ID	Indicator name	Indicator Definitions	Units
1	TP*	Total precipitation	Total amount of precipitation during the research period	mm
2	WD*	Number of wet days	Number of days with precipitation ≥ 0.1 mm during the research period	days
3	RX1day	Max one-day precipitation amount	Monthly maximum one-day precipitation	mm
4	SDII	Simple daily intensity index	The ratio of the total annual precipitation to the number of wet days (≥ 1 mm)	mm/day
5	R10	Number of heavy precipitation day	Annual count when precipitation ≥ 10 mm	days
6	R20	Number of very heavy precipitation days	Annual count when precipitation ≥ 20 mm	days
7	CDD	Consecutive dry days	Maximum number of consecutive days when precipitation < 1 mm	days
8	CWD	Consecutive wet days	Maximum number of consecutive days when precipitation ≥ 1 mm	days
9	R90p*	Wet days	Annual total precipitation from days > 90th percentile	mm
10	R95p	Very wet days	Annual total precipitation from days > 95th percentile	mm
11	R99p	Extremely wet days	Annual total precipitation from days > 99th percentile	mm
12	PRCPTOT	Annual total wet-day precipitation	Annual total precipitation from days ≥ 1 mm	mm

Results

The quality control step revealed some atypical and extreme values for several stations. For the RP station, measurements were not recorded during the spring and summer of 2016 (from March 8th to July 25th). This break of 140 days can have a serious impact on the results. Errors are especially apparent for the TP and WD indices (336.6 mm and 87 days), which are significantly lower than for the other stations. In order to be able to use data from this station in the analysis, an interpolation step was performed using the data for this same period collected at the other stations. Corrections were made for the TP, WD, R10, R20, CDD and PRCPTOT indices by calculating the average value for all the other stations for the same period. Moreover, suspicious data were noticed in the KA station for 2016 and 2017, especially for the TP, WD, CWD and PRCPTOT indices. The values appeared to be extremely high, compared to the other stations. An excessive amount of precipitation was recorded without knowing its origin. In this case, it was not possible to estimate precisely whether the station functioned properly and in which periods it malfunctioned. Accordingly, the KA station was excluded from further analysis. Table 3 shows the index values for all seven precipitation stations, for the 2015–2018 period. The presented data seek to show different parameters of extreme precipitation events for each year, as well as the overall situation during the four-year monitoring period.

Figure 2 shows the exponential distribution of daily precipitation for the entire research period. The data are summarized from all precipitation stations. Outcomes in the graph show that precipitation values from 0.1 to 1.0 mm are the most frequent. Towards higher precipitation values the frequency rapidly decreases, and between 38.1 mm and 90.1 mm, the frequencies are 3, 2, 1 or 0.

A statistical approach, based on the ANOVA *F*-test, was run to estimate the results in terms of significance. An ANOVA single parameter test was run (Table 4) with the aim of measuring the variance of two different precipitation station groups based on land cover, i.e. 'urbanised' and 'non-urbanised'. Therefore, the aim of this study was to check the potential impact of land cover on the previously calculated climatic indices.

The results obtained using the ANOVA single factor test revealed one relation for the CDD index at 95%, and two relations for CDD and Rp95 indices at 90%. Indeed, the *F* values for CDD and Rp95 were 11.11 and 5.25, respectively. Both exceeded the *F*' value of 3.78 with $\alpha = 0.1$ and only the CCD value exceeded the *F*' value of 5.99 with $\alpha = 0.05$.

Table 3. Precipitation indices calculated for each station per year, for the whole research period (2015–2018)

Indices	y/st.	'urbanised'				'non-urbanised'	
		GC	AD	SA	FU	RP	SK
TP*	2015	658.8	670.6	651.1	630.8	602.3	637.7
WD*		145	149	129	157	137	137
RX1day		60.1	62.4	55.2	80.4	61.6	73.3
SDII		4.5	4.5	5.0	4.0	4.4	4.7
R10		17	17	19	16	16	17
R20		6	6	5	4	5	6
CDD		33	33	33	33	38	33
CWD		7	7	7	7	7	7
R90p*		5.3	5.9	5.6	5.4	5.0	5.0
R95p		8.3	8.6	10.1	9.1	8.1	8.7
R99p		23.9	23.1	21.9	20.6	21.6	24.5
PRCPTOT		636.8	649.7	632.5	602.9	584.0	621.3
		GC	AD	SA	FU	RP	SK
TP*	2016	721.0	714.8	656.9	710.7	694.0	683.5
WD*		140	154	139	153	145	141
RX1day		33.3	35.8	31.5	35.9	32.1	45.8
SDII		5.1	4.6	4.7	4.6	3.9	4.8
R10		24	22	21	24	21	22

Indices	y/st.	'urbanised'				'non-urbanised'	
		GC	AD	SA	FU	RP	SK
R20	2016	6	8	4	8	6	6
CDD		34	34	34	34	38	34
CWD		5	4	5	4	3	4
R90p*		6.6	6.3	5.5	6.2	2.2	5.7
R95p		13.4	12.4	11.8	11.2	6.8	11.5
R99p		24.7	24.4	21.7	27.4	15.5	25.3
PRCPTOT		705.5	693.0	639.0	688.5	674.1	661.4
		GC	AD	SA	FU	RP	SK
TP*	2017	477.7	543.8	493.2	509.5	498.1	484.9
WD*		149	161	134	156	145	148
RX1day		26.6	41.2	60.4	34.4	29.0	26.1
SDII		3.2	3.4	3.7	3.3	3.4	3.3
R10		12	13	11	11	13	13
R20		1	4	3	3	2	2
CDD		17	17	17	17	17	17
CWD		4	4	5	4	4	4
R90p*		4.6	4.6	4.6	4.6	4.3	4.9
R95p		8.1	7.9	6.9	7.6	8.3	8.0
R99p		14.8	19.1	14.2	17.5	16.2	16.2
PRCPTOT		453.9	525.0	474.5	483.6	478.9	460.7
		GC	AD	SA	FU	RP	SK
TP*	2018	642.0	689.4	662.9	718.9	725.3	569.6
WD*		128	150	132	150	144	135
RX1day		47.9	48.6	71.2	94.0	55.8	28.8
SDII		5.0	4.6	5.0	4.8	5.0	4.2
R10		18	19	15	19	17	17
R20		5	5	7	7	7	6
CDD		28	24	24	24	24	35
CWD		5	7	7	7	7	7
R90p*		4.8	5.5	4.5	4.8	6.2	4.5
R95p		9.8	11.1	8.3	10.2	9.8	9.1
R99p		23.9	25.1	25.9	28.9	28.6	23.0
PRCPTOT		630.9	672.1	649.5	699.6	708.5	551.6
		GC	AD	SA	FU	RP	SK
TP*	TOTAL (2015-2018)	2499	2619	2464	2570	2520	2376
WD*		562	614	534	616	571	561
RX1day		60.1	62.4	71.2	94.0	61.6	73.3
SDII		0.024	0.024	0.029	0.037	0.028	0.031
R10		71	71	66	70	67	69
R20		18	23	19	22	20	20
CDD		34	34	34	34	38	35
CWD		7	7	7	7	7	7
R90p*		5.3	5.8	5.2	5.2	5.1	5.0
R95p		9.7	9.9	9.1	9.7	8.8	9.2
R99p		23.4	24.5	23.5	23.8	23.2	23.3
PRCPTOT		2427	2540	2396	2475	2445	2295

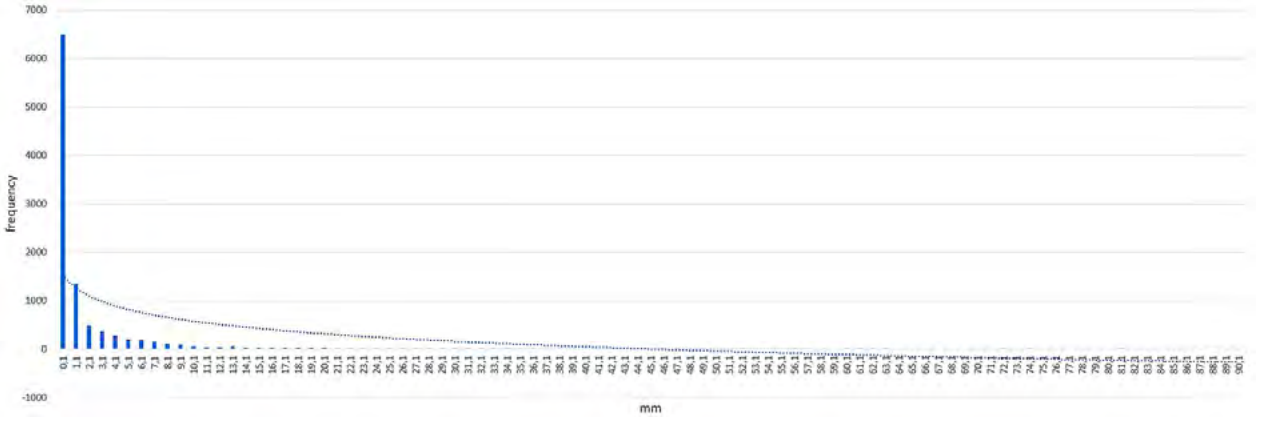

Figure 2. Inverse exponential distribution for the daily precipitations for all stations in 2015–2018

This underlines the difference for consecutive dry days and very wet days between the two different land cover groups. The other indices did not show relations although some *F* values were close to *F'* values. The *F'* value would be lower if more groups and samples were defined.

Table 4. Outcomes of the ANOVA *F*-test based on the correlation between 'urbanised' and 'non-urbanised' (except the KA station) group of stations and with statistically significant threshold (*F´*) defined at the level of 90 % and 95%

Indices	*F* value	*F´* value at 95%	*F'* value at 90 %	Relation
TP*	2.63	5.99	3.78	no apparent relation
WD*	0.4	5.99	3.78	no apparent relation
RX1day	0.2	5.99	3.78	no apparent relation
SDII	0.13	5.99	3.78	no apparent relation
R10	0.95	5.99	3.78	no apparent relation
R20	0.21	5.99	3.78	no apparent relation
CDD	**11.11**	**5.99**	**3.78**	**relation at 90% and 95%**
CWD	0.0	5.99	3.78	no apparent relation
R90p*	3.53	5.99	3.78	no apparent relation
R95p	**5.25**	**5.99**	**3.78**	**relation at 90%**
R99p	2.86	5.99	3.78	no apparent relation
PRCPTOT	2.74	5.99	3.78	no apparent relation

Discussion and concluding remarks

It is largely admitted that heavy rainfall intensification is a consequence of climate change processes all over the Globe (IPCC, 2013). This problem, which generates pluvial flood hazard, is more pronounced in urban areas, especially in medium and large cities, as a consequence of old or underdeveloped water drainage systems (EEA, 2012). The same problem has been observed in Novi Sad, which is not only the second largest city in Serbia but also a historical city. There are several recurrent locations where pluvial floods occur after each extreme precipitation, i.e. traffic intersections, underpasses, streets, etc. Based on the multi-year monitoring of extreme rainfalls and pluvial floods in urban and suburban/rural areas of Novi Sad, it has been established that the average occurrence of pluvial flood events is four per year but it reached 11 in 2018 (internal documentation of the PUC Water and Sewage Utility Novi Sad). These extreme precipitation events and floods usually occur in spring and summer months, especially from the beginning of May until the end of August. For instance, the results from May 16th until August 26th, 2018, show that there were nine days when the amount of precipitation was higher than 20 mm. This is also visible in Figure 2. Furthermore, spatial differences have been identified in the summer rainfall pattern. The stations recorded different values of precipitation depending on their location. A clear example for this is June 29th, 2018,

when the amount of precipitation for the same event ranged between 15 mm and 94 mm (FU – 94 mm; SA – 71 mm; AD – 49 mm; GC – 46 mm; KA – 37; RP – 27; SK – 16 mm). Two relations appeared at 90% of acceptability for the CDD and Rp95 indices, and one relation at 95% for the CDD index. It shows a significant difference for these indices depending on the type of land cover across Novi Sad (between the urbanised and the non-urbanised group). In addition, few other indices were close to showing a difference, notably PRCPTOT, TP, R90p, and R99p. Generally, based on the obtained outcomes of precipitation indices, it can be concluded that during extreme precipitation or dry events there may be notable differences between urbanised and non-urbnised areas. These differences may most frequently occur in the summer period, when surface has an important role on the local weather (based on convective processes), i.e. on heavy precipitation events.

According to the present results, more relations could appear or some refinement of the acceptability threshold could be performed. To reach that goal, several factors could be developed or improved – namely: a) a denser monitoring network of precipitation stations would provide more accurate spatial tendencies; in Novi Sad, stations are mostly located in suburban/rural areas and most of the urbanised parts of the Novi Sad are not adequately covered by the sensor network; b) the urban area of Novi Sad, as a medium-sized city covering about 102 km2, is probably not large enough to catch in details the real precipitation/rainfall differences between different land cover types and detect possible differences based on urbanisation types; c) it is better to analyse monitoring periods longer than four years, but in this study the time frame for precipitation measurements was determined by the onset of the network; d) it is important to ensure proper functioning of the gauge station, because of the incoherent values already obtained; in Novi Sad, the complete monitoring system is functioning since 2015; e) in addition to the elements mentioned, the analysis of the weather conditions and the movement of atmospheric masses should be useful in the process of establishing precipitation and pluvial flood issues.

The literature data on high-resolution precipitation monitoring confirm the previous statements through the analysis of the outcomes. Wang et al. (2018) conclude that urban environments probably play a positive role in generating short-term heavy precipitation through enhancing deep convections induced by higher surface temperatures and higher aerosol concentrations. The analysis of Wang et al. (2018) was based on high-resolution precipitation data and urban extent data in the Pearl River Delta (China). The extreme precipitation and the mean intensity were positively correlated with urban extent, whereas wet hours were negatively correlated. According to Han et al. (2014), the effect of urban extent on precipitation can be studied in three different ways: a) urban heat island (UHI); b) urban surface roughness; and c) higher aerosol concentration. Furthermore, Han and Biak (2008) have found that UHI causes an upward motion downwind of the urban area, which partially explains the increasing precipitation in urbanized areas. Increased precipitation based on surface roughness and anthropogenic high aerosol concentration has also been detected by Cotton and Pielke (2007) and Rosenfeld et al. (2008). Burić and Doderović (2019) have found that the urban area of Podgorica has up to 100 mm higher annual rainfall, compared to the non-urban area. According to Wang et al. (2015), urban extent is strongly correlated to the maximum precipitation amount, whereas Shepherd (2005) has concluded that urban expansion plays an important role in shaping regional climate. Accordingly, the effect of urban extent on climate has become a major research focus in the previous decade, keeping also in mind the hazard of pluvial flood in urban areas. Research projects on this topic are also implemented in Central Europe. The *URBAN-PREX* is a project focusing on monitoring, forecasting and developing an online public early warning system for extreme precipitation and pluvial floods in the urban areas of the Hungarian-Serbian cross-border region. The measurement data from the two precipitation networks deployed in Novi Sad (Serbia) and Szeged (Hungary) will be used to fine-tune remotely sensed data, thereby enabling the development of a more precise two-day forecast model for the area covered by the research programme. The measurement and forecasting data are freely available in real-time on the project website, project social pages and a mobile Android application giving an early warning to citizens and public authorities in order to protect them and prepare an effective response to these extreme precipitation events and pluvial flood situations (Prokić et al., 2019). Other projects with a similar goal are being developed – e.g. the *Amsterdam Rainproof* project, seeking to make Amsterdam resistant to the increasingly frequent showers and make better use of the free rainwater drained through permeable paving, green roofs and façade gardens. In the United States, the *INTENSE* project has acquired data from more than 23,000 rain gauges from its global sub-daily rainfall dataset (GSDR) and has provided evidence of the intensification of hourly extreme precipitation (Blenkinsop et al., 2018).

Figure 3 presents the numerous risks and adverse effects posed by pluvial flooding that are the result of extreme and intensive precipitation/rainfall in urban and suburban/rural areas (Prokić et al., 2019). The

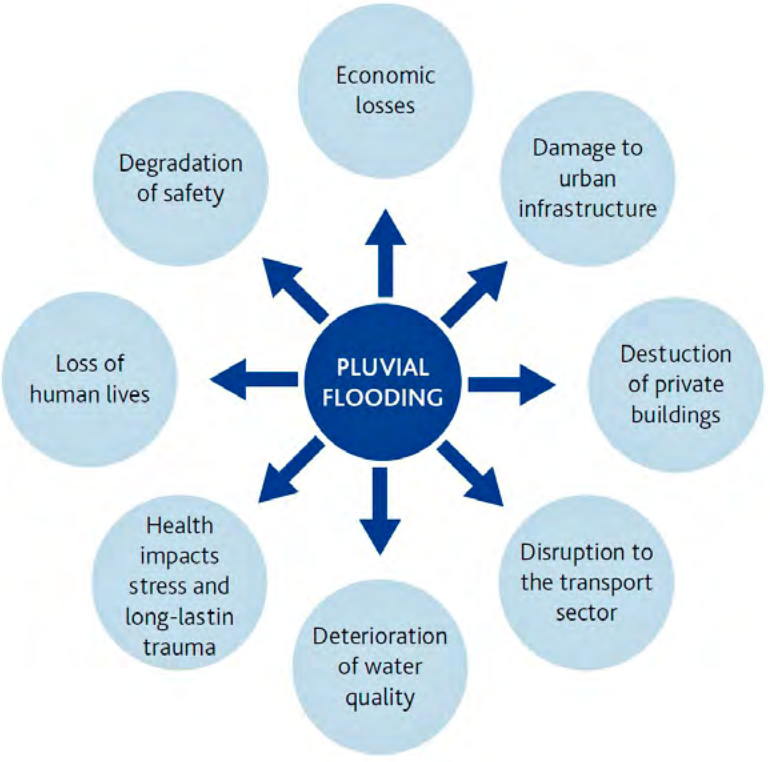

Figure 3. Risks associated with pluvial floods resulting from extreme and intensive precipitation/rainfall events across urban and suburban/rural areas
Source: Prokić et al., 2019

direct and indirect impacts of extreme and intensive precipitation/rainfall include loss in economic terms, the damaging and destruction of private buildings and urban infrastructure, the loss of human lives, the degradation of safety (Sentić and Đorđević, 2019) and the deterioration of water quality (Szewrański et al., 2018a). Urban pluvial flooding is the predominant cause of weather-related disruptions to the transport sector (Pregnolato et al., 2017) and city traffic delays and inconvenience (Zhou et al., 2012). Examples of indirect effects include lost working hours and health impacts on affected residents, which may occur if sewer water flows onto streets or if pluvial flood water stands stagnant (Sušnik et al., 2014). The indirect impacts may occur beyond the location and time of flood events – e.g. long-lasting trauma and stress (Szewrański et al., 2018b). According to Gaume et al. (2009), pluvial floods are one of the most significant natural hazards in Europe, causing serious risk to life and infrastructure, namely the destruction of buildings. Finally, detailed and systematic research of extreme precipitation events and the resulting occurrence of pluvial floods could be, in the future, an important contribution to local communities towards devising measures for adaptation strategies and adequate protocols for mitigation action steps.

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Evaluation of the Urban Regions of Serbia – Functional Polycentricity

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Abstract

The subject of this paper is an evaluation of defined urban regions in Serbia, with an aim towards identifying their basic features, with special emphasis on the measurement of their functional polycentricity. These features include methods with following indicators: share of settled inhabitants to overall population number in the centre of urban region and surrounding area, according to the outcome; concentration level of employees in centres and structure of activities of active population performing an occupation, functional dependence of settlements in the area of the region and determining the functional polycentricity index of the urban region. Therefore, the goal of the paper is to clarify the difference between the urban regions that have developed in the area of Serbia, which are significant factors for further planning of polycentric and balanced regional development. The results of the survey show differences between urban regions. Almost half of the urban regions in Serbia have characteristics of monocentricity, while few polycentric urban regions differ in number of secondary centers. Certain differences between urban regions refer to the results related to share of the employees in primary centres in connection with the secondary centre region, if refers to a polycentric region, or in comparison to the region as a whole, if it implys to monocentric urban regions. All in all, primary differences between urban regions pertain to the degree of functional polycentrism.

Keywords: Urban region; characteristics; functional polycentricity index; functional dependence of settlements

Introduction

After the development of a model for distinguishing a set of centres for which the city regions will be defined (these are urban settlements with more than 50,000 inhabitants and more than 15,000 employees[1]), a model for identifying settlements belonging to the urban region has been formed (Živanović & Tošić, 2017). The results of application of these models shows that in the 16 defined urban regions, with 3,243,546 inhabitants, which is 45% of the total national population. This points to the conclusion that the number of urban regions in the territory of Serbia is small, of relatively small spatial coverage and lower demographic concentrations. Nevertheless, the examination of the basic features of urban regions shows that there are serious differences among them.

In this context, the subject of this paper has been selected, which is, therefore, the evaluation of defined

[1] An explanation of such choice of indicators is given in the paper by Živanović & Tošić, 2017. The hierarchy of the Urban system of Serbia is characterized by disproportionality, incoherence and asymmetry, emphasized by the pronounced urban primacy of Belgrade (Ip = 5.03), as well as the small number of large cities, and supplemented by the absence of urban settlements populated with 200.000 to 1,000,000 inhabitants, macro-regional functions, which would be the bearers of Serbia's internal balanced development. For a general overview of the evolution of the urban system in Serbia, see Živanovic Z., et al., 2019.

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urban regions with the aim of identifying their basic features, with a special emphasis on measuring their functional polycentricity.

Providing this type of input will facilitate the planning process and allow the direction of development and ultimately the achievement of a clearly proclaimed national goal for balanced regional development. The basic measure for achieving that goal is a polycentric urban system. Although achieving polycentricity at the national level is considered a significant measure in the process of overcoming uneven regional development, the research of the importance of primary and secondary centres of urban regions, on meso and micro level, also contributes to achieving the hierarchy of the overall polycentric urban system on the national territory. The application of methods for defining the degree of polycentricity of urban regions will contribute to quality and facilitate planning of the future territorial organization of national urban regions on one hand, and will be an instrument for enhancing regional development on the other.

In connection with this goal, we believe that the contribution of this paper is to point out to the various forms of existence and functioning of urban regions, as an important factor of further planning, as well as to assess the developmental significance of the primary center of the urban region. In addition, the (non)existence of secondary centers in some urban regions has been identified. For the purpose of their formation, i.e. affirmation of the existing ones, it is necessary to take appropriate planning measures, which will contribute to decentralization, overall regional development and reducing regional imbalances.

Creating methods for measuring polycentricity in urban regions, or defining functional polycentricity indexes, is an additional contribution to the international debate on urban regions/polycentric development.

The state of previous research

The urban region is a spatial-functional system composed of one or more centres of different degrees of centrality and hierarchy through which the flow of population, capital and information between centres and settlements in their gravitational environment is carried out. The concept of city-region is actually very old and dates back to the work of 19th century.

In the most recent period, the basic features of urban regions are subject of numerous scientific papers (Etherington & Jones, 2016, 2017; Hennig, 2018; Lawton, 2018; Rus et al., 2018), since the city for a long time is not the subject of research without an surrounding area that gravitates to it (Andreasen et al., 2017; Yankson et al., 2017). In the last decades, in professional circles dealing with this issue, the focus of interest is shifting from the city to the city-region as the primary unit of analysis (Davoudi, 2008; Parr, 2005, 2008; Nielsen, 2015; Agergaard & Ortenbjerg, 2017; Vasárus et al., 2018; Kristóf, 2018).

In former Yugoslavia, first attempt of determining zones of impact of the city is recorded by Bohinec (1926), exploring the gravitational area of Ljubljana. One of the greatest contributions to the study of urban regions was made by Vresk (2002) who was continuously been involved in the analysis of the relationship between cities and their environment already since the 1970s.

A number of geographers (Bukurov, 1980; Djurić, 1970; Ilić, 1970; Milojević, 1956; Savić, 1958; etc.) was dealing with development of the concept of nodal regions and forms of their spatial-temporal expression of the region of Serbia as well, such as Perišić (1985), Veljković et al. (1995) and later other authors were dealing with its reviewing and planning. Theoretical methodological settings of these issues are given in the works of Tošić (2000). The concept of the implementation of functional urban areas aims to increase territorial cohesion in the region, based on the principles of noddlity and sustainable development (Živanović, 2017).

Access to the issue of urban planning research has been changed in accordance with the actual laws in the area. Primarily, it refers to population changes in accordance with the dominance of developmental activities, on communications and interactions in space. The second half of the 20th century is a key period of more intensive introduction of quantitative methods in the analysis of urban regions. Quantitative methods primarily relate to the degree and processes of concentration of the population and employees, the functional structure of the centre and the periphery, settled population and daily migrations-which are the most relevant indicator for distinguishing the urban regions (Gajić et al., 2018).

In recent years, however, increasing attention has been paid to measuring polycentricity of urban regions. According to Faludi (2005), there is a universal agreement that polycentrism, as the existence of several centres at both national and regional levels, is more likely to result in what is usually described as "territorial cohesion". Research in this field exist as well, but the estimates show that such e.g., among the EU Member States, there is no harmonized interpretation or understanding of the concept of polycentricity

(Waterhout, 2002). Nevertheless, in the contemporary literature on urban systems, functional polycentricity is considered to be one of the basic analytical concepts. Functional polycentrism refers to the establishment of functional relationships (intensity, direction, duration, territorial reach and character) between the centres of the urban region. According to some authors (Kloosterman & Lambregts, 2001) a system is polycentric when its economic structure is characterized by specialization in urban areas, leading to economic complementarities between cities. Except economy, service activities, as well, can be subject to consideration characteristic of complementarity centres. The other functional aspect is the interaction among centres. Cities are physically interconnected by infrastructures and by flows of commuters, trade or information: these interrelationships would be characterized by higher intensity in polycentric regions, compared to monocentric. In monocentric regions, the strongest gravity links are definitely to the centre (Sat, 2018). And research referring to polycentricity relate to analysis of its characteristics on one hand, and its measurement by certain quantitative methods on the other. Different authors developed various methods for measuring region polycentricity. Limtanakool et al., (2009) measured functional polycentricity by calculating The Entropy Index (EI) on the case of the Netherlands. Grunfelder et al., (2015) compares indicators of polycentricity in a monocentric and a polycentric urban region in Denmark. Burger et al., (2009) designed methodology for measuring functional and morphological polycentricity, which is applied on the example of England and Wels. Spatial and general functional polycentricity is also measured by Green (2007). So far, functional polycentricity has not been quantitatively expressed in Serbia.

Research methodology

The paper on which we are complementing already gave the number of settlements belonging to each urban region, the number of inhabitants living in them, the degree of centralization of urban regions, etc. The methods of this research will refer to:

1. urban regions as areas of concentration of the population, or as an immigration region by pointing to a share of immigrants from the total number of residents in the centre of urban region, as well as in other areas that belong to the region, the aggregate of, that is, in a surrounding area (hereinafter referred to as surrounding area);
2. ratio of concentration of employees in centres of urban regions, as well as the share of concentration of employees in the primary with respect to the other, the secondary centres[2]2 of the region, as well as to the region as a whole;
3. structure of activities of active population performing an occupation in the area of urban regions, which was assayed by monitoring the share of employees by sectors in the centre of urban region in relation to the surrounding area;
4. functional dependence of settlements in the area of urban regions of Serbia, which is defined on the basis of the model presented in Table 1;
5. Although a functional polycentricity can be measured by various methods, and mostly by analysis of structure of activities in centres in the region and establishing possible existence of complementarity among them, as well as examining the intensity of daily migration between centres in the region, for the area in Serbia, we consider that the most suitable is the following method for establishing functional polycentricity index:

Table 1. A model for defining the share of the functional dependence of the settlement

Ratio of functional dependence of settlements	Daily emigrants' share (in %)	Share of employees in secondary and tertiary-quaternary sector in the dwelling (in %)
Functional independent settlement	< 20	> 50
Partially dependent settlement	> 20	> 25
A completely dependent settlement	> 50	< 25

Source: Authors' estimates

$$IP = n - \sum_{i=1}^{n} (1 - L_i)$$

- IP = functional polycentricity index of the urban region
- n = total Number of centres (regional-primary centre and secondary centres) in the urban region

[2] Secondary centres were considered all other urban settlements, with the exception of primary centres, in the area of defined urban areas of Serbia, except for the City of Belgrade, where only municipal centres are considered as secondary centres.

$L = C/(D/n)$ ratio of the number of employees in each centre in relation to the average number of employees in the centres of the region

- C = number of employees in each centre of the urban region
- D/n = average number of employees per centre of the urban region

Urban regions that have only one city settlement on its territory are monocentric. An absolute monocentric region would have value $IP = 0$ in case that all employees work in the primary centre. Regions in which there are employees that work outside of the primary centre (in other settlements that are not secondary centres of the region), are also monocentric, but with the value of the IP from 0 to 1. A region with two or more centres has an IP greater than 1. If the IP value is greater, the region has more centres, or the region is more polycentric.

Assessment of the characteristics of the urban regions of Serbia

Urban regions of Serbia as immigration areas

Number of immigrants, in principle, decreases according to the size of the centre of the urban region. Although the absolute number of immigrants is very different, the share of immigrants in the total number of inhabitants, both in centres and in their surrounding areas, is fairly uniform in all urban regions, i.e. it is in line with the existing total number of inhabitants (Table 2).

There are several times more inhabitants settled in the centres than in their surrounding area (Valjevo, Kragujevac, Subotica, Zrenjanin, Čačak, Vranje,

Table 2. The share of the settled population in the urban region in 2011

Centre of the urban region	Number of immigrants in 2011	Share of immigrants in the total population number (%)	Share of immigrants in total number of immigrants (%)			
			from the area of the same municipality	from the same area	from another area	from abroad
Belgrade	591,614	50.71	0.12	4.95	57.79	37.07
the surrounding area	259,417	57.37	8.82	25.65	40.84	24.64
Novi Sad	136,925	59.07	2.92	17.36	46.01	33.69
the surrounding area	103,836	58.71	15.60	23.99	19.03	41.33
Niš	88,844	48.51	2.92	25.10	59.79	12.15
the surrounding area	50,967	46.73	18.91	41.47	34.60	4.98
Kragujevac	67,080	44.47	6.62	14.02	67.20	12.04
the surrounding area	6,760	50.59	32.43	11.69	48.33	7.51
Subotica	39,203	40.04	18.17	5.42	47.16	29.21
the surrounding area	6,218	58.14	50.10	2.77	22.76	24.38
Zrenjanin	34,309	44.84	20.48	28.21	28.96	22.33
the surrounding area	4,772	46.43	35.08	8.70	19.53	36.67
Pančevo	37,742	49.53	12.07	17.55	42.44	27.91
the surrounding area	17,957	43.73	22.68	6.33	32.39	38.58
Čačak	32,935	44.91	17.55	27.16	39.86	15.40
the surrounding area	5,334	50.45	36.56	21.95	29.53	11.90
Smederevo	6,615	52.26	53.24	6.28	68.84	14.77
the surrounding area	9,502	46.83	30.53	3.38	55.89	10.17
Kraljevo	32,336	50.39	18.95	12.03	55.16	13.83
the surrounding area	17,309	52.51	34.80	10.95	44.64	9.60
Leskovac	22,051	36.58	27.82	28.77	33.68	9.68
the surrounding area	30,086	46.88	10.09	22.25	21.38	3.07
Valjevo	25,230	42.81	30.87	23.08	31.27	14.78
the surrounding area	1,702	47.24	59.69	13.51	20.51	6.29
Kruševac	27,174	46.26	19.25	22.62	47.12	10.98
the surrounding area	18,212	42.46	40.22	17.09	36.18	6.51

Centre of the urban region	Number of immigrants in 2011	Share of immigrants in the total population number (%)	Share of immigrants in total number of immigrants (%)			
			from the area of the same municipality	from the same area	from another area	from abroad
Vranje	29,881	40.41	33.29	40.47	17.97	8.25
the surrounding area	9,736	42.39	47.06	36.72	10.68	5.48
Šabac	25,050	46.46	25.87	32.67	23.46	17.95
the surrounding area	12,340	59.27	34.43	29.77	14.98	20.75
Užice	21,822	41.45	24.15	45.32	17.38	13.11
the surrounding area	5,545	50.51	51.54	27.16	11.09	10.21

Source: Statistical Office of the Republic of Serbia (SORS), 2013d

Užice), but there are two examples of urban regions with more settled in the surrounding area than in the centre (Leskovac and Smederevo).

Most of them are settled in the regions from other areas, especially in the case of regions with large centres, but there is a significant share of settled from the area of the same municipality (Smederevo and the surrounding areas of centres of Subotica, Valjevo Kruševac, Užice and Vranje), as well as from the same area (Vranje, Užice and the surrounding area of Niš). The larger share of immigrants from abroad is in the case of larger centres and their surrounding areas, i.e. in urban regions of Vojvodina Province (in northern part of Serbia).

The degree of employees concentration

The degree of employees concentration in urban regions is very different and is within the range from 60% to 95% (Table 3). The lowest value of this indicator is related to the city of Novi Sad, which, with 8 secondary centres in the area of the region, has all predisposition for considerable polycentricity. Belgrade and Niš, though both with 4 secondary centres, have different values of concentration level of employees, due to a huge absolute number of employees in the centre of the region. Consequently, in case of Belgrade, concentration level of employees is high, as much as 74%. In case of Niš the value of that indicator does not exceed 70%, as well as in case of centres of urban regions

Table 3. The degree of employees concentration in the primary centre, 2011

Centre of the urban region	Number of employees in the centre of the urban region	Number of employees in the surrounding area	The degree of employees concentration in the centre of the urban region	Number of secondary centres in the urban region	Primacy Index of urban regions*
Beograd	428,353	149,839	74.08	4	21.23
Novi Sad	86,534	53,177	61.94	8	3.03
Niš	57,764	25,761	69.16	4	25.38
Kragujevac	46,618	3,040	93.88	0	—
Subotica	31,674	2,939	91.51	1	14.61
Zrenjanin	24,306	2,602	90.33	0	—
Pančevo	24,942	10,255	70.86	2	6.27
Čačak	23,798	2,795	89.49	0	—
Smederevo	18,886	4,235	81.68	0	—
Kraljevo	19,453	8,443	69.73	2	17.12
Leskovac	15,951	2,683	85.60	0	—
Valjevo	20,205	1,024	95.18	0	—
Kruševac	17,102	9,704	63.80	1	13.35
Vranje	17,125	5,443	75.88	1	15.67
Šabac	17,344	5,724	75.19	0	—
Užice	18,361	3,425	84.28	1	8.17

Source: Statistical Office of the Republic of Serbia (SORS), 2011
** Number of employees in the centre of the region refers to the number of employees in all secondary centres.*

in whose areas are two secondary centres (Kraljevo and Pančevo).

Other urban regions are characterized by a concentration level of employment in regional centres from 75% to as much as 95%. The regions that besides the regional centre do not have urban settlements in their area are also interesting, but their concentration level of employees in the regional centre is relatively low (Šabac = 75%), or lower than some centres that have one secondary centre (in addition to Palić, the concentration level of jobs in Subotica is 91%, while, for example, in Smederevo it is by 10% lower, although neither settlement belonging to the urban region of Smederevo has no city status, i.e. they were not seen as a secondary centre). Economic objects located in cadastral municipalities of surrounding settlements may be the reason for lower concentration of employees in the primary centre of the region. Such examples bring up a question about structure of population activities which inhabit the urban region, as its centre and the surrounding area, which is subject to the analysis that follows.

The difference between regions also stems from the share of employees in the primary-regional centre in relation to the share of employees in other centres in the region. This value would be the primacy index of the regional centre within the urban region. According to the results obtained among the 16 regions of Serbia, the highest primacy index is found in Niš and Belgrade, and the lowest ones in those regions whose primary centres in their hinterland have secondary centres, which are more important centres of activity: Novi Sad, Pančevo and Užice. Urban region that do not have any secondary centre in their area have no value of primacy index (Table 3).

Structure of activity

In the structure of activity, both of the centres of urban regions and the surrounding areas of these centres, the tertiary-quaternary sector is dominant, but this dominance is far more noticeable in the centres than in the surrounding areas. In fact, the secondary sector dominates in the surrounding areas of Užice, Šabac, Vranje, Valjevo and Smederevo. It is also noticeable that in all regions the share of employees in the secondary sector in the region is higher than in the centre of the urban region (Table 4).

The structure of employees by sectors of activity of the centres of the selected regions does not fully correspond to the one that is distinguished by the very cen-

Table 4. Structure of the activities of urban regions, 2011

Centre of the urban region	The share of the active population that is occupied by sectors of activity (%)				
	I	II	III	IV	III and IV
Belgrade	0.54	17.08	40.21	42.17	82.38
the surrounding area	2.14	23.05	38.86	35.17	74.03
Novi Sad	1.16	20.39	37.43	40.65	78.08
the surrounding area	6.42	30.49	32.89	29.75	62.64
Niš	0.39	22.01	32.65	44.94	77.59
the surrounding area	5.60	33.75	28.94	31.10	60.04
Kragujevac	0.89	32.11	28.99	37.62	66.60
the surrounding area	10.82	39.24	26.90	22.55	49.45
Subotica	2.99	29.20	34.32	33.03	67.35
the surrounding area	9.39	29.08	33.87	27.21	61.07
Zrenjanin	3.02	35.20	26.83	34.58	61.41
the surrounding area	12.73	40.81	23.01	23.08	46.09
Pančevo	2.07	27.75	34.08	35.91	69.99
the surrounding area	9.50	37.95	26.15	26.10	52.25
Čačak	2.02	32.69	35.25	29.79	65.04
the surrounding area	14.85	35.07	29.49	20.32	49.80
Smederevo	1.28	40.29	26.06	31.85	57.91
the surrounding area	7.90	46.91	24.02	20.46	44.48
Kraljevo	1.36	25.10	32.24	40.93	73.17
the surrounding area	6.60	35.10	27.74	30.03	57.77
Leskovac	3.70	24.43	29.47	44.47	73.94
the surrounding area	7.96	35.10	27.96	28.64	56.60

Centre of the urban region	The share of the active population that is occupied by sectors of activity (%)				
	I	II	III	IV	III and IV
Valjevo	1.67	37.51	26.56	34.01	60.57
the surrounding area	17.28	42.44	21.06	18.81	39.87
Kruševac	1.11	30.50	27.96	40.05	68.02
the surrounding area	8.99	41.66	24.66	24.12	48.77
Vranje	1.01	37.77	22.33	38.60	60.93
the surrounding area	6.75	51.27	17.84	23.73	41.57
Šabac	1.04	28.69	32.22	37.59	69.81
the surrounding area	3.77	42.21	30.01	23.16	53.17
Užice	1.36	35.79	29.50	33.23	62.74
the surrounding area	5.18	46.72	25.46	22.61	48.08

Source: Statistical Office of the Republic of Serbia (SORS), 2011

tres of urban regions. In other words, mainly a higher representation of the primary and secondary sector in the surrounding area is compensated by the smaller representation of the tertiary-quaternary sector.

The differences in the representation of the tertiary-quaternary sector of activity in the structure of employment between surrounding areas and centres do not exceed 20%. Differences in the representation of the secondary sector of activity in the structure of employment between surrounding areas and centres do not exceed 15%. Although larger differences should be expected between the shares of both development sectors between the centre and the surrounding area, such a situation is a consequence of deagrarization and the surrounding area itself, whose population is predominantly engaged in the activities of the secondary and tertiary-quaternary sectors. Relatively large share of the primary sector, or a small share in the quaternary sector of the population in the neighborhood settlements of some centres (Valjevo, for example) came up for a number of reasons–the existence of a production facility in settlements, a small number of settlements that do not have the equipment of public service facilities, etc.

Dominance of tertiary-quaternary sectors, both in urban region and surrounding areas, is based on the largest number of employees in the following activities: retail and wholesale and repair of motorized vehicles and motorcycles (within tertiary sectors) and state administration and defence and obligatory social insurance (within the quaternary sector).

Functional dependence of settlements in urban regions

All regional centres, except Pančevo, are functionally independent settlements, according to the applied model they have less than 20% of daily emigrants in overall active population and students and more than 50% of employees in tertiary-quaternary sector in the dwelling (Table 5).

On the study areas, 33 partially dependent settlements (Table 6) are recorded (with more than 20% of the daily emigrants, and more than 25% employed in the tertiary-quaternary sector). Among them are 16 municipal centres and even a regional centre of Pančevo, which is dependent on Belgrade (with 21.88% of daily migrants, among the regional centres only Smederevo has close to 20% of daily emigrants, which is by the model margin between functionally independent and partially dependent settlements). In addition to the proximity of Belgrade, the reasons for a higher share of daily emigrants from Pančevo centre are in the fact that the workplaces, or larger industrial facilities, are located in the cadastral municipalities of neighbouring settlements. Furthermore, among the partly dependent settlements there are also those in which the share of daily migrants is very high (more than 50%), and the share of employees in the tertiary-quaternary sector in the residential area is only about a quarter. Such settlements, for example, are Sremčica and Umka.

In the total number of settlements in surrounding area regional centres functionally completely dependent settlements are absolutely dominant, from which more than half of the active are daily emigrants (in regions of Užice, Čačak, Vranje and Belgrade more than ¾ of the surrounding area has more than 70% of daily emigrants, while on the territory of Vojvodina there are no or very few numbers of settlements among surrounding area of the regional centre that have such a high percentage of daily emigrants), while in the dwelling less than a quarter of the active population performing an occupation are employed in the tertiary–quaternary sector.

Functional polycentricity index

Among 16 defined urban regions there are numerous regions with only one urban centre on their territory, centre of the region, without secondary centres. Therefore, these centres (Kragujevac, Zrenjanin,

Table 5. The share of employees in development sectors and the share of daily emigrants in settlements in urban regions, 2011

Centre of the urban region	Share of employees in secondary and tertiary sector in the dwellings in the total active population performing an occupation (%)	Share of daily migrants in total number of active population performing an occupation and students (%)
Smederevo	67.59	19.25
Kraljevo	71.22	15.65
Užice	75.34	12.29
Šabac	77.25	11.15
Čačak	78.49	11.14
Zrenjanin	84.24	10.78
Leskovac	79.89	10.48
Kruševac	79.02	9.10
Novi Sad	84.66	8.83
Valjevo	78.91	8.64
Vranje	81.26	8.28
Subotica	86.52	6.08
Kragujevac	84.14	5.54
Beograd	92.00	3.50
Niš	86.67	7.86
Pančevo	71.99	21.88

Source: Statistical Office of the Republic of Serbia (SORS), 2011

Table 6. Functional dependence of settlements in urban regions

Urban Region	Functional independent settlement	Partially dependent settlement	A completely dependent settlement
Belgrade	regional centre	5 (4 MC)	54
NoviSad	regional centre	9 (5 MC)	17
Niš	regional centre	8 (4 MC)	99
Kragujevac	regional centre		20
Subotica	regional centre		3
Zrenjanin	regional centre		3
Pančevo		2 (2 MC)	7
Čačak	regional centre		9
Smederevo	regional centre	1	10
Kraljevo	regional centre	1	24
Leskovac	regional centre		7
Valjevo	regional centre	1	2
Kruševac	regional centre	3 (1 MC)	45
Vranje	regional centre	1 (1 MC)	36
Šabac	regional centre	1	4
Užice	regional centre	1	6

Note: *MC = municipality centre*

Čačak, Smederevo, Leskovac, Valjevo and Šabac) can be considered functionally monocentric. None of these regions has the values of the polycentricity index, $IP = 0$, since all employees do not work only in the regional centre, but also in other settlements of the region. Polycentricity index of monocentric regions ranges between 0 and 1 (Table 7), depending on the number of employees of the region outside the regional centre. Therefore, the values are identical to the values that refer to the number of employees in the centre of the region in relation to the total number of employees in the region.

Table 7. Functional polycentricity of urban regions

Centre of the urban region	Secondary centres	Functional Polycentric Index (IP)	Share of employees in all centres of the urban area in total employees in the region (%)
Belgrade	Barajevo, Grocka, Obrenovac, Surčin	3.87	78
Novi Sad	S. Karlovci, Irig, Temerin, B. Petrovac, Petrovaradin, Beocin, Futog, S. Kamenica	7.42	82
Niš	Niška Banja, Merošina, Gadžin Han, Doljevac	3.59	72
Kragujevac	/	0.94	94
Subotica	Palić	1.96	98
Zrenjanin	/	0.90	90
Pancevo	Kačarevo, Starčevo	2.46	82
Čačak	/	0.89	89
Smederevo	/	0.82	82
Kraljevo	Mataruška Banja, Ribnica	2.21	74
Leskovac	/	0.86	86
Valjevo	/	0.95	95
Krusevac	Ćićevac	1.37	69
Vranje	Vranjska Banja	1.61	81
Sabac	/	0.75	75
Uzice	Sevojno	1.89	95

Source: Authors' estimates

Subotica, Kruševac, Vranje, and Užice are following by the value of functional polycentricity index, which with one urban settlement belonging to the urban region, except for the regional centre, have a functional polycentricity index less than 2. In the area of urban regions of Kraljevo and Pančevo, in addition to the regional centre, there are 2 urban settlements, and accordingly the their functional polycentricity index is between 2 and 3. Although having numerous secondary centres in the area of their urban regions, Niš and Belgrade, due to the high concentration of employees in the regional centre, still have a functional polycentricity index of less than 4. Far more polycentric urban region was established around Novi Sad, with 8 urban settlements, secondary centres. The region's functional polycentricity index, calculated on the basis of the applied methodology, is even IP = 7.42.

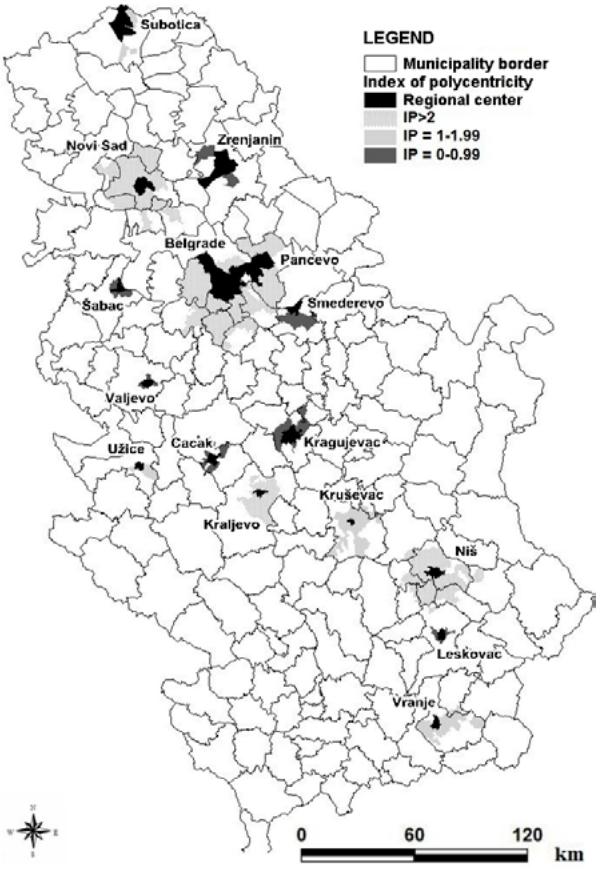

Figure1. Functional polycentricity index

Conclusion and recommendations

The results of this study show some similarities, but also differences in the basic characteristics of urban regions of Serbia, which should be taken into account when defining future planning solutions related to the regional development of Serbia.

Similar status characteristics of the urban regions according to the latest census (2011) is predominantly related to the dominance of the share of development sectors of activity, both in centres and in their surrounding areas. Service activities (tertiary-quaternary sector) on average have a higher share than production (secondary sector), both in centres of urban regions and in their surrounding areas. Production activities are dominant only in the surrounding areas of industrial centres of Vranje, Valjevo and Smederevo.

The degree of employees concentration in the centres of the region is expected to be high, ranging from 60% to 95%, and is not associated with the size of the centres, nor with the size of urban regions by the number of inhabitants, nor with the number of settlements in the region that have characteristics of complete dependence from the centres (determined according to the method that brings in relation the share of employees in development activities in the settlement and the share of emigrants from the settlement towards the centre). However, higher concentration values of employees in the centre of the urban region are brought into connection with a small number of secondary centres, i.e. with the existence of only one centre in the region, which points to the need to implement decentralization, that is, decentralized concentration as a principle promoted by national strategic development documents (SPRS, 2010-2020).

Significant differences between urban regions are related to the degree of their polycentricity. Almost half of the urban regions in Serbia have characteristics of monocentricity (Kragujevac, Zrenjanin, Čačak, Smederevo, Leskovac, Valjevo and Šabac). In the polycentric region there, a number of secondary centres varies, one in the case of Subotica, Kruševac and Užice, up to eight on the example of Novi Sad. Certain differences between urban regions refer to the results related to share of the employees in primary centres in relation to the secondary centre region, if it is a polycentric region, or in comparison to the region as a whole, if it comes to monocentric urban regions.

The functional polycentricity index (IP) of urban regions of Serbia, obtained by application of the designed method, has higher values in urban regions with a higher number of centres. For the sake of further development–the dispersion of the activities should be performed in order to achieve a more functional polycentricity. Notwithstanding the high concentration of employees in the primary centres, the index points to dispersion of the labour function, or the existence of a greater or lesser concentration of employees in secondary centres in the area of urban regions. There is a certain number of employees in the surrounding areas of monocentric region with a share of 5–25%, since there are significant industrial facilities on their territories, and those surrounding areas have properties of centre of work.

Therefore, future development solutions should be directed to strengthening these settlements, whose affirmation would be a step towards the achievement of the general national goal of decentralization at all territorial levels and, ultimately, a balanced regional development as a precondition for general prosperity.

We propose to public policy and decision makers to intensify activities on the re-industrialization of Serbia, that is, to introduce some forms of industrial production in areas of urban regions, as areas favorable for production, both in terms of concentration of population and capital, and infrastructure and human capital. In particular, the deployment of, as a rule, small and medium-sized industrial enterprises in secondary centers should be defined in accordance with cluster principles, or in accordance with the type of production in the centers of urban regions. Such an approach in planning is considered to be a key initial factor in the formation and affirmation of secondary centers, which in the future will contribute to further attraction of the population and agglomeration of activities, and thus to decentralization and overall development of urban regions.

Research using similar demographic and functional characteristics of centres and their environments can determine the characteristics of urban regions in other areas. Similar research has already been done in some European countries (Poland, the Netherlands, England, Wales…). Determining the functional polycntericity of urban regions according to the methodology used in the paper may find its application in countries with significant differences in regional development. Polycentricity could be achieved through favourable (international) investment projects, activation of local potentials, agglomeration of economic activities and, consequently, population concentration in medium-sized centres. Accompanied with incentives, this approach could encourage young people to settle in those centres. This would have to be dome to make them attractive and competitive. By improving the situation in those centres and their immediate surroundings, development process-

es in the country's interior would be encouraged and this could help mitigate the differences that mark the current regional imbalance. The future spatial effects of urban regions will depend on the height of the centrality level in the functional gravitational zone of urban centres.

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Hydrometeorological Drought Hazard and Vulnerability Assessment for Northern Bulgaria

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Abstract

In recent years, threats of natural origin, including those associated with the occurrence of drought is a topic that arouses interest in representatives of local government agencies, federal governmental authorities, scientific communities and residents of cities and villages. A significant part of the economy of Northern Bulgaria is agricultural, which increases the need for careful water management and planning. The aim of this study is to identify the drought hazard with regard to its spatial extends, frequency and severity and to assess the vulnerability to drought in Northern Bulgaria at the regional scale (NUTS-2). The standardized precipitation index (SPI), Standardised Precipitation-Evapotranspiration Index (SPEI) and Streamflow Drought Index (SDI) at 12-month time step for the period 1961–2012 were used to obtain drought hazard index (DHI). In order to assess drought vulnerability, Drought Vulnerability Index (DVI) was calculated based on the following parameters: population density, municipal water use, industrial water use, agricultural water use, and public water services. The results of the study show low DHI values and homogeneous distribution of drought hazard in the north part of Bulgaria. However, the drought vulnerability in the investigated area is very high due to the higher consumption of water by industry, municipal water supply, and extensive agricultural lands. Our results provide an elaborated understanding of the drought hazard and drought vulnerability and will be helpful as an early step in the development of risk-based drought management plans.

Keywords: Drought, SPI, SDI, hazard, vulnerability, Northern Bulgaria

Introduction

Drought affects more people than any other natural hazard and it is considered by many to be the most complex but least understood of all-natural hazards (Hagman, 1984). The causes of this phenomenon are not well recognized yet, and its effects are of a different nature than, for example, flood events. They grow over time, becoming visible in the long term and extend to much larger areas. It occurs in both high and low rainfall areas and virtually all climate regimes. According to the climate models increasing of drought and prolonged dry periods combined with high temperatures are expected during the 21st century (Dai, 2013; Trnka et al., 2011; Trnka et al., 2015). This fact requires further development of water consumption surveys in various sectors.

Due to various causes and consequences, different types of droughts are analyzed in the scientific publications. The classic classification of droughts is given by Wilhite and Glantz (1985) who determine four categories: meteorological, agricultural, hydrological, and socioeconomic drought. From the meteorological point of view, the drought is associated with waterless periods with different duration. Meteorological drought can be determined "on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period" (Na-

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tional Drought Mitigation Center - NDMC). The essential characteristics of meteorological drought are intensity and duration (Wilhite, 2000). Instead of meteorological drought, some authors use the term atmospheric drought (Koleva & Alexandrov, 2008) or climatological drought (Tate & Gustard, 2000). The main measure of drought is insufficient rainfall for a particular activity, i.e. crop growth, water supply for irrigation, the water level in dams (WMO, 1993; Alexandrov, 2006). Hydrological drought is related to the impact of meteorological drought and occurs when the long-term droughts lead to reducing of river runoff and groundwater (Koleva & Alexandrov, 2008). Tate and Gustard (2000) analyze hydrological drought as river flow drought and groundwater drought. Often, drought may be defined in terms of the differences between water supply and water demand time series. When demand exceeds supply, the water shortages occur, which represents the starting point of a drought (ICID, 2017). In order to make a comprehensive research on drought, the type, the intensity, the duration, the spatial range, and the impact have to be examined. Several studies on drought provide details about its characteristics and occurrence in Bulgaria during the last decades or century (Knight et al., 2004; Koleva & Alexandrov, 2008; Alexandrov, 2006; Alexandrov, 2011; Nikolova et al., 2012, Popova et al., 2014). Tran et al. (2002) point out that the drought can occur at any time, extend over a long period, and over large areas to a very severe level in Bulgaria. On the base of Cumulative Precipitation Anomalies and Standardized Precipitation Indices Nikolova & Alieva (2011) analyze dry periods in the Danube River Plain (Bulgaria). Popova et al. (2015) evaluate maize crop risk in relation to observed trends to drought. The potential in application of atmospheric drought index as a predictor of soil drought in the agricultural regions of Southern Bulgaria was analyzed by Georgieva et al. (2017). The occurrence of hydrological and meteorological drought in North Bulgaria (Danube River Plain) is characterized by Radeva et al. (2018). Drought and heat are identified as a major abiotic stress that reduce crop productivity in Bulgaria according to Petkova et al. (2019) Water shortages and increasing drought conditions were also identified by experts in neighboring regions in Serbia, Romania and Hungary (Milošević & Savić, 2013; Urošev et al., 2016; Szabo et al. 2019). The impact of drought on crop yield in Europe including Bulgaria was investigated by Trunka et al. (2016).

The economic development requires the satisfaction of water needs, both in society and in the economy. Bulgaria belongs to countries with limited water resources. Their high variability of occurrence in time and space causes necessity of rational water management. Recognition of the phenomenon of drought as well as developing methods of counteracting its effects should be an element of national strategies, plans and programs, and a detailed discussion of the problem should take place at the all levels of government. Drought preparedness planning should be considered to minimize the effects of drought on people and resources. For this goal, drought components, called hazard and vulnerability, have to be quantified. While hazard is a probability of occurrence of an event, vulnerability refers to the exposure to the hazard.

The overall objective of the present paper is to bring clarification of the drought hazard in Northern Bulgaria. The first stage of the research is an analysis of meteorological and hydrological droughts in terms of their duration and magnitude using standardized precipitation index (SPI), Standardized Precipitation-Evapotranspiration Index (SPEI) and Streamflow drought index (SDI). The second stage is drought vulnerability and drought hazard assessment in Northern Bulgaria. The research work is based on hydro-meteorological and socio-economic data. Assessment of drought hazard as well as vulnerability to drought at the regional scale may allow for better land use planning and water resource management during drought conditions in Northern Bulgaria. The results from the present study could be used in the development and implementation of wide range of measures and programs to reduce the negative impact of droughts.

Study area and data

The study area includes Northern Bulgaria and the main investigated territory is the Danubian plain located to the north of the main ridge of the Balkan Mountains and south of the Danube river. The relief is dominated by lowlands, hills and plateaus in the east (Figure 1). The area covers a total surface area of about 48,596 km^2 (43,7 % of the total surface area of Bulgaria) and has a population of 2,041,296 (30% of its total population). The region comprises three administrative regions NUTS - Severozapaden (Northwest), Severen centralen (Northcentral) and Severoiztochen (Northeast) (Figure 1).

Northern Bulgaria constitutes the largest water region in the country administered by the Danube River District. The total freshwater resources, excluding those in the Danube River, are estimated at 5,371 billion m^3, based on the long-term annual rainfall data for 1981-2014. The average annual per capita volume is

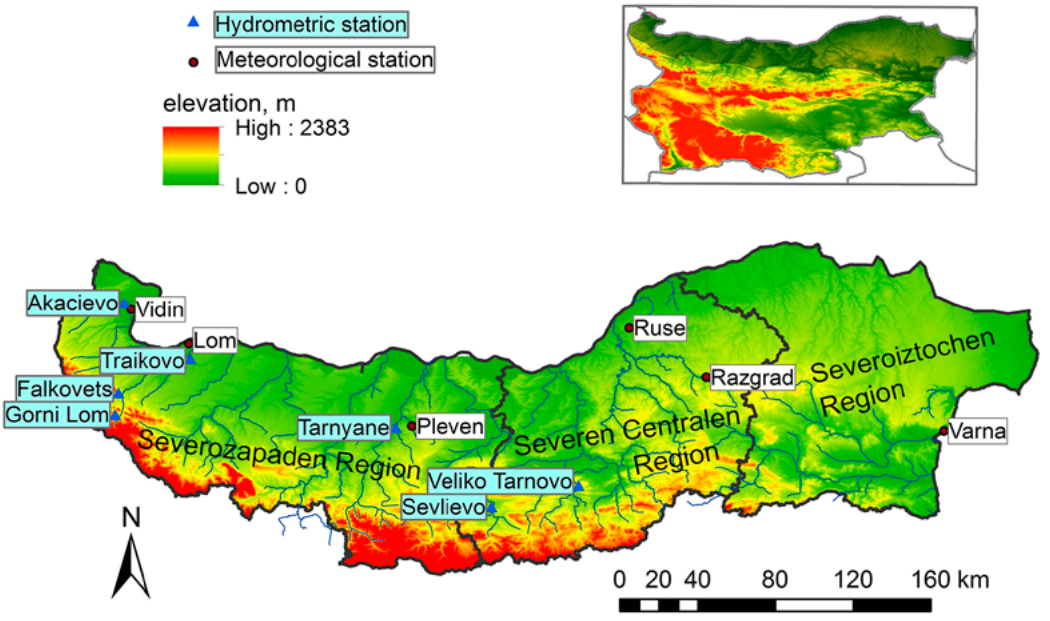

Figure 1. Studied area and location of hydrometric stations and meteorological stations used for the research

about 1,610 m³ and the usable part of it is from 800 to 1,000 m³/capita/yr (average for Europe it is 5,300 m³/capita/yr) (NSMDWS, 2012). The fact that more than 80% of the total freshwater resources are formed outside the territory of Northern Bulgaria indicates the existence of a water barrier in terms of securing access to water resources.

The annual precipitation varies from 500 to 600 mm and the annual evaporation is from 450 to 500 mm. The maximum of the annual cycle of precipitation is in June (in some places in May) with values between 70- and 90-mm. The monthly maximum is lower (60 – 70 mm) in the north-west (station Vidin) and in the eastern part of the investigated area. The mean annual temperature is 11-12 °C (Topliiski, 2006).

The seasonal distribution of precipitation shows maximal values in summer and spring in most of the investigated territory. The difference is observed in the east part of the area (station Varna) where the seasonal amounts of precipitation are relatively evenly distributed with a slight predominance of autumn and winter values over summer and spring. In relation to the annual precipitation totals, the regions of Lom and Pleven (central part) and Varna and Silistra (eastern part) are defined as arid areas (Alexandrov, 2011).

According to updated River Basin Management Plan for Danube region (2016 - 2021) severe or moderate droughts occur in the Danube plain nearly every year. The pressure on water resources increases during summer when water abstractions are higher, due to agricultural uses and increased demand from the tourist sector.

In order to achieve the aim of the study the hydrological, meteorological and socio-economic data were used. The monthly observed streamflow data were collected from seven hydrometric stations located in the Danube Plain (Figure 1, Table 1) over the multi-year period 1960/61–2012/2013. The period of study has been chosen depending on the availability of recorded data for all stations in the basin. The hydrological sta-

Table 1. List of hydrometric stations used for the study

River name	Station name	Elevation (m a.s.l.)	Drainage area (km²)	Investigated period
Topolovets	Akacievo	250	305	1961-2015
Lom	Trajkovo	442	1087	1961-2015
Lom	Gorni Lom	1100	88,5	1961-2013
Vojnishka	Tarnyane	260	269	1961-2013
Stakevska	Falkovets	-	325	1961-2015
Rosica	Sevlievo	604	1090	1961-2015
Yantra	Veliko Tyrnovo	545	1289	1961-2015

Source: Hydrological reference book of the rivers in Bulgaria, 1957

Table 2. List of meteorological stations used for the study

Meteorological station	Latitude	Longitude	Altitude	Investigated period
Vidin	43° 59'	22° 51'	31	1961-2015
Vratsa	43° 12'	23° 32'	309	1961-2015
Lom	43° 49'	23° 13'	32	1961-2013
Oryahovo	43° 43'	23° 58'	29	1961-2013
Pleven	43° 24'	24° 37'	160	1961-2015
Russe	43° 51'	25° 57'	37	1961-2015
Razgrad	43° 33'	26° 30'	346	1961-2015
Silistra	44° 07'	27° 16'	15	1961-2013
Varna	43° 12'	27° 57'	39	1961-2015

Source: Meteorological yearbook, National Institute of Meteorology and Hydrology

tions are located on different independent small and medium-sized rivers in the Severozapaden (NW Bulgaria) and Severen centralen (NC Bulgaria) regions (Figure1, Table 1). In the Severoiztochen (NE Bulgaria) region there is a lack of reliable hydrological data. Meteorological data are monthly air temperature and precipitation from six meteorological stations situated in Northern Bulgaria (Figure1, Table 2). The monthly precipitation data were used for calculation Standardized Precipitation Indices (SPI) and the Standardized Precipitation Evapotranspiration indices (SPEI) were calculated based of monthly precipitation and air temperature data. Drought vulnerability was evaluated by utilization of socio-economic data as population density, municipal water use, industrial water use, agricultural water use and water services.

Methodology

In order to investigate the spatial and temporal extents and severity of meteorological drought occurrence in the study area, Standardized Precipitation Index (SPI) (Mckee et al.1993) and Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2010; Begueria et al., 2010) were used. SPI is standardized and can be computed at different time scales, allowing it to monitor the different kinds of drought (Keyantash & Dracup, 2002). The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution, so that the mean SPI for the location and desired period is zero (Edwards & McKee, 1997). The SPEI is computed as the difference between the cumulative precipitation and the potential evapotranspiration and allow to evaluate the effect of air temperature on drought occurrence and intensity.

The method of Streamflow Drought Index (SDI) developed by Nalbantis &Tsakiris (2009) was used in this work to characterize the hydrological drought events for the studied area. Its calculation is similar to SPI, and is based on monthly observed streamflow volumes at different time scales. For SDI calculations, the hydrological year started in November and ended in October.

All three indices (SPI, SPEI and SDI) indicate the drought severity according to its intensity and duration. According to the SPI, SPEI and SDI criterion, drought conditions are defined with values lower than 0. The descriptions of drought states are provided with the criteria in Table 3.

In the proposed methodology, the reference periods start from November of each year, which is considered the beginning of the hydrological year in Bulgaria. In order to evaluate the drought, the SDI, SPI and SPEI are calculated with a 12 - month time step.

Table 3. Classification of drought conditions according to the SDI and SPI

Probability (%)	Drought Description	Criterion
1,7 5,1 9,5	Extreme wet Very wet Moderate wet	SDI/SPI/SPEI ≥2.0 2 ≥ SDI/SPI/SPEI ≥ 1.5 1,5 ≥ SDI/SPI/SPEI ≥1.0
67,2	Normal	-1.0 ≥ SDI/SPI/SPEI ≤ 1.0
9,5	Moderate drought	-1.5 ≤ SDI/SPI/SPEI ≤ - 1.0
5,0	Severe drought	-2.0 ≤ SDI/SPI/SPEI ≤ - 1.5
2,0	Extreme drought	SDI/SPI/SPEI ≤ - 2.0

Source: MCKEE et al. (1993); Nalbantis and Tsakiris (2009)

Based on drought indices the maximum intensity of dry events is determined according to the classifi-

cation from table 1. Meteorological and hydrological drought are evaluated in term of their duration and magnitude. The drought duration is determined as a period when the drought indices (SPI, SPEI of SDI) for any of the time scale are below 0. With the increasing of time scale each new month has less impact on the total precipitation and this determines the indices which indicate a few dry events but with longer duration (McKee et al. 1993). In the present paper the extreme drought duration is pointed out.

The formula given by Mckee et al. (1993) has been applied in order to assess drought magnitude (DM) as follow:

$$DM = -\left(\sum_{j-1}^{x} SPI_{ij}\right)$$

where j is the first month when *SPI* becomes negative and *x* is the last consecutive month with the negative value of the index.

The drought magnitude represents the positive sum of the drought indices that are negative over consecutive months. Instead *SPI*, *SPEI* or *SDI* can be used in the formula for drought magnitude. Drought magnitude (*DM*) and duration (*D*) were used for calculation of the average drought intensity over the duration (*ADI*), (Mckee et al., 1995, Bonaccorso et al., 2003, Zhang et al, 2015).

$$ADM = \frac{DM}{D}$$

To calculate the probability of occurrence of a potentially damaging phenomenon we used Drought Hazard Index (*DHI*) according to the methodology proposed by Shahid et al. and later by Rajsekhar et al. Using a weighting system based on the cumulative distribution function, Weight (*W*) and rating (*R*) scores are assigned based on the normal cumulative probability function to drought hazard assessment using severity and occurrence probability. Weight scores are determined by considering the *SPI/SDI* intervals, such that weight =1 for normal to mild drought (*MLD*), weight =2 for moderate drought (*MD*), weight = 3 for severe drought (*SD*), and weight = 4 for extreme drought (*ED*). Furthermore, each class receives a rate R from 1 to 4, based on its probability of occurrence. The final *DHI* is aggregated as:

$$DHI = (MLDr \cdot MLDw) + (MDr \cdot MDw) + \\ + (SD \cdot SDw) + (EDr \cdot EDw)$$

where *MLDr*, *MDr, SDr*, and *EDr* represent the ratings of Mild, Moderate, Severe, and Extreme categories, respectively, and *MLDw*, *MDw, SDw*, and *EDw* represent the weights of drought categories. The *DHI* values were then rescaled to a 0–1 range, and evenly classified into four groups as given in Table 4.

Table 4. DHI, DVI Classification for Hazard and Vulnerability Assessment

DHI, DVI Values	Classification
to 0.25	Low
0.25 to 0.50	Moderate
0.50 to 0.75	High
0.75 to 1.00	Very high

Source: Rajsekhar et al. (2015)

Drought Vulnerability Index (*DVI*). Vulnerability is a relative measure and it describes the degree to which a socio-economic system or physical assets are either susceptible or resilient to the impact of natural hazards (Wilhelmi & Wilhite, 2002). Selection of vulnerability indicators is directly relevant to the local study context and the particular hazard (United Nation Development Program, 2004). We selected five socio-economic indicators, which include: population density (*PD*), municipal water use (*MWU*), industrial water use (*IWU*), agricultural water use (*AWU*) and public water services (*PWS*). We used data from the National Statistical Institute (Bulgaria) for the period 2010 - 2016. The indicator values are turned into their scaled values. Then the Drought Vulnerability Index (*DVI*) is calculated using the following equitation.

$$DVI = \frac{PD + MWU + IWU + AWU + PWS}{5}$$

Based on the value of *DVI*, vulnerable regions were classified under four classes (Table 4).

Results and discussion

Drought occurrence

In order to analyze the spatial and temporal distribution of dry years, we have extracted for each station and each year in the investigated period the values of drought indices (SPI-12, SPEI-12, and SDI-12) which correspond to the period from November to October (hydrological year). SPI, SDI, SPEI time series for all stations were investigated to exam temporal drought patterns. According to the adopted classification, the calculated standardized precipitation index (SPI-12)

Table 5. Number of dry years according to the drought indices

Meteorological stations	SPI	SPEI	Hydrometric stations	SDI
Severozapaden (Northwest)				
Vidin	28	29	Akacievo	32
Lom	26	27	Tarnyane	29
Pleven	27	28	Falkovets	25
			Gorni Lom	25
			Traikovo	27
Severen centralen (Northcentral)				
Ruse	31	28	Sevlievo	27
Razgrad	27	26	Veliko Tarnovo	28
Severoiztochen (Northeast)				
Varna	29	29		

in the study area was distinguished from 26 years for Lom (Severozapaden region) to 31 years for Ruse (Severen Centralen region) in which drought occurred of varying intensity (Table 5). SPEI-12 shows between 26 and 29 dry years in most northwest and east parts of the study area. SDI-12 indicates a hydrological drought in 25 to 32 years in Severozapaden region. The number of years with hydrological drought in this region decreases with the increase of altitude (hydrometric stations Falkovets and Gorni Lom) and also from the west (station Akatsievo) to the east (station (Traikovo). The Hydrological drought was observed in 27-28 years in the Severen Centralen region (Table 5)

The present study demonstrates that according to the averaged over the entire area drought indices the occurrence levels of extreme hydrological drought are higher than the meteorological drought. The SPEI-12 shows the lowest occurrence level in Severozapaden region (1.9%) and the highest in Severen Centralen region (3,2%) where SPI-12 shows extreme drought in only 1,5% of the investigated years (Table 6). SDI-12 shows no substantial differences in the occurrence of extreme hydrological drought between the regions (Table 6). The occurrence levels of severe droughts have the highest levels in Severozapaden region (in 6,5% of the investigated years).

In comparison to SPI and SDI, SPEI shows the increase of frequency of severe drought and a decrease in the occurrence of mild drought. The highest frequency of mild drought was established by SPI for the three investigated regions. The results of the investigation indicate the tendency that the percentage occurrence of the meteorological and hydrological drought events in the studied area is substantially high. However, the frequency of extreme hydrological drought is higher than extreme meteorological drought while for the mild drought SDI is slightly lower than the results obtained by SPI-12 and SPEI-12.

Figure 2. presents the distribution of drought indices during the period 1961-2015. Due to a lack of hydrological observation and data, the hydrological drought is investigated for the period 1961-2013.

In most of cases, good synchronicity between meteorological and hydrological drought was observed. The most prolonged drought period both for Severozapaden and Severen centralen regions is 1982/83 – 1995/96 with a short interruption in 1985/86 and 1990/91. Other dry periods are1999/2000 – 2003/04, 2006/07 – 2007/08 and 2010/11 – 2012/13. These periods are clearly manifested in the Severozapaden region, while in Severen centralen region dry periods are shorter or interrupted with a normal year. The beginning of the dry periods is characterized by a clearer manifestation of the meteorological drought, while the hydrological drought is better expressed at the end

Table 6. Drought occurrence – average for Northern Bulgaria in % of investigated years

Drought Category	Severozapaden (NW Bulgaria)			Severen centralen (NC Bulgaria)			Severoiztochen (NE Bulgaria)	
	SPI 12	SPEI 12	SDI 12	SPI 12	SPEI 12	SDI 12	SPI 12	SPEI 12
Extreme drought	2,7	1,9	4,7	1,5	3,2	4,1	2,1	2,4
Severe drought	4,3	6,5	4,5	4,1	4,5	3,2	4,1	5,1
Moderate drought	8,3	9,9	9,4	9,6	9,6	11,1	9,4	9,6
Mild drought	34,7	29,6	29,4	38,3	35,2	26,6	37,2	32,4

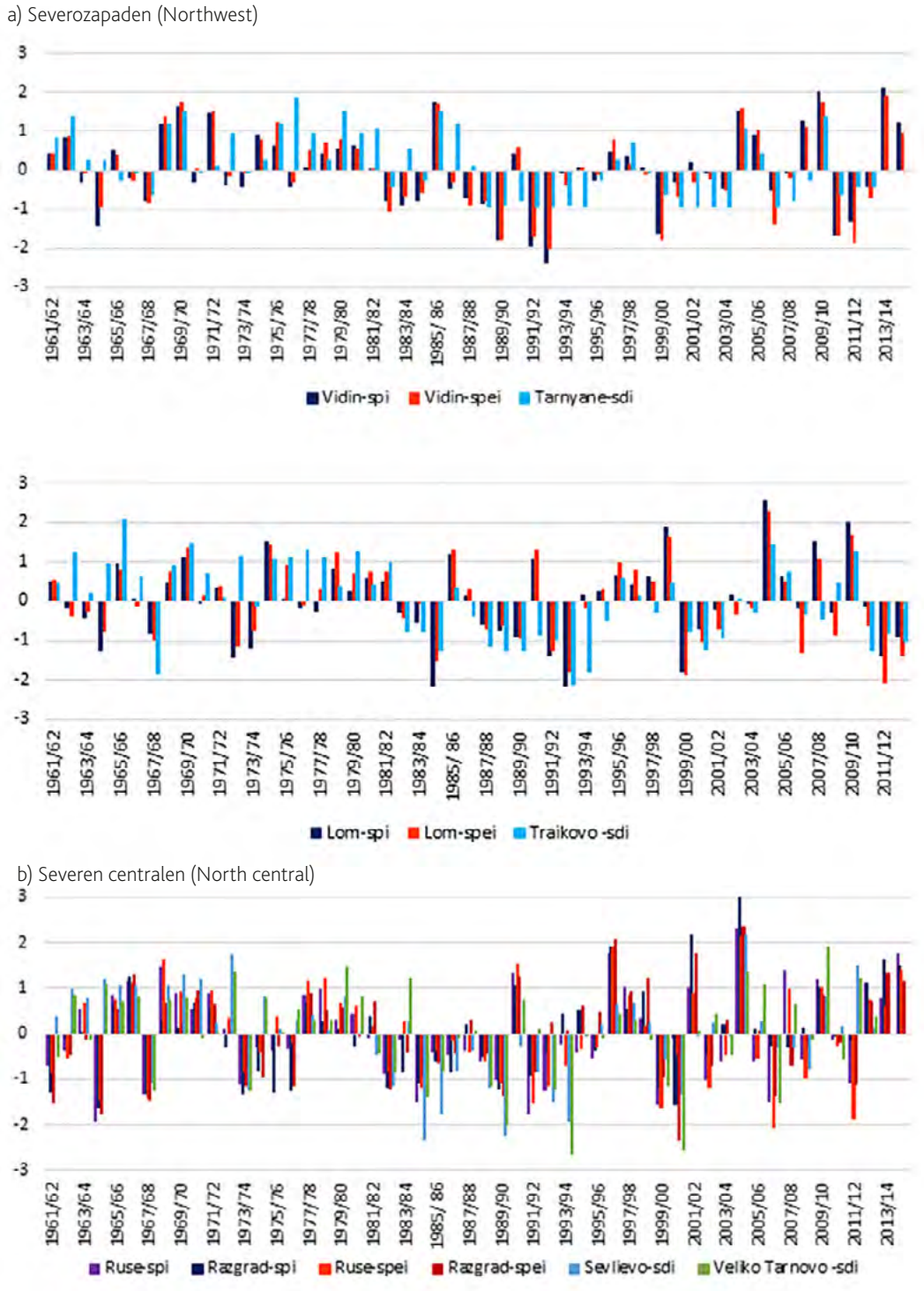

Figure 2. The distribution of SPI-12, SPEI-12 and SDI-12 in selected stations

of the periods and even observed after the end of the metrological drought.

According to SPI and SPEI dry periods in the Severoiztochen region are 1982/83 – 1992/93, 1999/2000 – 2001/02. 2006/07 – 2007/08 and 2011/12. Despite the different investigated period Šurda at al. (2019) found the similar results for the region of Nitra (Slovakia), where the years 2006, 2011 and 2012 were among the driest years.

For the investigated periods, the dry years were observed mainly in 80^{-es}, 90^{-es} and since 2000. According to European Drought Centre database (see: www.geo.uio.no/edc) the drought in 80^{-es} and 90^{-es} significantly affected the Mediterranean countries, Southeastern Europe, as well as the UK and even Northern Europe. Spinoni et al (2015) also show the occurrence of drought in many European areas during 80^{-es} and 90^{-es}.. The temporal distribution of the occurrence

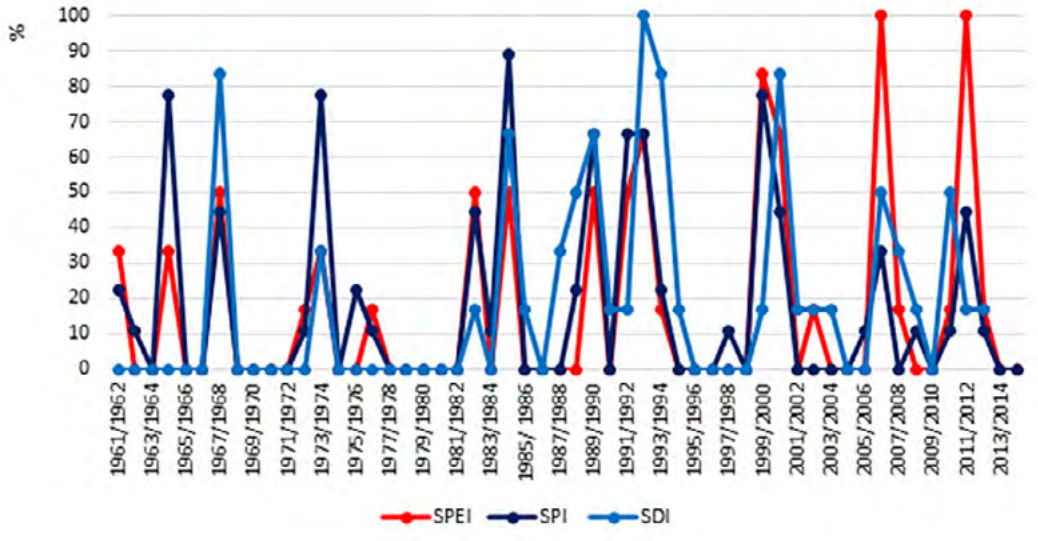

Figure 3. Percentage of investigated stations with dry years (moderately, severely, and extremely)

of different types of droughts in the investigated stations shows synchronicity in the most of cases (Figure3). From the other side, some differences have been observed. During the first decades of the investigated period, dry years are indicated mostly by SPI and SDI while since 2000 the occurrence of dry years determined by SPEI increases. This could be explained with the increase of temperatures during the last decades. The increase of drought in South Europe due to the temperature rise is confirmed also by van der Schrier et al. (2013) and Spinoni et al. (2015a).

According to SPI drought was widespread in 1984/1985 when various types of drought were observed in 90 % of the investigated stations. SPI shows dry years in about 80% of investigated stations in 1964/1965, 1973/1974 and 1999/2000. SPEI indicates as driest years 2006/2007 and 2011/2012 when the drought occurred in all of the investigated stations. For these years SPI confirms the occurrence of drought in about 35 – 45 % of the investigated stations and hydrological drought was observed in 50% of the investigated stations (Figure3). The occurrence of hydrological drought is connected mostly with the precipitation and not with the air temperature.

Drought magnitude and average drought intensity

Drought magnitude (DM) and average drought intensity (ADI) are investigated based on entire rows of drought indices calculated at step 12 (SPI-12, SPEI-12, and SDI-12) for the investigated period.

The extreme observed values of meteorological drought indices are observed mainly in 2001, 2007 and 2013. For temporal and spatial distribution, the higher synchronicity is observed for SPEI-12, rather than for SPI-12 (Table7). In the Severozapaden region, SPEI indicates extremely low values in January 2001 (2013 for station Pleven). For stations, Vidin and Lom January 2001 was an extremely low SPI-12 as well. On the other side, SPI-12 for station Pleven is showing extremely low in September 1993. For the regions, Severen centralen and Severoiztochen SPEI-12 show extremely low values in 2007 for July and August respec-

Table. 7. Extreme observed values of meteorological drought indices

Meteorological station	SPI-12	Year	Month	SPEI-12	Year	Month
Severozapaden (Northwest)						
Vidin	-2.81	2001	Jan	-2.47	2001	Jan
Lom	-2.88	2001	Jan	-2.53	2001	Jan
Pleven	-2.97	1993	Sept	-2.73	2013	Jan
Severen centralen (Northcentral)						
Russe	-2.57	2001	Jan	-2.75	2007	Jul
Razgrad	-2.09	1977	Apr	-2.95	2007	Jul
Severoiztochen (Northeast						
Varna	-3.35	1985	May	-2.58	2007	Aug

tively. The occurrence of the extreme values of SPI-12 for the Severen centralen and Severoiztochen regions is asynchronous during the study period.

Extreme values of SDI-12 are observed asynchronously with the extreme meteorological drought indices. In most of cases, the extreme values of SDI-12 are observed in 1994. The lowest extreme hydrological drought event was identified in February 1994 for station Gorni Lom (NW Bulgaria) with a value of - 2.95, and in December 1984 for Yantra river, station Veliko Tarnovo (NC Bulgaria), Table 8.

Table. 8. Extreme observed values of hydrological drought indices

Hydrometric stations	SDI-12	Year	Month
Severozapaden (Northwest)			
Tarnyane	-1.20	1991	Jan
Falkovets	-2.72	2001	Apr
Gorni Lom	-2.95	1994	Feb
Traikovo	-2.44	1994	Mar
Severen centralen (Northcentral)			
Sevlievo	-2.57	1991	Feb
Veliko Tarnovo	-2.68	1994	Dec

When the values of the SPI, SPEI and SDI continuously remain negative for consecutive months, the impacts of drought can become more damaging. In order to measure this effect, drought magnitude was calculated. The drought magnitude and drought duration obtained for Northern Bulgaria is shown in Table 9. During the investigated period, the highest drought magnitude (75.17) has been observed in NE Bulgaria (station Varna) where SPI 12 indicates the extreme duration from November 1982 to February 1988 (Table 9). On the other side, the average drought intensity (ADI) is highest for Pleven station, NW Bulgaria (1.64). In comparison to SPI-12, SPEI-12 shows lower DM and ADI. A difference has been established for spatial and temporal distribution as well – DM is highest for NW Bulgaria (station Pleven, 56.44) with the duration from November 2006 to April 2011. The ADI varies from 0.62 (NC Bulgaria) to 1.31 (NE Bulgaria).

DM calculated on the basis of SDI-12 shows higher values, while ADI is close to one established by SPI-12. The highest ADI (1.37) according to SDI 12 was observed during the period February 1998 to December 1995 in NW Bulgaria (Table 10).

Table 10. Extreme duration-intensity of hydrological droughts

Hydrometric stations	Start	End	DM	ADI
	Duration (months)			
Severozapaden (NW Bulgaria)				
Tarnyane	Nov 1988	Apr 1997	86.79	0.85
	102			
Gorni Lom	Feb 1988	Dec 1995	130.58	1.37
	95			
Traikovo	Mar 1987	Feb 1996	123.23	1.14
	108			
Severen centralen (NC Bulgaria)				
Sevlievo	Feb 1985	Oct 1995	156.32	1.21
	129			
Veliko Tarnovo	Sept 1999	Sept 2002	49.42	1.34
	37			

Table 9. Extreme duration-intensity of meteorological droughts

Meteorological stations	SPI-12				SPEI-12			
	Start	End	DM	ADI	Start	End	DM	ADI
	Duration (months)				Duration			
Severozapaden (NW Bulgaria)								
Vidin	Dec 1991	Jun 1995	50.30	1.14	Feb 1992	Aug 1995	48.70	1.13
	44				43			
Pleven	Jul 1992	Jul 1995	60.57	1.64	Nov 2006	Apr 2011	56.44	1.05
	37				54			
Severen centralen (NC Bulgaria)								
Russe	Jul 1992	Feb 1995	38.85	1.21	Jan 1988	Apr 1991	24.65	0.62
	32				40			
Razgrad	Oct 1973	Feb 1978	58.57	1.11	Feb 1974	Feb 1978	43.44	0.89
	53				49			
Severoiztochen (NE Bulgaria)								
Varna	Nov 1982	Feb 1988	75.17	1.17	Nov 2006	Nov 2009	48.39	1.31
	64				37			

Analysis of the DHI and DVI

Drought hazard assessment (DHI) for Northern Bulgaria, was calculated by using the probability of occurrence and severity based upon weight and ratings, as described in the methods section. "Low" drought hazard class was detected based on SPI-12, SDI-12, and SPEI -12 in Severozapaden and Severen centralen regions (Table 11). "Moderate" drought hazard based on SPI-12 was detected as 0.25 for station Varna in Northeast Bulgaria (Severoiztochen region). High levels of DHI were not detected in the 12-month time scale for SPIs, SPEIs and SDIs. The DVI was calculated based on five indicators for vulnerability. The scores of the vulnerability index range on a scale from 0,81 (Severoiztochen region) to the most vulnerable 0,85 (Severen centralen and Severoiztochen regions) (Table 11). According to this analysis, the regions are recognized with the highest vulnerability, with DVI values close to or higher than 0.6. Severozapaden and Severen centralen regions are vulnerable in all the five sub-categories, while the Severoiztochen region is less vulnerable to Industrial Water Supply (0,5).

In order to have more detailed information about drought hazard and vulnerability, it is necessary to direct the future study to the local and municipality level. This analysis may help for developing various strategies for mitigation and adaptation to climate change and for effectively tackling environmental and social problems related to water scarcity.

Table 11. DHI and DVI scores for Northern Bulgaria according to the SPI, SDI and SPEI

Regions	DHI/SPI		DHI/SDI		DHI/SPEI		DVI	
	Score	Class	Score	Class	Score	Class	Score	Class
Severozapaden	0.21	Low	0.22	Low	0.21	Low	0.85	Very high
Severen centralen	0.22	Low	0.21	Low	0.23	Low	0.84	Very high
Severoiztochen	0.25	Moderate	-	-	0.21	Low	0.81	Very high

Conclusion

Accurate drought monitoring and forecasting are essential tools for drought mitigation efforts and reduction of social vulnerability. In this study, the SPI, SPIE, and SDI were proved to be useful indexes for finding out drought severity, magnitude and drought hazard in Northern Bulgaria. Droughts that occurred in the considered stations did not follow a specific order. According to SPI and SDI, the driest multi-year periods were detected in the 1980s and 1990s. In addition, according to SPIE, the driest multi-year periods were after the year 2000. Obtained results showed that the Severozapaden and Severen centralen regions are more prone to extreme drought events, while in the Severoiztochen region the occurrence of severe meteorological drought is higher. The highest drought magnitude according to SPI has been observed in Severoiztochen region, while the average drought intensity (ADI) is highest for Severozapaden region. The drought hazard index identified by using SPI and SDI weight and rating scores between 1960/1961 and 2012/2013 show low values for all stations. The results obtained by this study indicate that North Bulgaria is with a high degree of overall vulnerability to drought. Thus, it is recommended for local authorities to adopt preparatory adaptive measures for drought risk management planning strategies in order to address future drought conditions.

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Developing A Socio-Spatial Index Methodology for Measuring Cross-Border Mobility

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Abstract

The article proposes a cross-border mobility model for borderlands by developing a multivariate socio-spatial index. Existing methods of evaluating cross-border mobility tend to focus simply on physical and security dimensions of the state borders. However, because of the complex dynamics of relationships among the countries, a multidimensional approach including the economic, social, administrative and spatial relationships have to be considered holistically. The proposed cross-border mobility modeling and index methodology includes spatial and non-spatial multivariate data for assessing the permeability of state borders by using fuzzy logic methods. GIS techniques are used to combine economic, social, administrative and spatial dimensions of relationships for creating the multivariate socio-spatial index and to visualize the results. The results of the proposed methodology experienced for the borderlands of Turkey show that measuring the degree of cross-border mobility can improve the understanding of relationships among the states for developing more effective cross-border policies.

Keywords: cross-border mobility; multivariate index; socio-spatial data; fuzzy membership

Introduction

Composite index construction is a technique to integrate large amounts of heterogeneous data in a compact way (Santeramo, 2016). This provides a comparison of complex issues in multifarious fields such as engineering, geography, environment and economy (Cherchye et al., 2006). Measurement of multidimensional issues of the social, cultural, political, economic, spatial and so forth ought to be represented by different measurements instead of by single descriptive indicators (Lun et al., 2006, Bandura & Campo, 2006). As having a multinational and socio-spatial content, border mobility becomes a multidimensional issue in terms of concept, data and scope. In analytical studies, borders are mostly discussed more or less subjectively i.e. white-gray-black, and in a narrower scope regarding specific areas or regions (Zartman, 2010; Popescu, 2006). In various studies, different methods and approaches have been developed for cross-border mobility and permeability (Star & Thomas, 2002; Stephenne & Pesaresi, 2006; Hisakawa et al., 2013) due to the availability of data. These approaches are limited in terms of producing a generalizable model due to low diversity in the data sets they use. Thus, there has not been a holistic framework for measuring the mobility considering socio-spatial characteristics of the border region in a multivariate context. Thus, analysis needs to be reconsidered in a broader and multi-dimensional way that will help nation states to make rational and effective decisions and to designate border policies due to cross-border mobility model.

In literature, state borders are mostly defined as bridges, barriers or action spaces. The use of cross-

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border mobility approach in the analyses conducted at national or supranational borders has come to the fore mainly in the context of sovereignty and border security (Dodson, 2000; Missbach, 2014; Stephenne & Pesaresi, 2006). In political border management context, mainly related to territoriality (Anderson, 2001), "space" dimension has been added to the analyses regarding the control of border space and the movements inside the border regions (Sack, 1986). Other approaches, using economic (O'Dowd, 2002) and geographical indicators (Star & Thomas, 2002) have considered border as physical boundaries. In this study, cross-border mobility refers to a multivariate and multi-dimensional context including economic, social, administrative and spatial interactions in the border regions. In order to measure cross-border mobility in a multivariate and multi-dimensional context, different evaluation methods can be developed (Starr & Thomas, 2001; Stephenne & Pesaresi, 2006; Kolejka et al., 2015; Hisakawa et al., 2013). Based on geographical data, Starr & Thomas (2001) present a framework that illustrates the relationship between the EU's process-based permeable boundaries and the integration process using different vector and raster datasets, such as the ease of interaction or border detection of the areas requiring security measures. Stephenne and Pesaresi (2006) develop a permeability model that utilizes accessibility, concealment and security indicators by emphasizing geographic permeability. In addition to these studies, the latest models are characterized by the use of GIS technologies. Hisakawa et al. (2013) measure porosity of state borders by using the geographical and physical data along with geocomputational methods.

Existing methodologies have carried out analyses focusing attention on specific aspects of the interactions on border regions. However, in order to comprehend the complex socio-spatial structure of border regions, a holistic perspective is needed that will integrate the tools of present models and the complex socio-spatial components of the border regions. In the face of these considerations, this paper develops a cross-border mobility model for measuring the interactions at state borders, considering socio-spatial characteristics of both sides of the neighboring countries. The proposed model aims to contribute to the research field mainly in two dimensions. Firstly, it presents an initiating framework with its multi-dimensional approach regarding the complexity of border regions. Secondly, concerning the blurred nature of border regions, it integrates fuzzy logic into the combined index methodology. Within this framework the paper starts with conceptual explanations as a basis for the model. Then, it proposes a multivariate socio-spatial mobility index for borders integrating economic, social, administrative and spatial data. The application of the model to Turkish and its neighboring state borderlands helps to find out the cross-border interaction level that will develop effective and unique public policies based on help to the multivariate border mobility levels.

Developing the Socio-Spatial Index and the Cross-Border Mobility Model

In cross-border interaction analysis, cross-border mobility is the main determining function, which differentiates due to the nature of the border and requires analyses at different scales. Context-dependent variation of mobility definitions in literature is related to the conceptual framework being displayed academically. Within this process, border interaction has generally been reconceptualized by security-based issues (Anderson & O'Dowd, 1999:597), as well as social, economic and spatial (geography-based) interaction discussions. Security-based approach is a form of political cross-border management and this military defense based perspective on the border is characterized by the fact that central governments ignore the social and economic dimensions among neighboring countries by seeing the border basically politically and militarily (Anderson & O'Dowd, 1999). Physical barriers and control points are designed as basic tools in security-based analysis. On the other side, social and economic interaction analysis prioritizes economic and social relations and features that consider the formal and informal relationships occurring among the neighboring countries. Lastly, geographic-based spatial analysis includes more analytical elements when compared to the other two approaches. It measures geographic permeability by using digital maps and measurable physical and geographical data. These three approaches have unique and differentiated analysis that measure mobility due to their objectives, but they do not provide a holistic model for nation states cross-border mobility (Stephenne & Pesaresi, 2006; Starr & Thomas, 2001).

In the production of cross-border mobility model and the multivariate social-spatial index, these concepts are redefined both by physical features and by an overarching content that includes spatial, social, cultural, economic, administrative and security related issues. In order to analyze the cross-border mobility of state borders, first of all, it is necessary to determine what is passing through the borders, how they pass, and what is being filtered. For determining these, concrete variables have to be defined primar-

ily. In theoretical and empirical studies, cross-border mobility has been considered as the total probability of the transition of goods, capital, information, and people to the other side of the national boundaries. While the measurement of flows is more quantitative, the measurement of mobility is more complex as the content of permeability can change over time by the restrictive and facilitative factors or by national policies. While constraints can be spatial and political barriers, as well as socio-cultural diversity, facilitators can be government supported policies, provided incentives and quality of infrastructure.

Redefining the cross-border mobility concept by a multivariate analysis of economic, social, administrative and spatial variables causes a more generalizable and widened geographical context that help to understand the level of relationships among the neighboring countries. The proposed cross-border mobility index created by different variables provides an opportunity to identify the current situation and display the potentials for the convergence of cross-border regions. Created by objective indicators of economic, social, administrative and spatial interaction levels along national boundaries, the proposed GIS-based multivariate cross-border mobility modeling forms the basis for the empirical study of Turkish national land borders.

Data and Methods

Data Sources

This study integrates socio-economic and spatial data for the creation of a multivariate cross-border mobility index to apply in Turkey's national land borders. The main goal is to understand how cross-border socio-spatial flows affect the level of interaction by neighboring countries in tandem with the global processes. The study proposes a model to fill the theoretical and empirical gap for measuring the mobility on nation state borders by developing a holistic approach. It integrates multivariate spatial and tabular data of economic, social, administrative and spatial variables in local, regional and national levels into a systematic and comprehensive composite index. Thus, the cross-border mobility model perceives and analyzes the border not only as spatial passages but as an integration of political, socio-spatial, socio-cultural and economic interactions. Figure 1 demonstrates the adaptation of composite index methodology to the proposed model.

Two key steps have been established for the development of the index. The first is the creation of data sets and indicators, and the second is the determination of the geographical scope. Based on literature, 22 theoretically and practically important and relevant variables, measuring the flows among countries were chosen to ensure a multidimensional approach in understanding the complexity of the border region. The proposed model was developed by using compiled and computed variables to measure the socio-spatial

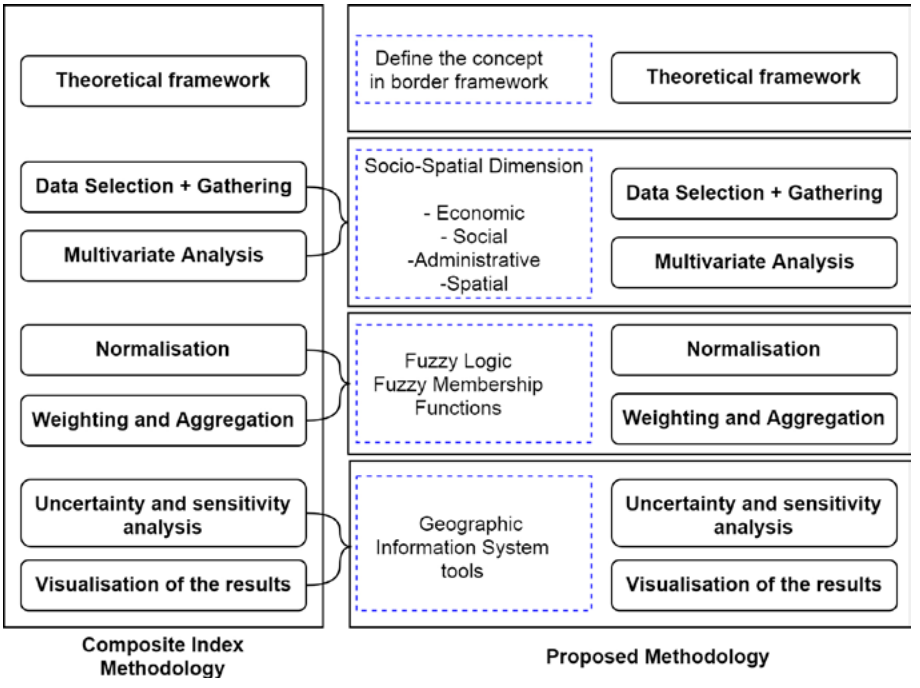

Figure 1. Composite index methodology and proposed model

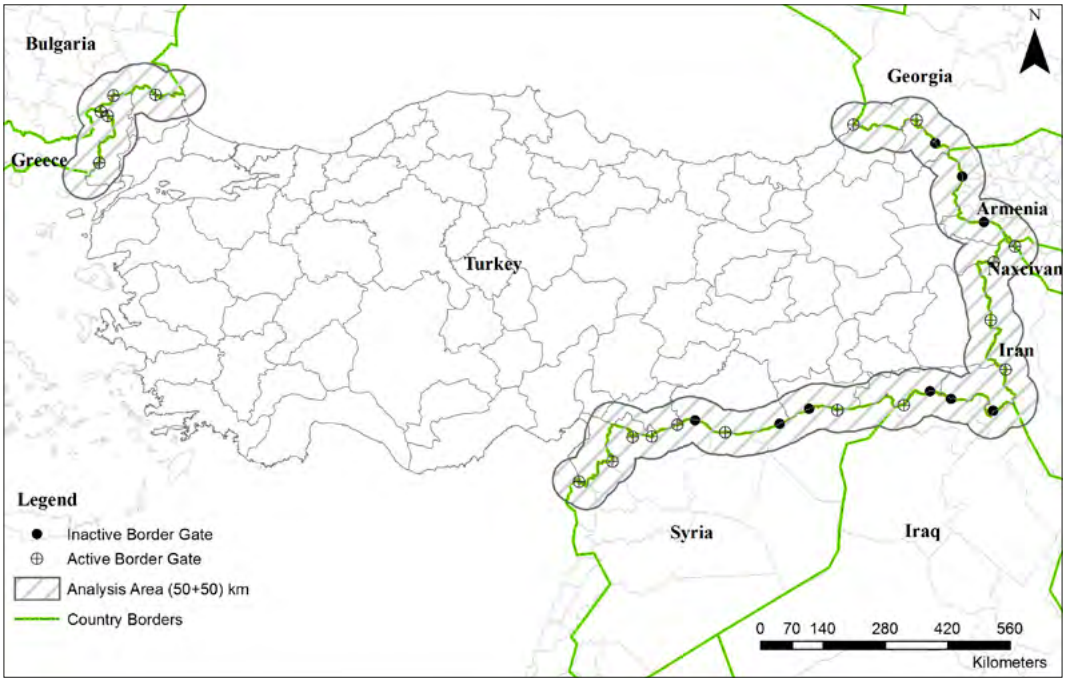

Figure 2. Analysis area and the border gates

interaction in an area of 50 km buffer of the borderline for both sides (Figure 2). In the related literature (Perkmann, 2002, Stephenne & Pesaresi, 2006), the boundary depth for defining the border regions vary between 50 to 100 km where most of the social, economic, administrative and spatial interactions along the border occur. Publicly available data were gathered from different data sources like the Turkish Statistical Institute, General Directorate of Security, Turkish Military Services, several ministries at national level, and local government authorities. In order to minimize the impact of refugee mobility caused by Syrian civil war, 2013 and 2014 data were used.

Defining Subindex Groups for Cross-Border Mobility Indicators

For creating multidimensional indices, it was necessary to separate the variables into subgroups, which would increase the robustness of the conceptual framework and clarify the set of indicators. It would also improve the user's understanding of driving forces behind the index and would determine the relative weights across different factors (Nardo et al., 2005). Thus, mobility indicators for the study were separated into four subgroups: economic, social, administrative and spatial.

Together with the trade flows between countries, the factors related to the level of correspondence, trade ability and volume, easiness and potential of the economic relationships were assessed as economic mobility in the first subindex group. The indicators discussed by several studies in cross-border economic and regional integration literature were adapted to determine the levels of economic relations (Obstfeld & Rogoff 2001; Nitsch, 2000; Evans, 2003). Thereby, trade volume by countries, total passenger volume crossing the border, amount of multinational capital investment, direct foreign investment in the border regions, foreign trade balance, border gate types according to customs characteristics, commercial trade quotas for cities located in borderlands, and distance of borderlands to free economic zones were used as economic indicators.

The second subindex group comprises social mobility indicators that try to reveal the possibility of social interaction levels. In this context, religious and sectarian differences and similarities in the border region and the similarities of nationality and historical backgrounds that would help to reveal the dimensions of social permeability were considered. The race/ethnicity structure, religious and sectarian similarities and differences (Izady, 2008a; Izady, 2008b; Meirav, 2011, Luo et al., 2016), social and cultural service volume and population, and settlement densities within 50 km and 100 km depth of the borderline were examined.

The third subindex group was defined for administrative mobility. Indicators in this group determined by national or supranational arrangements were mostly put into practice by central governments. Administrative mobility covered the entire border control mechanism on the borders between the two countries. In this framework, visa arrangements which were determined by central governments and considered as indicators of the ease of transition to the other side and visa restrictions by a destination country for

citizens reduce cross-border flows by %20 (Czaika and Neumayer, 2017), number of illegal transit attempts at the border, number of smuggling incidents at the border, characteristics of the customs gates, and number and type of sister cities that could coincide with political proximity were taken into consideration.

The fourth subindex group was spatial indicators that had the highest potential to be measured analytically. These were natural thresholds (streams, lakes, etc.), artificial thresholds created by security concerns and making the border less permeable, number of settlements and their densities, average transportation time among the cities on both sides of the border, and road and railway transportation infrastructures.

As composite index validity depends on the strategic objectives of the research (Mazziotta & Pareto, 2013), variables reflecting the flows among countries were chosen to ensure a multidimensional approach in understanding the complexity of the border region. After subgrouping the main index components and related variables, all economic, social, administrative and spatial data in tabular form were analyzed in Geographic Information Systems Software (ArcMap) in order to realize necessary steps for achieving multivariate socio-spatial cross-border mobility index for border regions (Figure 3).

The data for Turkish borderlands consisted of a spatially referenced longitudinal database that included nearly 3300 km long and 100 km wide area with 16 million population for the year 2013. The borderland was divided into 10 x 10 km grids that consisted of 343 grids in total. Four subgroups of variables were rasterized before applying fuzzy classification methods that were used for the standardization of each layer.

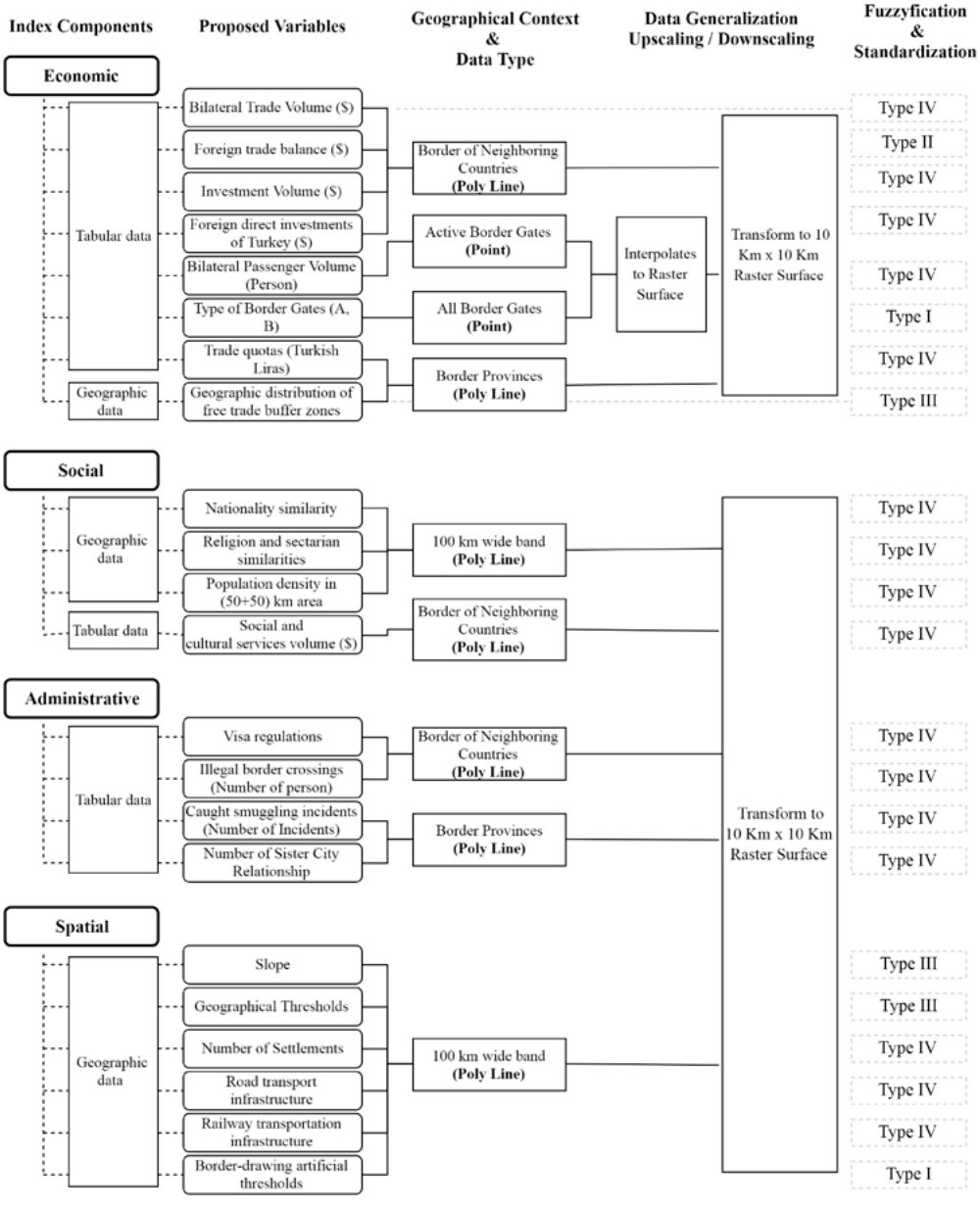

Figure 3. Subindex components and data preparation

Fuzzy Logic as a Method of Reclassifying and Standardizing Data

By the mutual agreement of neighboring nation-states, border regions are separated by clear lines. However, due to the maintaining interaction among local inhabitants, they are transformed into areas with intermediate mobility values. Thus, they can be expressed with degrees of membership to a fuzzy set than with binary classification. However, studies on the measurement of the mobility at state borders have displayed definitive expressions based on expert opinions, but intermediate values are ignored (Dombi, 1990).

The proposed methodology in this study is associated with the fuzzy set theory that is used for quantifying the membership relationship of layers to specific sets, where a membership function defines the level of confidence, and whether an element belongs to the set or not (Zadeh, 1965). The fuzzy membership is generally used to reclassify and transform the input data into a scale of 0 to 1 indicating the membership strength of a set, based on the possibility of being a member of a set (Mesgari et al., 2008). Membership functions are important for reclassifying rasters since they affect the fuzzy inference system (Ross, 2010:89). In other words, membership functions are the representation of the degree of belonging to a fuzzy set by the type of functions. In theoretical and practical studies; triangular, sigmoid, sinusoid, trapezoid, Gaussian, bell and linear types of functions are determined to be the most suitable membership functions. These functions, which can be expressed by mathematical formulas and shapes, can be calculated with the parameters compatible with GIS software.

In this study ArcGIS spatial analyst tool is used for determining the appropriate membership function type. While reclassifying and transforming the raster data into a layer, firstly each data is reclassified and transformed into a 0 to 1 scale, identifying the possibility of belonging to an appropriate set. Then, within this framework, four types of membership functions are standardized by taking into account the data types and distributions related to the border mobility context (Figure 4). Here, each membership function transforms the data in a specific way to capture the interaction at the borderlands. The pixel values generated due to the data obtained by fuzzy logic are used as inputs. Thus, new pixel values are standardized according to the data type and distribution. With this fuzzification process, fuzzy cluster membership is performed for each data set. The values between 0 and 1 indicate the probability of fuzzy cluster membership, while a value of 1 indicates absolute membership. According to type, distribution, and standard deviation of the data, appropriate membership function is chosen to obtain the most appropriate transformation via different conversion parameters.

Type I is a fuzzy membership conversion method where expert-defined minimum values are assigned to 0 membership and maximum values are assigned to 1 membership by linearly. Thus, it transforms the input values linearly on 0 to 1 scale, with 0 being assigned to the lowest input value and 1 to the largest in-

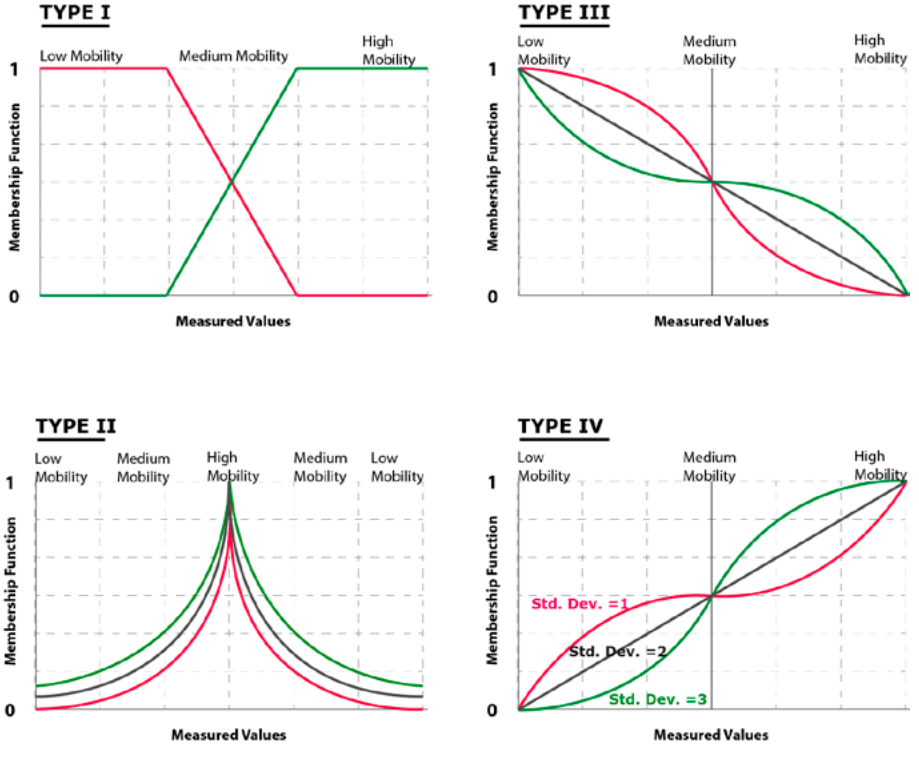

Figure 4. Types of Fuzzy Membership Functions

put value. All the values between 0 and 1 are assigned to base on a linear scale, with the larger input values closer to 1, smaller values closer to 0. Type I is applied to data sets where the measured values increase or decrease linearly. Type II is a fuzzy membership conversion method that transforms the original values into a normal distribution. The midpoint is assigned to be 1, and the rest of the inputs decrease in both positive and negative directions moving away from the midpoint. In Type II maximum values in data distribution correspond to the middle of the distribution. Type III is a fuzzy membership function where small values are assigned to 1, large values are assigned to 0 membership based on the arithmetic mean and standard deviation. Type III is used for the data types where the smaller values in the data set are more mobile. Type IV is the opposite of Type III where large values are assigned to 1, small values to 0 membership based on the arithmetic mean and standard deviation. Contrary to Type III, in Type IV, the mobility level is high in large values but less in lower values.

In the standardization of multivariate data sets, generally boolean or expert methods are used. However, in this study, the fuzzy membership classification method was used for the standardization, before using map algebra operations. Using fuzzy set memberships is a significant step as it provides a very powerful tool for the standardization process (Jiang & Eastman, 1999). Standardization through the use of fuzzy set membership provides the particular relationship between data distribution and decision-making that enhances cross-border mobility precision. Thus, before the determination of border mobility, all the related data were transformed into a pixel-based structure for the spatial representation of the data. In this structure, the data was assigned to 10x10 km pixels. Thus, it was possible to perform pixel-based raster mathematical operations. The mobility of a relevant pixel value was evaluated in the GIS environment. 22 indicators were considered and mobility analysis was done by fuzzy membership classification (Type I, Type II, Type III and Type IV) by using weighting factors accommodating the relative importance of the cross-border mobility indicators (Figure 3).

The cross-border mobility model was obtained by combining the values of economic, social, administrative and spatial subindexes, by using simple additive weighted (SAW) method, which uses an averaging procedure based on the linear dependence of mobility from its constituting elements of economic, social, administrative and spatial. Each grid had values between 0 and 1 for each variable of economic, social, administrative and spatial dimensions. After producing raw data acquisition and transformation to the appropriate spatial layers the overall model produced as the total of the economic, social, administrative and spatial permeability weights (Figure 5).

Continuous values for each economic, social, administrative and spatial raster layers representing the mobility and the boolean constraints were extracted from each grid resulting in a dataset consisting of approximately 343 individual grid for each of the var-

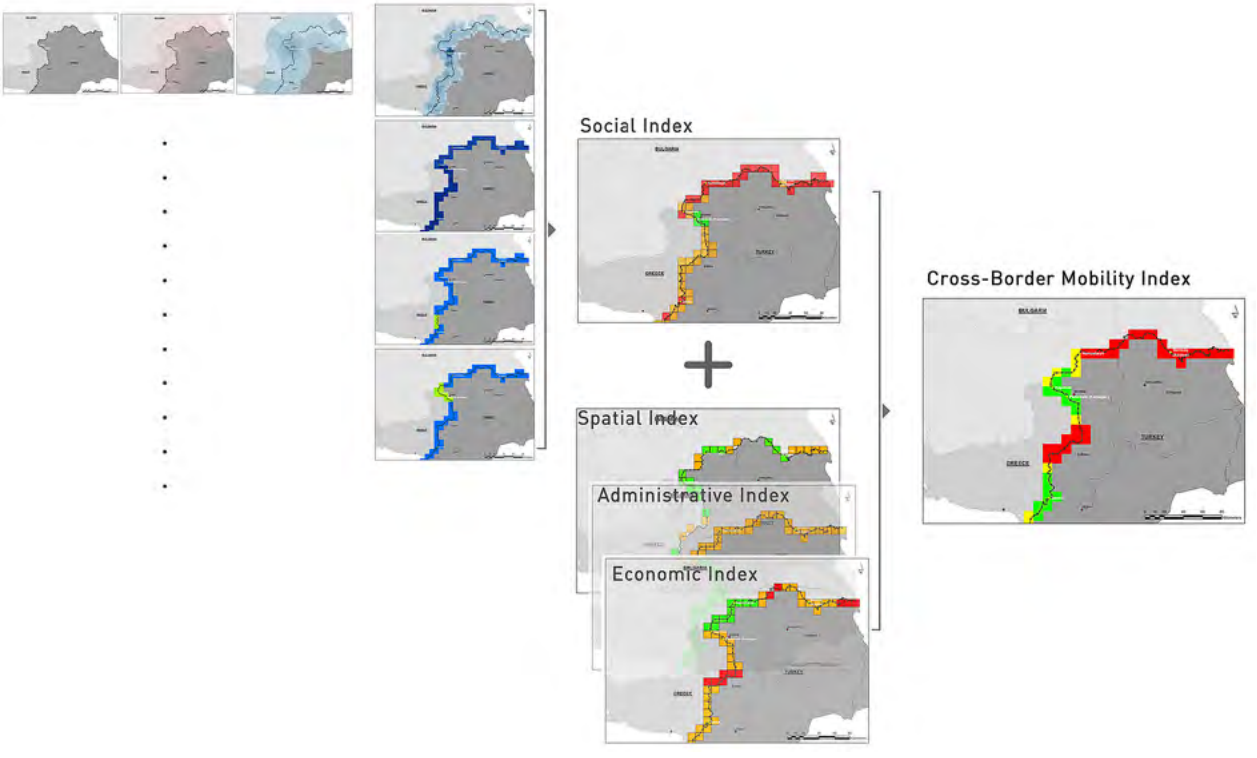

Figure 5. The process of obtaining multivariate socio-spatial cross-border mobility index

iables. Thus mobility values were standardized to a common scale between 0 and 1 using fuzzy membership functions.

The effectiveness of the proposed model is based on the principle of fuzzy logic which uses proper membership function on each of the cross-border mobility variables instead of giving individual rank to them. Thus, fuzzy logic is used for reclassifying and transforming each border mobility layer to a common scale.

Results & Discussion

The proposed cross-border mobility model provides an integrated measurement of mobility levels for borderlands, and it also provides separate information on mobility levels of economic, social, administrative and spatial aspects of the border region. In this framework, three cross-border mobility classification levels were defined and presented as low mobility, medium mobility and high mobility levels in order to simplify the results of the study. The standardized approach derived from the combined index methodology reveals cross-border mobility levels of state border regions in an economic, social, administrative and spatial manner.

Figure 6 demonstrates the economic, social, administrative and spatial cross-border mobility levels separately and also gives the total cross-border mobility level of the Turkish borderlands. When the mobility maps are evaluated in three categories of low, medium and high mobility levels, it is seen that the mutually agreed border policies and the level of political relationships of the countries have a significant effect on cross-border mobility. The implemented foreign policies between countries differentiate the economic, social, administrative and spatial interaction levels.

For a detailed observation hypothetically for each grid, the highest level of the total cross-border mobility would be 1, if the grid got the value of 1 from all the 22 variables.

However, in the analyzes, none of the 10x10 km grids are found to be fully dynamic. Accordingly, the most dynamic grid gets a mobility value of 0.47 while the least get 0.04. The total cross-border mobility level by countries, the number of grids by the country borders and the average mobility values by countries are listed in Table 1. Accordingly, the Nakhchivan border has the highest cross-border mobility in terms of the average boundary mobility values. The lowest mobility level is in the Armenia border because of the inactive border crossing.

Table 1. Permeability rankings by country

Country	Total Cross-Border Mobility Level	Number of Grids	Mean Mobility
Nakhchivan	0,38	1	0,38
Iran	17,3	62	0,28
Greece	6,33	23	0,28
Syria	29,38	111	0,26
Georgia	8,59	35	0,25
Iraq	10,37	47	0,22
Bulgaria	5,16	26	0,20
Armenia	5,98	38	0,16

When each axis of economic, social, administrative and spatial is considered separately, the highest cross-border mobility values are observed in social (0,69), spatial (0,64), economic (0,60) and administrative (0,54) axes respectively. In the covariance matrix, it is observed that there is an inverse relationship between spatial and social mobility levels (Table 2).

In areas with high spatial border mobility, social mobility indicator values tend to be low; in areas with

Table 2. Covariance matrix

	Economic	Social	Administrative	Spatial
Economic	3,578190e-004	2,066561e-006	5,911725e-005	1,515355e-005
Social	2,066561e-006	5,988344e-004	5,451609e-005	-5,779285e-006
Administrative	5,911725e-005	5,451609e-005	5,189675e-004	1,009887e-005
Spatial	1,515355e-005	-5,779285e-006	1,009887e-005	3,979517e-005

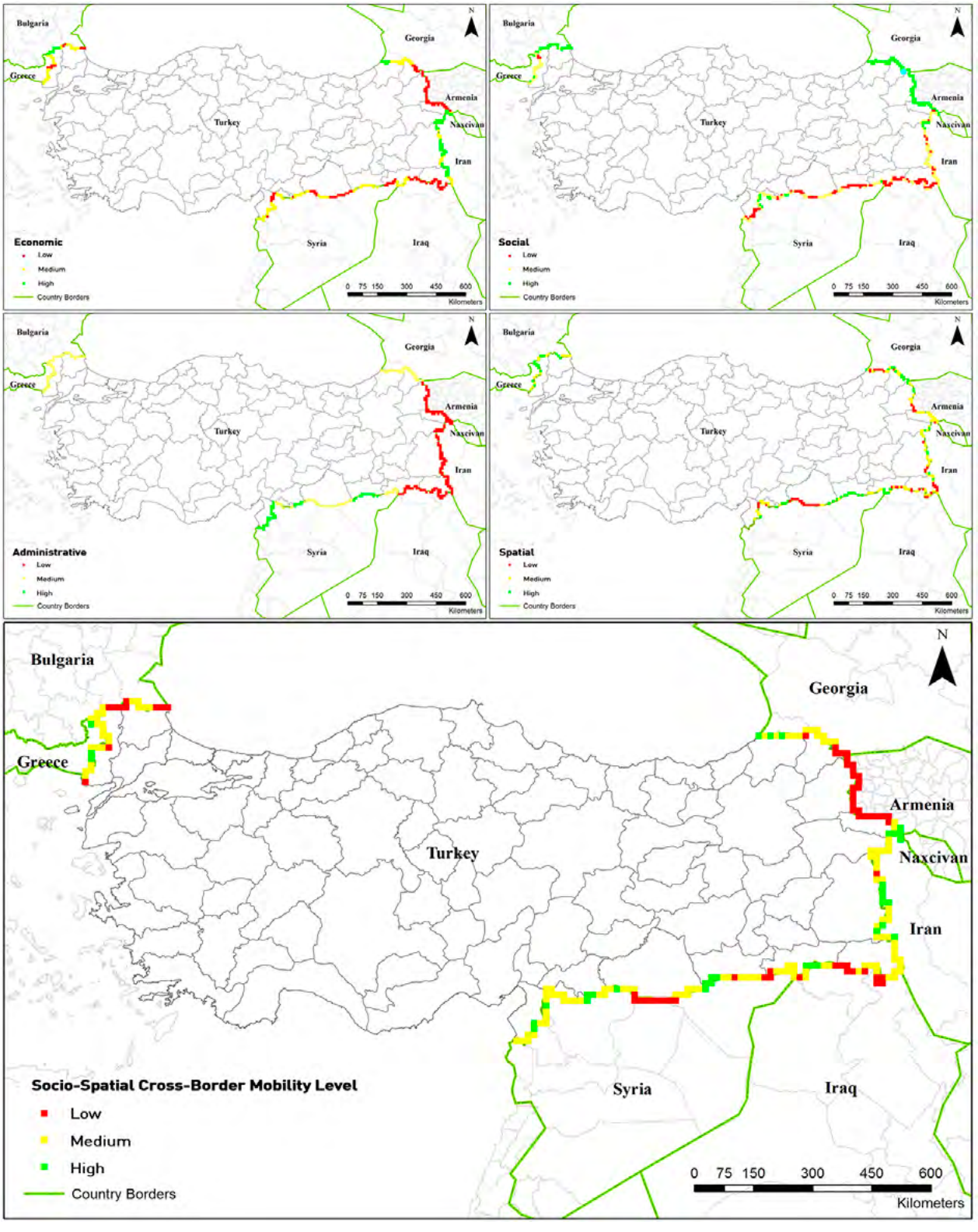

Figure 6. Cross-border mobility maps of the Turkish borderlands

high social mobility, spatial mobility values tend to be low. Examples of this inverse relationship are observed in the minefields adjacent to the border region with Syria that carry the characteristics of artificial barriers and low permeable areas. It is revealed that the minefields in the border regions do not directly affect social permeability in that region. On the contrary, these areas with low spatial mobility levels, have high social mobility levels.

In the correlation matrix, it is observed that the links among the whole axes are close to 0, which indicates that there are no strong connections among the

Table 3. Correlation matrix

	Economic	Social	Administrative	Spatial
Economic	1,00000	0,00446	0,13719	0,12699
Social	0,00446	1,00000	0,09779	-0,03744
Administrative	0,13719	0,09779	1,00000	0,07027
Spatial	0,12699	-0,03744	0,07027	1,00000

axes. This makes it difficult to estimate the direction of one axis by looking at the direction of the other axis (Table 3).

While the cross-border mobility increases around the border gates, it decreases in borderlands where geographical thresholds are high, population density is low and transportation infrastructure is limited. On the other hand, the level of mobility around inactive border gates is not 0, which indicates that it is not the border gates only that increase or decrease the permeability values on their own, but other different socio-spatial relations that affect the cross-border mobility level.

In the total socio-spatial cross-border mobility, the regions with the lowest mobility are Iraq, Armenia and some parts of the Bulgarian border, mainly affected by spatial and administrative variables. The low mobility zone at Syrian border is located along the borderline with minefields, which appears as a spatial barrier for cross-border passages. On the other side, for Armenia border, the low levels of mobility is because of the inactive border gates and no border crossings because of the distant political relationships. When the axes are evaluated separately; for the economic axis, the lowest mobility is on Armenia border and the highest mobility is on Iran border around Kapıköy border gate. For the social axis, the lowest mobility is on Armenian and Georgian borders and the highest mobility is on Iraq border. For the administrative axis, the lowest mobility is on Iraq and Armenia border and the highest mobility is on Syrian border. According to spatial mobility indicators, it is difficult to generalize for the entire borderline where cross-border mobility is affected at the point level data. Consequently, these cross-border mobility levels help to understand the socio-economic and spatial interaction levels in different borderlands that give clues for the policymakers to develop foreign relationships accordingly.

Conclusion

This study reveals the cross-border mobility among neighboring countries, based on a multidimensional approach, including the economic, social, administrative and spatial relationships, rather than a one-dimensional approach addressing solely the security issues. Thus, by using 22 different variables derived from theoretical and practical studies, four different types of sub-groups including economic, social, administrative and spatial components are achieved. Fuzzy membership functions are used in the normalization and standardization of the data sets. The concepts of fuzzy logic used in connection with the fuzziness contained by the border regions also correspond to the nature of the concept of cross-border mobility. Four different indices obtained from the analyses address different dimensions of border mobility, which is important in terms of allowing the decision makers to understand cross-border relationships in holistic manner.

The study makes two key contributions, both conceptually and methodologically. The conceptual contribution relates to propose cross-border mobility modeling and redefine the border mobility. It provides clues on how the socio-economic and socio-spatial dynamics can be treated without considering the borders of the countries, which politically/artificially divide the socio-spatial structure of the whole region. Besides, it clearly indicates which neighboring regions converge to each other or which of them diverge from each other along the borderline. Thus, it provides clues on how to see the borders and how to shape the regional and national level policies with the neighboring countries by considering the cross-border mobility of the border regions from a holistic perspective. This can help the establishment of cross-border multi-level governance policies including actors related to the border region.

The methodological contribution is related to measuring the cross-border mobility level by a more comprehensive and flexible set of indicators, instead of solely security-oriented indicators. It develops an innovative composite index methodology for a comprehensive understanding of socio-spatiality of border regions, which have various levels of interactions. The pillar of the methodological contribution is the spatialization of socio-economic data by means of upscaling and downscaling, and the use of fuzzy logic in the reclassifying and standardizing of data. The index can be utilized as a model for

other border regions to assess the cross-border mobility of the nation-state borders via the socio-spatial approach and fuzzy logic methods in GIS. It can be used for comparing the characteristics of border regions, or for estimating future developments following the same method and the same set of variables by using the computational procedures. The four different sub-indices obtained here demonstrate different dimensions of the border mobility separately. The integrated multivariate socio-spatial index, obtained from the total of the four indexes by using the SAW method is important in terms of providing an insight into the whole picture of cross-border relationships, which can be interpreted by nation-states on a country-by-country basis.

Acknowledgment

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Attitudes among Geography Teachers in Bosnia and Herzegovina toward Geospatial Technology Use: Gender, Age and Regional Differences

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Abstract

The use of geospatial technology at lower levels of education has become a global tendency. However, Bosnia and Herzegovina is a country that is virtually uncharted in this regard, and the present paper has the main purpose to change that fact. Results of a survey conducted among geography teachers place this country within the entry category. Different attitudes among various groups of teachers (based on gender, age and regional distribution) have also been tested. Although the general hypotheses could not be confirmed, certain specific differences have been found, such as in the use of virtual globes, theoretical knowledge of GIS and willingness to attend educational training courses.

Keywords: geospatial technology; GIS; geographical education; geography teachers

Introduction

In the 21st century, school geography should be understood in its wider context as part of an overall education that must have a contemporary character and be able to respond to the challenges of the present and the future alike. In that regard, certain global trends also relate to geography itself (Kerski, 2015). Technological progress has resulted in a revolutionary change in education. This applies in particular to the computerization and digitalization of teaching and learning processes (Donert, 2014; Karolčík et al., 2016). It seems to be unambiguous that, in teaching geography, computer technology plays a particularly important role in terms of visualization of geographic contents in a given area (Jo et al., 2016), but also in terms of modelling some general phenomena and processes. The focus on the need to replace those strictly traditional approaches taken to the education process where the student occupies a mere passive position, with a move toward active and critical geography (Macía Arce et al., 2017), has encouraged the introduction of a Geographic Information System (GIS) and other types of geospatial technologies in the education system (Çepni, 2013; Metoyer & Bednarz, 2017). Besides GIS, geospatial and geoinformation technologies also require the use of dynamic and interactive maps, virtual globes, remote sensing, GPS, and other devices for augmented reality (Baker et al., 2015; Kerr, 2016; Stojšić et al., 2019).

Despite many advantages and opportunities that GIS provides to the lower levels of education (primary and secondary), the progress made in the field of promoting the use of geospatial technology in classrooms on the global level is pretty slow. Even many highly developed countries, which have the potentials to invest sizable funds in education, have faced obstacles and a number of aggravating factors in this process, which is why the use of modern geotechnological resources in geography and other school subjects

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has not yet reached the desired level (see Höhnle et al., 2016). First steps in the application of this kind of technology in geography teaching were made in 1990s, when the number of studies undertaken on this topic have also seen a more significant level of increase. Anđelković and Pavlović (2015) have classified all scientific studies conducted in this field into three main periods, with critical years of 2000 and 2010 separating them. In the current stage, the interest in the educational dimension of GIS was expanded to cover all continents and a large number of different countries (Kerski et al., 2013). However, over the last two decades, regional disparities in its implementation level have become increasingly evident, and thus this issue has attracted attention of some researchers (Bednarz & Van Der Schee, 2006; Höhnle et al., 2011; Yuda et al., 2009;).

Kerski et al. (2013) have divided countries into the following three categories, based on the level of their GIS use in secondary education (which could be extended to primary schools too): entry, adoption and invention. In general, the invention category includes highly developed countries, which have a long history of implementation of innovative teaching methods and technologies. Finland is a great example of substantial progress made in this field (Johansson, 2003; Riihelä & Mäki, 2015). Taiwan, where 84% of geography teachers have used GIS technology in the classroom (Lay et al., 2013; Wang & Chen, 2013), also deserves to be mentioned as a country that applied a highly successful strategic model in geographical education. On the other hand, there is a wide variety of countries where GIS is used only by enthusiasts among teachers, while majority of them do not have the skills and know-how required for its application. As a rule of thumb, these countries belong to the so-called entry category. Besides Africa, Latin America and some regions of Asia, most of post-socialist countries in Europe also fall within this category. However, considering the fact that it reached the adoption/development stage, Czech Republic stands out as a significant exception (Král & Řezníčková, 2013; Svatonová & Mrázková, 2010), which holds true to some extent for Hungary too (Bartha, 2010; Czigány et al., 2018). Generally, the education systems of post-socialist countries suffer from a number of negative consequences of socioeconomic transition and the slow process of adopting new innovative approaches, which is why the case study of Bosnia and Herzegovina should be considered in this light.

Among all of the post-socialist countries, Bosnia and Herzegovina has suffered the gravest consequences of the transition process, since it was engulfed into the flame of a fierce armed conflict, which took place in the period between 1992 and 1995. The war ended with the Dayton Peace Agreement, which resulted in the creation of a highly complex and dysfunctional administration apparatus in the country, which, in addition to a wide range of already existing socioeconomic problems, has had a negative impact on education as well. In essence, there are three basic types of curricula, which are largely built on ethnic foundations and then additionally modified in each of its administrative subdivisions. The said circumstances have also made the introduction of geotechnologies into the classrooms rather complex. GIS technology first appeared in Bosnia and Herzegovina only after 2000, when it gradually began to find its place in some government institutions, agencies and private companies. In higher education, GIS was initially introduced in 2005 at the University of Sarajevo (Department of Geography), when the students were enabled to use the ArcGIS software. On the other hand, the introduction of GIS technology into lower levels of education has not been implemented to any significant extent yet (Drešković & Avdić, 2017). Therefore, this study aims at examining the attitudes of Bosnia and Herzegovina's geography teachers towards geospatial technologies and the possible differences among them, which could be of potential significance for creating any future strategies for geographical education.

Hypotheses

Together with the global GIS expansion in overall education, the need for research support in this field has also become quite recognizable (Baker et al., 2012). In order to find a solution to this matter, a group of authors created a research agenda for geospatial technologies and learning (Baker et al., 2015). One of the main issues that came into focus of this agenda was the requirement for further professional development of geography teachers in the field of geospatial technologies. At an earlier point at the beginning of this century, a research agenda for cognitive and usability issues in geovisualization was made by another group of authors (Slocum et al., 2001). Individual and group differences have here been defined as one of the major research themes within the scope of the above studies. It was argued that it is fully inappropriate to see the users of geovisualisation as a homogeneous group, since there is an immense number of variables that could have a bearing upon a person's ability to work with this kind of methods, such as their expertise level, culture, sex (gender), age, education, socioeconomic status, etc. By combining and analyzing all these papers in the context of professional development of geography teachers in Bosnia and Herzegovina, it seems to be reasonable to examine any potential differences identified among these teachers in terms of their gender, age and regional distribution.

Gender-based differences in terms of affinity toward computer technology, as well as in terms of their geographical and spatial skills were more pronounced in the older studies, which show that females were usually being outperformed by males (Busch, 1995; Montello et al., 1999). However, some more recent studies indicate that there is a steady trend of reducing this gender gap (Colley & Comber, 2003), especially regarding the differences among teachers in how they are able to cope with the educational technology (Sang et al., 2010). Some authors attribute this to the expansion of web-based learning (Clark et al., 2007; Crocco et al., 2008) and the laptop effect (Kay, 2006). Although male teachers still perform better in certain aspects of computer use (Meelissen & Drent, 2008; Stephens, 2013) or spatial thinking (Shin et al., 2016), the general results in this field of study could be understood as mixed, due to a number of studies where such differences were not found (Lay et al., 2013; Teo, 2008). The use of GIS was also discussed from the point of view of feminist geography (Kwan, 2002; Sharp, 2005).

Along with the gender factor, many studies have also tried to explore the age differences in terms of computer technology use (Afshari et al., 2009; Mead et al., 1999;Schubert et al., 2012). Results usually show that younger teachers tend to be more comfortable with the use of computers and geospatial technologies, such as GIS in particular (Kim et al., 2011), but this does not necessary mean that they are using them more often in the classroom compared with their older and/or more experienced colleagues (Russel et al., 2003). In the present study, the age of 43 is taken as the critical age drawn as a clear cut-off line between the younger and older groups of respondents, which is based on the sample's mean and median values.

Regional differences between geography teachers could be anticipated to arise as a result of urban-rural differentiation between certain spatial units. Compared with the predominantly rural areas, the regions with higher levels of urbanization usually have the more favorable socioeconomic conditions that are conducive to a higher degree of overall progress, including a higher level of technological modernization of the educational process itself (Howley et al., 2011). However, information technologies can be seen as an efficient tool used to overcome some education issues in remote rural areas (Arnold et al., 2005). As far as the case study of Bosnia and Herzegovina is concerned, it seems like an obvious choice to take Sarajevo Canton and Central Bosnia Canton as statistically most representative regions. These two cantons have been selected on account of regional disparities between them, as well as on account of the fact that they are sufficiently large to enable the taking of an adequate sample of geography teachers. Sarajevo Canton is the most densely populated and most economically developed part of Bosnia and Herzegovina, with an urbanization rate of 86% according to the latest 2013 Population Census statistics. On the other hand, Central Bosnia Canton is one of the most prominent rural regions in the country with an urbanization rate of only 30% and none of its towns has more than 20,000 inhabitants.

Having in mind the above circumstances prevailing in Bosnia and Herzegovina and worldwide, but also the current trends in research concerning the educational use of geospatial technologies, it seems appropriate to put forward the following three main hypotheses in this study:

1. There are significant gender-based differences among geography teachers in terms of the respondents' affinity towards geospatial technology in a representative sample;
2. There are significant age-based differences among geography teachers in terms of the respondents' affinity towards geospatial technology in a representative sample;
3. There are significant regional distribution differences (urban vs. rural) among geography teachers in terms of the respondents' affinity towards geospatial technology in a representative sample.

Methodology

In order to explore the perceptions and attitudes among the geography teachers about the use of geospatial technology in the education process, this study was designed in the form of survey, as the most effective and conspicuous method. In this case, the survey was conducted on a voluntary basis immediately after the lectures were delivered about the use of GIS and geospatial technologies, which were otherwise an integral part of the regular teachers' professional development training courses held during 2018 in each canton separately. The survey included a total of 83 respondents, but since one of them failed to answer the majority of the questions, the total number of respondents taken into account in the sample was reduced by one (n = 82). The sample included geography teachers from Sarajevo Canton (51 teachers) and from Central Bosnia Canton (31 teachers). It covered more than one half of the geography teachers in both regions. Most of the surveyed teachers work only in elementary education (78%), of whom approximately

55% teach geography only, while the rest of them also teach some other school subjects in addition to geography (mostly history).

Table 1. Sample structure

Male teachers	28
Female teachers	54
Younger teachers (under 43 years)	38
Older teachers (43+ years)	38
Teachers of unknown age	6
Teachers from Sarajevo Canton (predominantly urban region)	51
Teachers from Central Bosnia (predominantly rural region)	31
Total sample size	82

The survey was conducted by using a set of printed questionnaires, which were disseminated to all participants of professional training. Although it was anonymous, the survey required from the respondents to provide their basic demographic information, such as gender, age and work experience. Information about the region (canton) where they are employed as teachers was coded instantly by the researchers. The main part of survey was focused directly on the teachers' affinities and practices regarding the educational use of geospatial technologies, such as GIS in particular. It consisted of 23 close-ended questions, 16 of which included items from a linear 5-point Likert scale, and it was used for the purpose of testing the previously made hypotheses.

The results obtained in the survey were processed by using the required descriptive and inferential statistics. The descriptive results are reflected primarily in the percentage share of the selected options. With regard to the questions that included the Likert items, the arithmetic mean ($\bar{x}$) was also calculated. The Likert items were quantified within the usual range of evaluation scores, where the most favorable answer in the context of the modernization of geographical education scored 5 points, and the least favorable 1 point. An equal point interval was established within the range of the five responses on the scale. The descriptive analysis in this study provides a general overview of the current status concerning the modernization of geography teaching in Bosnia and Herzegovina, including the predispositions for implementation of GIS-based concept at the primary and secondary level of education.

Inferential statistics methods are used to test the hypotheses and make an analysis of differences in the responses among different groups of respondents. For that purpose, two-tailed Student's t-test has been used as the tool for computing the statistical significance of the difference between the parameters inferred from the data set. Although there are major differences in the views about the reasonable choice of an adequate statistical method for inferential analysis of the data collected through the Likert scale, the t-test proves to be a fairly common and reliable statistical test used for this particular purpose (De Winter & Dodou, 2010). In this research study, the test was conducted with regard to the mean values calculated by taking into account the answers received from a range of different respondent groups that were interpreted on the basis of the their gender, age and region. Thus, the differences were tested on the basis of the existing independent variables in accordance with each individual question, which in this sense could be regarded as a measure for making a separate sub-hypotheses. However, for the purpose of examining the previously established general hypotheses, the next step was to calculate the mean of the mean values for each individual respondent's answer within the same group variable. The values calculated in this way were then tested with the Student's t-test, where the p-value indicates the statistical significance of their differences by the standard margin ($\alpha = .05$).

Results

Out of the total number of the surveyed teachers, about 78% of them were able to say with certainty that they have heard about GIS before. Those who at least have some basic knowledge of the subject have indicated that they learned about it mostly in the first decade of this century, particularly after 2005, which coincides with the introduction of GIS technology in higher education at the University of Sarajevo. The highest number of the respondents have pointed out that they gained the initial knowledge of GIS through their professional education (30%) or their university studies (29%). However, only 17% of the teachers have had the opportunity to learn a bit more about GIS during their studies. Approximately the same percentage of the respondents have had a direct contact with GIS technology so far, while 11% of the surveyed respondents have had one of the GIS software packages installed on their own computers. According to the answers collected from them, some kind of GIS software is currently available in only 6% of schools.

In addition to the basic information, the following Likert items-based questions have provided a clearer picture of the practices and affinities of the teachers regarding GIS technology and other forms of geotech-

nological innovation in the teaching process. Over 80% of the respondents have circled the lowest level option for their own theoretical knowledge of GIS, the skills of using it, as well as the skills to use it in the classroom. However, it is encouraging to note that 78% of them have mentioned GIS to their students at least once during their lectures so far. On the other hand, only 18% of the surveyed teachers (n = 55) are recorded to have used GIS for teaching preparation at least once, 21% (n = 57) as a means of demonstration in the classroom, and only 14% (n = 57) have enabled their students to use GIS. It is worth noting that in these questions the sample size was reduced, since a significant number of responses had to be removed from the aggregate results due to an inconsistency with some previous responses, which is probably due to the lack of understanding of the main point of these questions on the part of the respondents.

The answers were more favorable to some extent when it comes to other types of modernization in geographical education. This applies to the fieldwork, the use of virtual globes such as Google Earth, other geovisualization softwares, and GPS. Opinions regarding the future development could be reported as fairly positive. The vast majority of the respondents (86%) have expressed an interest in attending educational workshops on the utilisation of GIS in geography teaching, and almost half of them have expressed a particular desire for it. Also, 73% of teachers are planning to use GIS in the educational process in the future. Over 80% of them agree that GIS should be introduced into geography education on the secondary school level, while somewhat lower value of the responses has been found in the context of primary education and extracurricular activities.

This Likert items-based group of questions is also considered within the framework of inferential statistics. Regarding the first hypothesis, the t-test analysis was focused on gender differences. To as many as 12 out of 16 questions from this group, the male teachers gave more favorable answers, but a statistically significant difference was found only in three cases. It was thus established that the male teachers evaluate their level of theoretical knowledge of GIS as significantly higher compared with their female colleagues ($t = 2.147$, $p = .037$). They also mention GIS more often in the classroom ($t = 2.750$, $p = .008$) and use virtual globes ($t = 3.268$, $p = .002$) in lessons more frequently. On the other hand, the female teachers are more likely to believe that the use of GIS technology should be part of geographical education, which refers in particular to geography in secondary schools ($t = -2.199$, $p = .034$). Taken overall, in line with the generally required level of statistical significance ($\alpha =$

Table 2. Results of five-point Likert items based questionnaire on teachers' practices and attitudes towards geospatial technology

Questions	n	1(%)	2(%)	3(%)	4(%)	5(%)	$\bar{x}$	SD
Theoretical knowledge about GIS	81	56.8	17.3	24.7	1.2	0.0	1.70	0.89
Skills of using GIS technology	81	58.0	17.3	23.5	1.2	0.0	1.68	0.88
Skills of using GIS technology in the teaching process	81	58.0	19.8	21.0	1.2	0.0	1.65	0.85
Frequency of mentioning the GIS in the teaching process	79	21.5	39.2	34.2	5.1	0.0	2.23	0.85
Frequency of using GIS for preparation of the teaching process	55	81.8	5.5	7.3	5.5	0.0	1.36	0.85
Frequency of using GIS as a demonstration aid in the teaching process	57	78.9	10.5	5.3	3.5	1.8	1.39	0.88
Frequency of giving opportunity to students to use GIS	57	86.0	5.3	8.8	0.0	0.0	1.23	0.60
Frequency of using virtual globes in the teaching process	78	32.1	19.2	34.6	9.0	5.1	2.36	1.17
Frequency of using other geovisualization softwares in the teaching process	79	25.3	30.4	38.0	2.5	3.8	2.29	1.00
Frequency of conducting the fieldwork with students	79	11.4	29.1	39.2	16.5	3.8	2.72	1.00
Frequency of using geolocation technology in the teaching process	79	38.0	30.4	24.1	6.3	1.3	2.03	1.00
Attitude towards future use of GIS in the teaching process	80	2.5	2.5	22.5	45.0	27.5	3.93	0.91
Interest for attending GIS educational training	81	1.2	3.7	8.6	38.3	48.1	4.28	0.87
General attitude towards introduction of GIS in the primary schools	81	1.2	4.9	19.8	42.0	32.1	3.99	0.92
General attitude towards introduction of GIS in the secondary schools	78	1.3	2.6	14.1	37.2	44.9	4.22	0.88
General attitude towards introduction of GIS in the extracurricular activities	80	0.0	2.5	25.0	51.3	21.3	3.91	0.75

Table 3. Mean values ($\bar{x}$) for different groups of geography teachers

Questions	Gender differences		Age differences		Regional differences	
	Male	Female	Younger	Older	Urban	Rural
Theoretical knowledge about GIS	2.00*	1.55	1.74	1.57	1.82	1.52
Skills of using GIS technology	1.89	1.57	1.71	1.59	1.76	1.55
Skills of using GIS technology in the teaching process	1.82	1.57	1.79	1.46	1.68	1.61
Frequency of mentioning GIS in the teaching process	2.57*	2.04	2.32	2.11	2.43*	1.90
Frequency of using GIS for preparation of the teaching process	1.42	1.33	1.38	1.38	1.34	1.40
Frequency of using GIS as a demonstration aid in the teaching process	1.40	1.38	1.48	1.33	1.34	1.47
Frequency of providing students with the opportunity to use GIS	1.30	1.19	1.21	1.28	1.22	1.25
Frequency of using virtual globes in the teaching process	2.93*	2.04	2.50	2.18	2.59*	1.97
Frequency of using other geovisualization softwares in the teaching process	2.61	2.12	2.34	2.20	2.24	2.37
Frequency of conducting the fieldwork with students	2.96	2.59	2.84	2.57	2.80	2.60
Frequency of using geolocation technology in the teaching process	2.29	1.88	2.13	1.86	1.94	2.17
Attitude towards future use of GIS in the teaching process	3.93	3.92	4.03	3.86	3.94	3.90
Interest for attending a GIS educational training	4.21	4.32	4.55*	4.08	4.25	4.33
General attitude towards introduction of GIS in the primary schools	3.79	4.09	4.03	3.97	3.88	4.17
General attitude towards introduction of GIS in the secondary schools	3.88	4.38*	4.16	4.29	4.16	4.32
General attitude towards introduction of GIS in the extracurricular activities	3.93	3.90	3.89	3.94	3.90	3.93

** Values that are significantly higher than those from the comparative group (α = .05)*

.05), the first hypothesis about the existence of significant difference between the male and female geography teachers could not be accepted (t = 1.332, p = .191), despite the confirmed disparities that have occurred with regard to several indicators specified in some of the above parameters.

Compared with the case of gender, the age-based differences among the teachers concerning the use of GIS and other geospatial technologies have been proven to be even less significant. Somewhat more affirmative answers to the majority of the questions have been provided by the teachers in the younger age group (under 43 years), but a significant difference has been identified in only one case. Specifically, the existence of a considerably higher level of interest in attending GIS education workshops (t = 2.611, p = .011) has been recorded among the teachers in the younger age groups. On the other hand, the answers to certain other questions have revealed some surprising results. Thus, for example, to some extent the older teachers tend to believe more often that GIS technology should become an integral part of secondary education and extracurricular activities. Ultimately, the second hypothesis that the younger teachers have more positive attitudes towards the introduction of geospatial technologies into the classroom could not be confirmed (t = 1.023, p = .308).

The third hypothesis was tested by using the same questions as those formulated in the previous cases, but this time in the context of a comparison made between Sarajevo as a predominantly urban region and Central Bosnia as a predominantly rural region. Contrary to expectations, to some extent the teachers from the Central Bosnia region have responded more favorably compared to their colleagues from Sarajevo Canton. However, a statistically significant difference has been recorded in the responses to two specific questions, where the recorded values were higher for the group of teachers coming from the urban region. It was found that the geography teachers from Sarajevo tend to mention GIS more often during their classes (t = 2.881, p = .005) and they use virtual globes in teaching more frequently (t = 2.546, p = .013). However, due to the very mixed answers to the remaining questions, there has been no confirmation of the general hypothesis that the geography teachers from Sa-

Table 4. Inferential statistics (t-test) for general (null) hypotheses

Hypotheses		$\bar{x}$		t	d	p
H1	General gender differences	Male	Female	1.322	0.32	.191
		2.76	2.57			
H2	General age differences	Younger	Older	1.023	0.25	.308
		2.70	2.56			
H3	General regional differences	Urban	Rural	0.821	0.20	.418
		2.67	2.57			

rajevo Canton, as an urban region, have a greater affinity for the use of geospatial technologies compared with their colleagues who come from Central Bosnia ($t = 0.821$, $p = .418$).

Discussion and conclusions

Since this is the very first study of its kind conducted in Bosnia and Herzegovina, it is also one of the pioneer studies in the field of geospatial technologies use in education in the Southeast Europe. Its main purpose was to assess the situation in the country's primary and secondary schools regarding the place that geospatial technology occupies in geography education, with a special focus on the conditions for the implementation of the GIS concept. Its results indicate that there are generally unfavorable conditions for GIS integration into the teaching process, since a vast majority of geography teachers have never used such software at all. Even among those who have had an opportunity of using it, there are only a few enthusiasts who have actually introduced it into the classroom. These findings are comparable with those reported in some of the neighboring and adjacent countries, such as Serbia (Komlenović et al., 2013), Turkey (Demirci, 2009), Greece and Hungary (Bartha, 2010), as well as in some of economically less developed countries in other regions, such as Rwanda in Africa (Akinyemi, 2016). This survey has confirmed the assumption that Bosnia and Herzegovina belongs to the entry category according to the classification suggested by Kerski et al. (2013). There are parallels also with some early findings from the countries that are now considered to be part of the invention category, such as the USA and Finland (Johansson, 2003; Kerski, 2003). For countries like Bosnia and Herzegovina, the experience these countries have gained in the process can be used as a path to follow. In this regard, it is worth noting that a vast majority (86%) of the surveyed teachers have expressed willingness to attend eventual forthcoming educational training workshops or sessions organized on the topic of GIS use in education. Also, the fact that other forms of geospatial technology (such as virtual globes or other forms of educational software) have already been used by many teachers in geography classes, can be regarded as a significant step forward towards an efficient modernization of the teaching process.

The concept of learning and teaching through GIS appears to be a novelty for teachers in Bosnia and Herzegovina, for both those coming from the younger and those from the older age groups. The same applies to regional differences. This fact undoubtedly explains why neither of the three general hypotheses in this study could be confirmed. Due to the absence of any significant difference in the general average score between the male and female respondents, the conclusion that gender does not play any further direct role in terms of the teacher's attitudes towards information technology (Sang et al., 2010) can be supported by this study. On the other hand, in a more specific context, it is found that the male teachers have demonstrated a significantly higher theoretical level of knowledge about GIS (or at least they claim so) and that they mention GIS more often in their classes. The male teachers have also claimed that they use virtual globes, such as Google Earth, more frequently than the female teachers in the sample. This finding is consistent with Stephens's (2013) study on GeoWeb applications. Another finding is that virtual globes are used significantly more often in the classes by the teachers from urban regions too. These findings about virtual globes, along with a relatively high value of standard deviation, have made this particular question a very reliable parameter for measuring the discrepancies in terms of modernization of geographical education in Bosnia and Herzegovina. Unsurprisingly, the only age-related difference that has been found to be significant in the respondents' attitudes is their willingness to attend professional training designed for the purpose of GIS use. Similarly, Kim et al. (2011) have also reported that younger teachers in South Korea are more likely to participate in this kind of activities.

There are numerous recommendations in other studies about how to make progress in the imple-

mentation of GIS approach in geographical education on the primary and secondary level. Many authors have emphasized the importance of teacher training, which is one of the external conditions that need to be met in order to encourage and support any further development of this educational concept (Bednarz & Van Der Schee, 2006). Pre-service teacher geography and GIS intervention (Collins & Mitchell, 2019), as well as sustained quality professional development for in-service teachers (McClurg & Buss, 2007) are suggestions that can serve as the guiding principles in the achievement of the main goals in this and many other education fields. However, in the countries that are facing multiple organizational and financial problems, such as Bosnia and Herzegovina, the efforts to turn those kinds of plans into reality could be undermined by a number of challenges encountered in the process. Therefore, an optimal strategy should be to take a step-by-step approach. Extremely ambitious instant and ready-made projects, such as the immediate introduction of complex GIS softwares into education practice would probably result in resistance and rejection by the majority of teachers and thus ultimately fail. The present study shows that there are teachers who already use some type of geospatial technologies actively in their teaching process. Their experience should be used to encourage other teachers to follow suit perhaps even through peer-coaching. As far as GIS is concerned, the first step should be to enable the teachers to learn more about it, before using GIS as a standard teaching tool. A great interest expressed in the study by the teachers, particularly those of younger age, in attending GIS training workshops is extremely promising. However, the concept of such activities should be designed carefully, in order not to deter the study participants from using this technology in education.

In a broader context, this research should be understood as the first step towards reviewing the overall situation concerning the teachers' perspective on integration of geospatial technologies in geography teaching in Bosnia and Herzegovina, but also throughout the Southeast Europe. Namely, all countries in this region share a similar history of education development and face similar challenges in the current situation. Therefore, it would be both interesting and beneficial to make a number of comparative studies of this type in other countries as well, which would establish certain regular patterns in the general degree of efficiency of the modernization of geographical education in the transition countries. Of course, the requirement would also be to extend the regional scope of research across Bosnia and Herzegovina, since this study has covered only two emblematic regions rather than the entire country. On the other hand, some follow-up studies should be focused more specifically on those geography teachers who have already made certain progress in terms of application of new teaching strategies based on geospatial technology.

As far as the limitations of the current study are concerned, it is worth noting that the survey has covered a convenience sample made of those geography teachers who have decided to participate in professional development workshops, and they have not been selected randomly. This fact could have a certain impact on the results. Equally, there is a great likelihood that some respondents have provided certain answers that were not thought out well, due to an excessive number of questions in the original survey. What is more, it appears that for many respondents GIS technology is still a completely unknown area, which is why some of the questions turned out to be confusing and baffling for them. Therefore, some further studies should take this concern into account, with the belief that such types of surveys will have a greater significance once a greater number of teachers gain an insight into some practical aspects of GIS (through educational training or otherwise). Also, there is need to extend future research to other regions in Bosnia and Herzegovina (and possibly neighboring countries), so that sample size would become more comprehensive and representative.

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Multimedia Teaching Effectiveness in Natural Science Teaching

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Abstract

The aim of this research is to examine the difference in the contribution of the created multimedia models and the traditional teaching to the quality and durability of the students' knowledge of geographical content at all cognitive levels in the fourth grade of the primary school (10-11 years). This research included a sample of 142 students, divided into two groups: E (experimental) and C (control). The students in the C group were taught in the traditional way and the students of the E group taught using the created multimedia models. The quality of students' knowledge was examined by a post-test, while the durability of knowledge was examined by re-test. Variations in knowledge on post-test and re-test in both groups were observed at cognitive levels. At a higher cognitive level (analysis), students were better at re- testing than at a post-test. In the application of geographic contents in the fourth grade, multimedia teaching (MT) should be given priority over traditional teaching (TT).

Keywords: science teaching; modern technologies; quality of knowledge; student achievement

Introduction

Changes resulting from technological development and the expansion of information resources are reflecting on to the everyday activities of people, and therefore to the teaching process, as well. Accordingly, it is necessary to harmonize the educational process with achievements in the field of technological development. A multimedia-enabled classroom allows the teacher to engage students in the teaching process and make them more active; this process is no longer based exclusively on teacher lecturing, but becomes supported by various media: books, magazines, audiovisual media, television and computers. Multimedia tools can then create a complete and effective learning environment (Mahajan, 2012). The subject content adopted in the initial education that the student did not understand, but only mechanically learned, is not considered as quality knowledge and does not ensure its durability. In order to make students fully use their own cognitive resources, they need to be motivated and this motivation is achieved through multimedia teaching (Park et al., 2015). Technology motivates teachers to experiment and implement new approaches to teaching and learning process (Donnelly et al., 2011), as confirmed by Ertmer et al. (2015), who believe that constructivist beliefs contribute to the use of modern technology in support to the development of desirable skills of the 21st century. Fortunately, the newer generation of teachers is more prepared for the implementation of modern information technologies, thus modernizing teaching and bringing it closer to the interests of today's students (Martinović & Zhang, 2012).

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Research Focus

Over the past two decades, numerous studies have been carried out to determine the effects of multimedia teaching on students' achievements, their motivation for the learning process, and the development of their research skills. Numerous authors (Bargezar et al., 2012; Lam & Tou, 2014; Mayer, 2003; Torres-Ramirez et al., 2014; Tudor, 2013) confirm their positive results by comparing teaching enriched by multimedia with traditional teaching process. The results of previous studies, which applied modern technologies into the teaching process, indicated significant positive effects and a high level of achievement of students who have studied with computers versus classical verbal-textual methods (Cheng et al., 2012; Hançer & Tüzemen, 2008; Khan, 2011; Park et al., 2015; Pinto et al., 2014; Wainer et al., 2015). These results support the assumption that computer education modernizes the teaching process, motivates students and contributes to their activation and better knowledge acquisition. This is in line with Mayer (2003) claim that learning by using computers and multimedia (images, animation and words) allows learners to easily understand the content. Computer animation is also a highly effective teaching tool in demonstrating a process that cannot be directly observed in a natural environment. Rosen (2009) with his conclusion that learning becomes more effective when animation is used in the teaching process also support this claim. Some researchers examined the effects of applying multimedia technology and found that the use of animated movies improves students' achievements (Han et al, 2013; Kaptan & Izgi, 2014). They can increase internal motivation for learning, while the grading process, as an external factor of motivation for students, is regarded as an alternate motivating factor. However, not all researchers agree that usage of multimedia in teaching-learning process provides only positive effects. While some authors argue that the lack of imagination in creating their own mental models is due to the use of multimedia in teaching (Schnotz & Rasch, 2005), others consider that multimedia (as a simplified vision of a phenomenon) can have negative effects as it can contribute to the creation of certain misconceptions, not based on scientific facts (Mayer, 2003). However, this conclusion was disproved by the results of the research conducted by Gürbüz and Birgin (2012) as well as Huang et al. (2008) which confirmed that the use of multimedia and computers in teaching is more effective than the use of classical methods of teaching in terms of removing student misconceptions.

Data and methods

The aim of this research is to determine the differences in the contribution of the created multimedia models and the traditional teaching to quality and durability of the students' knowledge of the geographical contents at all cognitive levels in the fourth grade of primary school.

In accordance with the research goal, the following hypotheses have been defined:

1. MT contributes to the higher quality of the student's geographical knowledge on higher cognitive levels than TT.
2. Students achieve longer-lasting knowledge at higher cognitive levels when geography lessons are taught with multimedia models.

Models were created for selected teaching units from the theme "Work, Energy, Production and Consumption". The classes in both groups were applied in duration of 12 school periods. In the C group classes were held in classical approach, based on the oral presentation of the teacher, the use of textbooks and worksheet. E group students studied the content using MT: with the help of presentations prepared for research, using existing video materials, but also with the help of games and videos recorded for research purposes, in order to better understand individual phenomena and processes. The presentations were full of photos that followed more detailed explanations, documentary films (for example, how to obtain rubber or glass), animated videos with a dose of humor were used that stimulated curiosity of students and made educational content more interesting. Some of the videos had a striking message and strongly influenced the students and contributed to them thinking about the impact of man on his own environment and the ways we could pollute it or the way we could change our current condition. Repetition lessons were organized through a quiz presented in a presentation with numerous effects and animations that contributed to a more relaxed atmosphere at a time so that the students did not even notice how much the material was revised and affirmed in that way. In E group students learned content using textbooks and worksheets as well.

Sample of Research

This study included 142 students of the fourth grade (10 and 11 years old) from two primary schools in Sombor, Serbia. Both groups had the same number of students (71 each), which were equal in their knowledge based on the pre-test results, average grades from the subject *Nature and Society*, and average grade of student's overall success at the end of the first semester of the fourth grade.

Instrument and Procedures

The research technique was testing, and the instrument was a test (pre-test, post-test and re-test). All three tests were designed by the author of this research. The maximum number of points on the test was 58 points. Each test had 18 assignments divided into six levels of knowledge according to the revised Bloom's taxonomy: knowledge, understanding, application, analysis, evaluation and creation (Andreson et al., 2001).

Data Analysis

Statistical analysis of the data collected during the research was performed using the SPSS software version 19.00, using the following statistical results: t-test independent samples, Mann- Whitney non parametric test, Levene's equality of variances test, analysis of the variance of repeated measurements and Wilks-lambda multivariate test.

Results

The obtained results showed that the E and C groups are uniform on all three variables. By analyzing pedagogical documentation, it was established that the average grade at the end of the first semester of the fourth grade in the C group is 4.44 and in the E group is 4.53; the average grade at the end of the first semester of the fourth grade from the relevant subject in the C group is 4.30, and in the E group is 4.51 (*in Serbia, a numerical assessment is applied where the numerical assessment is formed on the basis of a five-grade scale (1 - fail, 2 - sufficient, 3 - good, 4 - very good and 5 - excellent*).The difference between the overall school success rate in the fourth grade of both groups was tested by the Mann-Whitney U test. The results show that the value of Mann-Whitney U test is U = 2339.5 with p = 0.46 is not statistically significant. The difference between the students successes at the end of the first semester of the fourth grade is also tested by the Mann-Whitney U test. The results show that the E and C groups do not differ in overall school achievement and achievement from the relevant subject at the midterm of the fourth grade.

Pre-test

The Cronbach Alpha pre-test coefficient is 0.81. The value of Levene's equality of variances test (Table 1) is statistically significant ($p = 0.03$, $p < 0.05$), which suggests that variance of the subpopulation in the sense of the dependent variable is non-homogeneous. After the initial testing, it was confirmed that the C and E groups were equal this parameter (the average grade of the pre-test in the E group is 2.82, and in the C group is 2.44). The applied t-test for an unequal variance, ($t = 0.91$, $p= 0.36$), is not statistically significant, indicating that there is no difference between the pre-test groups in general. Statistical analysis of results does not show statistically significant differences between groups, the conclusion is that E and C groups are equal in the amount of acquired knowledge from the relevant subject.

The difference in the quality of students' knowledge in E and C groups at the pre-test at different cognitive levels is shown in the table below (Table 2). After the initial examination, it was observed that the average grade of the students from the relevant subject at the end of the first semester of fourth grade class contrasted with the results achieved by the students in E and C groups at the pre-test. Pre-test questions included certain parts of the material from the relevant subject from the previous grades. The success of the students from both groups, as well as the average grade from the mentioned subject, indicate a high lev-

Table 1. The differences in the quality of knowledge between student E and C group on the pre- test

Pre-test	Levene's equality of variances test		t- test of equality of variances						
	F	Sig.	T	Df	Sig. (2-tailed)	Mean diff	The standard error difference	Limits 95% confidence intervals	
								Lower	Higher
Assumed equal variations	4.68	0.032	0.912	140	0.363	1.12	1.23	-1.31	3.55
Equal variations are not assumed			0.912	132.67	0.363	1.12	1.23	-1.31	3.55

Table 2. The differences in the quality of students' knowledge in the E and C group on the pre- test at the same cognitive level

Cognitive level	Group	$\bar{X}$	SD	t	p
Knowledge	E	7.81	1.42	1.700	0.091
	C	7.42	1.29		
Understanding	E	4.78	1.52	0.607	0.545
	C	4.62	1.66		
Application	E	6.26	2.15	0.893	0.373
	C	5.92	2.36		
Analysis	E	4.64	1.54	1.296	0.197
	C	4.24	1.93		
Evalution	E	3.62	2.16	0.369	0.713
	C	3.76	2.39		
Creation	E	3.39	2.65	0.015	0.988
	C	4.4	3.08		

el of student's knowledge. On the other hand, a significant drop in the student's performance after the pre-test was noted. Such low average marks on the pre-test can be explained by the fact that teachers usually require reproduction of the acquired knowledge from students, while there is no functional application of knowledge and opinion at higher cognitive levels.

After analyzing the quality of the students' knowledge of both groups at the same cognitive levels, it is possible to say that the E and C groups achieved similar results at all cognitive level on the pre-test: knowledge ($t = 1.700$, $p = 0.091$), understanding ($t = 0.607$, $p = 0.545$), application ($t = 0.893$, $p = 0.373$), analysis ($t = 1.296$, $p = 0.197$), evaluation ($t = 0.369$, $p = 0.713$) and creation ($t= 0.015$, $p= 0.988$). Based on the analyzed arithmetic mean scores obtained at different levels of pre-test knowledge, there is no difference noted in the E and C group. At the same time, the statistical analysis does not show statistically significant differences between the groups, so the conclusion is that E and C groups are equal in their knowledge of the relevant subject.

Post-test

The Cronbach Alpha post - test coefficient is 0.84. The contribution of MT to the quality of students' knowledge in the E and C group on post-test at different cognitive levels is shown in Table 3. Post-test results show that E group students achieved better results at all levels compared to the C group. The E group students achieved almost the same number of points on the level of knowledge both in the pre-test and in the post-test, while the levels of understanding, application, analysis and evaluation increased the number of points compared to the pre-test. Although the number of points achieved was slightly increased on the post-test compared to the pre-test, the difference is statistically significant.

Table 3. The differences in the quality of students knowledge in the C and E group on the post- test at the same cognitive level

Cognitive level	Group	$\bar{X}$	SD	t	p
Knowledge	E	7.28	1.97	4.737	0.000
	C	5.42	2.66		
Understanding	E	5.51	2.42	4.096	0.000
	C	4.01	1.87		
Application	E	6.39	2.44	6.196	0.000
	C	3.95	2.24		
Analysis	E	6.1	2.60	5.573	0.000
	C	3.8	2.20		
Evalution	E	3.89	2.30	6.312	0.000
	C	1.94	1.94		
Creation	E	2.97	2.12	4.164	0.000
	C	1.59	1.59		

Table 4. The difference in the total number of points achieved in the E and C group on the pre- test and the post-test

Group		Mean	SD	N	r	p
E	pre–test	31.51	6.39	71	0.71	0.000
	post-test	32.09	9.75	71		
C	pre-test	30.39	8.13	71	0.67	0.000
	post-test	20.71	7.61	71		

A decrease in the level of knowledge on the level of creation is visible in both groups, although in the C group drop in the post-test scores is more pronounced compared to the pre-test. After analyzing the quality of the knowledge of students from both groups at the same cognitive levels on the post-test, it is possible to say that E group achieves better results than the C group of students at the level of knowledge ($t = 4.737$, $p = 0.000$), understanding ($t = 4.096$, $p = 0.000$), application ($t = 6.196$, $p = 0.000$), analysis ($t = 5.573$, $p = 0.000$), evaluation ($t = 6.312$, $p = 0.000$) and creation ($t = 4.164$, $p = 0.000$). The obtained results indicate that there are statistically significant differences in the post-test achievements in group E.

In Table 4, the mean values of the points scored on the pre-test and the post- test in both groups are presented.

ly significantly better result on the post- test than on the pre-test.

In the E group, the average number of points achieved was slightly increased in the post-test compared to the pre-test, but the difference is statistically significant. In the C group, differences are also statistically significant, although the number of points achieved is significantly lower on the post-test.

Re-test

The Cronbach Alpha coefficient for the re-test is 0.83. After the analysis of the quality of the knowledge of the students from both groups at the same cognitive levels on the re-test (Table 6) it is possible to say that the E group achieved better results on the level of knowledge ($t = 10.859$, $p= 0.000$), understanding ($t = 7.875$, $p = 0.000$), application ($t = 5.525$, $p = 0.000$),

Table 5. The differences in the results of the E and the C groups on the pre-test and the post-test

GROUPS		Mean	SD	Stand. error of the mean	Limits 95% confidence interval		T	f	Sig (2 tailed)
					lower	higher			
E	Pre-test	- 0.58	6.89	0.82	-2.22	1.05	-0.71	70	0.48
	Post-test								
C	Pre-test	9.68	6.45	0.77	8.15	11.20	12.64	70	0.000
	Post-test								

On average, the respondents of the E group achieved a better result at the final test by 0.585 points than on the pre-test of knowledge with slightly higher variability of the results. C group students achieved an average worse result on the post-test by 9.676 points than on the pre- test. The correlation coefficient for the E group $r = 0.709$ is statistically significant ($p = 0.000$), which indicates that there is statistically significant correlation between the results of the pre-test and post- test of knowledge of the C group.

Testing of the differences between the results of the E and the C group on the pre-test and post- test was carried out through the t-test and shown in Table 5. The results indicate that there are differences in achievements on the pre-test and the post-test both in the E and in the C group. The results indicate the existence of differences between the results of the pre-test and the post-test of knowledge of the E group students. E group participants achieved a statistical-

evaluation ($t = 0.202$, $p = 0.202$) and creation ($t = 5.819$, $p = 0.000$). At the level of the analysis, both groups achieved an almost similar result ($t = 1.605$, $p = 0.111$), so that the difference is not statistically significant, indicating that there are no differences between the groups at the level of the re-test. The obtained results indicate that there are differences in achievement on the re-test in favor of group E (except at the level of analysis).

The difference between the results of the E and the C group in the post-test and the re-test was determined by the coefficient of correlation of the post-test and the re-test and are shown in Table 7.

On average, the respondents of the E group achieved a better result on the re-test for 10.147 points more than on the post-test with slightly lower variability of the results. C group respondents achieved on average, 9.24 points more on the re- test than on the post-test with significantly less variability in the re-

Table 6. The differences in the quality of students' knowledge in the E and the C group on the re- test at the same cognitive level

Cognitive level	Group	$\bar{X}$	SD	t	P
Knowledge	E	8.22	1.75	10.859	0.000
	C	5.04	1.75		
Understanding	E	7.74	1.89	7.875	0.000
	C	5.21	1.93		
Application	E	6.16	2.01	5.525	0.000
	C	4.21	2.18		
Analysis	E	8.8	1.92	1.605	0.111
	C	8.16	2.72		
Evalution	E	4.71	2.55	0.202	0.000
	C	2.40	2.17		
Creation	E	6.62	1.54	0.022	0.000
	C	4.93	2.052		

Table 7. The differences between the results of the E and the C groups in the post and re-test

Group		Mean	SD	N	r	p
E	Post-test	32.09	9.75	71	0.64	0.000
	Re-test	42.24	7.66	71		
C	Post-test	20.71	7.61	71	0.52	0.000
	Re-test	29.95	7.29	71		

sults. The correlation coefficient for the E group r = 0.62 is statistically significant (p = 0.000), which indicates that there is a statistically significant link between the results of the post-test and the re- test of knowledge in the E group. The correlation coefficient for the C group r = 0.52 is statistically significant (p = 0.000), which indicates that there is statistically significant correlation between the post-test and the re- test results in the C group.

Testing the difference between the E and the C group results on the post-test and the re-test was performed using the t-test and shown in Table 8.

The value of the t-test for the E group is statistically significant (p = 0.000), indicating that there are differences between the results of the post-test and the re-test in the E group. The value of the t-test for the C group is statistically significant (p = 0.000), indicating that there are differences between the results of the post and the re-test of the C group. The results indicate that there are differences in achievements in the post-test and the re-tests, in both E and C group (after three months there has been a significant increase in knowledge).

The analysis of the variance of the repeated measurements of the results obtained on the pre-test, the post-test and the re-test were compared. Table 9 shows their mean values and standard deviations.

The average number of points scored on the pre-test is higher by 9.676 points than on the post- test in the C group, and on the other hand, the E group achieved higher results in the post-test by 0.585 points. In the C group, the differences in the average number of points scored on the pre- test and the re-test were 0.436 points and in the E group they amounted to 10.732 points. Multivariate analysis of variance that was implemented by several tests, of which the Wilks' Lambda test was the valid one for our research, the significant impact of the experimental method on the test results was determined. The value of the Wilks'Lambda multivariate test is 0.370, Levene's test

Table 8. The differences in the results of the E and C groups in the post-test and re-test

GROUPS		Paired differences					T	df	Sig. (2-tailed)
		Mean	SD	Stand. error of the mean	Limits 95% confidence interval				
					lower	higher			
E	post-test	-10.15	7.63	0.91	-11.96	-8.34	-11.20	70	0.000
C	post-test	-9.24	7.33	0.87	-10.97	-7.51	-10.62	70	0.000

Table 9. Mean values and standard deviations of the pre-test, the post-test and the re-test results

Groups	Test	N	Mean	SD
E	pre - total	71	31.51	6.40
	post - total	71	32.09	9.75
	re - total	71	42.24	7.66
C	pre - total	71	30.39	8.13
	post - total	71	20.71	7.62
	re - total	71	29.95	7.29

for equality of variances is F=118.55 and is statistically significant ($p = 0.000$, $p < 0.05$), while the value of the effect (multivariate partial eta square), 0.63 (a major influence). An analysis of the variance of repeated measurements determined the great influence of the experimental method on the test results.

Discussion

In both groups, the students showed equal knowledge on pre-test at all cognitive levels, and very low knowledge at higher cognitive levels. This is based on the obtained results, as well as on the basis of the number of points achieved at each cognitive level. The students from the E and the C groups reached the highest scores at the first three cognitive levels (knowledge, understanding, application). The students knew how to theoretically explain a certain phenomenon, but tasks requiring the use of existing knowledge to explain a particular phenomenon, reading a text with understanding, or tasks in which they needed to express their views and explain them were a significant problem for a large number of students. The pre-test results suggest that students have learned the content of the previous three grades in a traditional way, without occasional repetition. The data support the claim that the assessment of knowledge in the education system of Serbia is most often based on the reproduction of knowledge, and that students are required to exclusively remember and reproduce the material presented by the teacher or presented in the textbook. The low students success on the pre-test suggests that in previous grades teachers did not sufficiently insist on applying the acquired knowledge, as well as on analysis and creation in the sense of creating new, better skills, applicable in solving future problems. The results of the study showed that MT influenced the E group students to achieve better post-test knowledge than the C group students. This claim is supported by the total number of points achieved on the post- test in both groups. The E group students were more successful in solving tasks at all cognitive levels in comparison with the achievements of the C group students. It was expected that the number of points achieved in the E group will be considerably higher at the higher levels (evaluation and creation), but as the difference in the number of points achieved between the two groups on these two levels is statistically significant (in favor of the E group) we can state that MT contributed to the quality of knowledge. On the other hand, the C group students achieved better results at a cognitive levels that experimenter did not expect. Possible reason why the students achieved better results at the cognitive level of application, and worse at the cognitive levels of knowledge and understanding was that they did not read the questions carefully, were rushing in task solving etc. This assumption has in favor their better performance on the re-tests, where they had the same tasks, only linguistically modified. Further research should verify this assumption, as well as possible reasons for this phenomenon. It was unexpected that the C group students at the post-test achieved significantly lower results compared to the pre-test and significantly lower results at certain cognitive levels (knowledge, application, analysis, evaluation, creation and somewhat worse at the level of understanding) which can be a significant starting point for further research to try and find out where do variations in achievements at the same cognitive levels come from. The possible reasons for this are the fact that the content is much more complex in the fourth grade than the contents of the previous grades. In general, the C group students at the post-test have accurately solved the tasks that were based solely on memorizing facts, their recognition and reproduction during testing. The total number of points achieved, as well as the success of students in both groups at cognitive levels on the post-test, partially confirms the first hypothesis of the research. The students in the E group have gained more durable knowledge than the C group students. The obtained results are in accordance with the author's assumption that the use of MT will influence the sustainability of students' learning by applying

MT (Cheng et al., 2012, Han et al., 2013, Kaptan & Izgi, 2014, Pinto et al., 2014; Wainer et al., 2015). Based on the results obtained on the re-test, there was no difference in the knowledge of the C and the E groups at the level of the analysis. When comparing students' knowledge in both groups on the re-test and the post-test at the same level, it can be concluded that the E group students forgot the knowledge needed to solve tasks at lower cognitive levels or that the students in the C group in the period of the post-test the and re-test had been further educated. The success of the students from the E group on the re-test is higher than the post-test at the highest level (creation). However, the students of the E group were not better in their knowledge than students from the C group at a lower level of evaluation. The reasons for such oscillations in students' knowledge on the same cognitive level at the post-test and the re-tests should be explored by future studies. What can be concluded from the total number of points on the post-test and the re-test is that the E group students achieved a higher number of points. This is unexpected information for the students of this group. The data indicate that there was no active and passive forgetting, which was expected (Robbins at al., 2001), but on the contrary, the improvement of knowledge was noted. It should be noted that the contents between the post-test and the re-test are not repetitive, but are disturbed by other contents. Perhaps the content that the students of the E group learned about, the ways of application and presentation, have become interesting to students over time, and they have been additionally educating themselves independently through different sources of knowledge (encyclopedias, internet etc). The results of the re-test partially confirm the second hypothesis of this research. Obviously, the verbal method of the teacher, as well as the textual method, which dominated the C group, was not enough for students to understand complex contents. The E group teacher focused more on students' attention, increased student interest for the content and learning process itself. All of that was missing in the test group C. The reason for the better quality and durability of the students' knowledge in this group should be sought in the fact that the use of animated videos most likely facilitated the better understanding of the content (Han et al., 2013; Kaptan & Izgi, 2014). The content of the multimedia models applied in this research was created in accordance with the interests, of the E group students. In this way the contents became closer and more interesting to the students, and most likely influenced the increased interest in learning new content. The content in the MT was more dynamic, more beautifully designed than the contents in the textbooks, followed by audio-visual effects, which most likely influenced the student's desire to learn. Multimedia has activated more of the student senses, which also affected the E group to understand and remember the adopted knowledge better than the C group students.

Conclusion

The students who learn using the created multimedia teaching model have achieved better and more durable knowledge than the students who learn the same contents through traditional teaching (verbal and textual methods). The created multimedia models used in this research contributed to the adoption of more advanced knowledge at the highest cognitive level of creation. The variations in the knowledge of the students on the same cognitive level were observed on the post-test and the re-test. At some cognitive levels, the students who have learned through created multimedia models have gained better knowledge on the re-test than on the post- test at the higher cognitive levels. Further research should examine the reasons for this phenomenon. Regardless of these variations in knowledge on certain cognitive levels in the application of geographic contents in the fourth grade of elementary school, the advantage should be given to MT over TT. Teachers themselves should create multimedia models in the processing of initial natural science content, as well as other content from integrated natural sciences, in order to adjust the content and make it more understandable and make it more understandable.

The reasons for a larger contribution of the multimedia teaching compared to the traditional teaching are reflected in the manner the students are learning through these two types of teaching. Using multimedia teaching, the students learn in a more obvious manner and the contents are in line with their interests and pre-knowledge. The contents presented in such a manner are more familiar and interesting to the students, they are more dynamic and better designed than the contents in the textbooks and they are accompanied by audio-visual effects, which undoubtedly contributes to students desire to learn and results in better scores. Such teaching climate enables a more active students' participation, which is followed by their engagement, as well as their motivation for further learning. The increase in motivation will reflect on the learning process and students' interest in the content. The interdisciplinarity of the school subject

shows that the conclusions of this study cannot be applied to all teaching contents. However, they can certainly be a foundation for further similar studies with a more representative sample.

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The Influence of GLOBE Culture Dimensions on Entrepreneurial Orientation in Tourism and Medical Service Sectors in Serbia

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Abstract

The main objective of the research is to examine, for the first time, the influence of dimensions of culture according to the GLOBE model on the dimensions of entrepreneurial orientation. The research sample belongs to the service sector within the transitional society of Serbia, i.e. tourism and medical sector, which are linked through the ever-growing health tourism industry. Different influences of dimensions of culture (uncertainty avoidance, performance orientation, group collectivism, assertiveness and gender equality) on dimensions of entrepreneurial orientation (work ethic. innovativeness, empathy, autonomy and risk readiness) are confirmed. The obtained results are important for defining the cultural framework which influences the development of entrepreneurial activities within tourism and health service sectors in Serbia.

Keywords: GLOBE model; culture dimensions; entrepreneurial orientation; service sector; transitional society

Introduction

Today's transitional societies are characterized (Munck, 2002) by a number of cultural specificities that cannot be found in highly developed capitalist societies which, particularly in the former socialist countries, are based on decades of strong focus on collectivism and a lack of orientation toward performance. There are, of course, significant cultural differences among the different transitional societies, having different histories and transition pathways (Mebrahtu et al., 2000). Numerous researchers of the economic problems of developing countries believe that the limited nature of economic development of these societies is a result of certain cultural patterns that have, to some extent, blocked them in the use of rational economic behavior and market functioning. Rostow (1960) believed that it was precisely detraditionalization that can stir the journey of such societies toward modernity. Particularly relevant to this work is the cultural context of entrepreneurship development.

Freytag and Thurik (2007) consider that low national income and poor technological development are not the main contributing factors to the low level of entrepreneurial activity, but that the differences observed are mainly institutional and of cultural nature. Therefore, many studies attribute a high level of entrepreneurial activity to the influence of cultural values such as freedom, independence, need for achievement, individualism/collectivism and materialism (Morris et al., 1994; Spence, 1985).

Entrepreneurship in tourism has made exceptional contributions to the global economic development (Lordkipanidze et al., 2005). When it comes to devel-

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oping countries, rapid increase in international tourist arrivals is partly influenced by the growing interest of postmodern tourists for destinations with cultural specificities and attractive cultural heritage. These destinations are challenging for postmodern tourists who are to some extent saturated with experiences in the well-known European destinations. Therefore, many countries have invested significant funds in the last decade to stimulate tourism development and especially entrepreneurship in tourism (Chang, 2011; Carmichael & Morrison, 2011).

The main goal of this study is to examine the influence of cultural dimensions in Serbia on entrepreneurial orientation in two service sectors, healthcare and tourism.

Many countries have recognized the possibility of linking the entrepreneurship activities between tourism and healthcare. Medical tourism refers to the cross-border healthcare, motivated by lower costs, avoidance of long waiting times or services not available in one's own country. Increasing attention is being paid to attracting medical tourists, including activities aimed at providing entertainment during the pre- and post-operative periods (Hopkins et al., 2010). According to the Zion Market Research (2018) report, global medical tourism market was valued at approximately USD 15.5 billion in 2017 and is expected to generate revenue of around USD 28.0 billion by the end of 2024. The industry has grown substantially in the past decades as citizens of the EU travel from richer countries like the United Kingdom, Sweden, Germany, Netherlands, and Ireland to seek affordable healthcare in other countries, primarily in Eastern Europe. Health tourism brings in €46.9 billion in revenue which represents 4.6% of overall tourism revenues and 0.33% of EU28 GDP (Fink, 2018).

The rapid development of medical tourism has led to the expansion of destinations which are specialized for dental tourism (Poland, Hungary, and Serbia), heart surgery (Turkey), hernias or other medical treatments (Connell, 2006). The influx of medical tourists brings numerous benefits to host destinations. It contributes to country's overall economy, creates jobs and opportunities for further development through the supply chains. As a growing tourism market segment, medical tourism provides numerous opportunities for entrepreneurial activities (Gredičak & Demonja, 2019).

Conceptual definition of culture and GLOBE model

Although there is no complete consensus on the definition of the term culture, scholars mostly agree that culture can be viewed as a set of parameters that allow one collectivity to be differentiated from another. Within this study we focus on the cultural indicators (parameters) in relation to tourism and entrepreneurship. Namely, for the last thirty years, the research, mostly by Hofstede (2001) and the group gathered around the GLOBE (Global Leadership and Organizational Behavior Effectiveness) project, has attracted attention of the scholars in the field of management, organizational behavior and entrepreneurship (House et al., 2002).

For the purpose of this study, we used the GLOBE model, because it is widely accepted and has found numerous applications in various fields including entrepreneurship. Furthermore, the orientation of society or organization towards performance is of great importance for entrepreneurial activities, which was not investigated within the Hofstede's model.

GLOBE cultural dimensions are defined as follows:

1. Uncertainty Avoidance is the extent to which member of an organization or society strive to avoid uncertainty by reliance on social norms, rituals, and bureaucratic practices to alleviate the unpredictability of future events.
2. Power Distance is the degree to which members of an organization or society expect and agree that power should be unequally shared.
3. Collectivism I: Societal Collectivism reflects the degree to which organizational and societal institutional practices encourage and reward collective distribution of resources and collective action.
4. Collectivism II: In-Group Collectivism reflects the degree to which individuals express pride, loyalty, and cohesiveness in their organizations or families.
5. Gender Egalitarianism is the extent to which an organization or a society minimizes role differences and gender discrimination.
6. Assertiveness is the degree to which individuals in organizations or societies are assertive, confrontational, and aggressive in social relationships.
7. Future Orientation is the degree to which individuals in organizations or societies engage in future-oriented behaviors such as planning, investing in the future, and delaying gratification.
8. Performance Orientation refers to the extent to which an organization or society encourages and rewards group members for performance improvement and excellence.
9. Humane Orientation is the degree to which individuals in organizations or societies encourage and reward individuals for being fair, altruistic, friend-

ly, generous, caring, and kind to others (House et al. 2002, pp.5-6).

The GLOBE model has two sub-models: the value aspect of the cultural dimensions (or the situation as it should be in the society or in the organization in the opinion of respondents belonging to the research society) and the perception of the real situation in the society or organization.

Culture and entrepreneurship

Hayton et al. (2002) believe that national culture can, on an individual level, encourage or demotivate entrepreneurial activities, *inter alia*, by creating a cultural framework to identify opportunities for entrepreneurial activities that are appreciated and supported by a number of incentive measures.

Research by Morris et al. (1994) suggests that in individualistic cultures, managers tend to be autonomous and independent and more willing than managers in collectivist cultures to adapt to high-risk situations. Entrepreneurs in an individualistic culture view external environments much more optimistically than entrepreneurs belonging to the society with a low degree of individualism (Palich & Bagby, 1995). In societies characterized by a high level of power distance, there is a general tendency to maintain an established social system and accept its own position in it, without a strong motivation to change one's status (Hojat et al., 2002). Managers in cultures characterized by a low degree of power distance are more willing to take risky actions in order to improve the strategic position of the organization they manage (Shane, 1993).

Some authors point to a negative correlation between uncertainty avoidance and entrepreneurial activity, considering that a society with a high degree of uncertainty avoidance is not prone to risk-taking activities and that members of such society have low levels of readiness to changes, which are very important for entrepreneurial activities (Thomas & Mueller, 2000). In societies with a high degree of human orientation, the support of the environment for entrepreneurial activities can be expected even in the event of initial failures, which can be particularly significant in societies with low levels of economic development. As entrepreneurs are aspiring to financial rewards as a consequence of high performance, a society characterized by the practice of rewarding high performance provides a good environment for the growth of entrepreneurial activities. Companies with a high future orientation provide a favorable framework for the development of entrepreneurial activities, which involves anticipating future opportunities for entrepreneurial activities through active analysis of future trends in the market. A study by Emrich et al. (2004) concludes that in societies characterized by high levels of gender equality, women have high social status and participation in the workforce and a similar educational level to men, and women's participation in entrepreneurial activities is also higher than in societies characterized by low levels of gender equality.

National cultures are particularly important for entrepreneurs in the tourism industry, to maximize the satisfaction of tourists from different countries with the service quality. Previous studies examined the impact of national cultures on the tourists' behavior (Money & Crotts, 2003; Tsang & Ap, 2007), as well as on local residents' attitudes towards tourism (Pavluković et al., 2017). Nedeljković, Koković and Nedeljković (2010) showcase the relationship between culture and tourists' behavior in the context of choosing tourism products. Service providers in the healthcare sector are also required to have a high degree of cultural sensitivity, which is of particular importance in a multicultural society (Bonder et al., 2001).

Entrepreneurial orientation

The widely used entrepreneurial orientation (EO) (Lumpkin & Dess, 2001), introduced by Covin and Slevin (1986), focuses on the following dimensions of this construct: risk taking, innovativeness and proactiveness, and is the result of an adaptation of the work of Miller and Friesen (1982) and Khandwalla (1976/77). Unlike personality dimensions that are dispositional and stable over time, entrepreneurial orientations are culturally conditioned and under the influence of the environment (Özsomer et al., 1997; Thomas & Mueller, 2000).

Thus, Baluku et al. (2019) evidence that personal cultural orientations and cultural intelligence impact the subjective success in self-employment, For the purposes of this research, a questionnaire was used to measure the following dimensions of entrepreneurial orientation: innovativeness, proactiveness, autonomy, work ethic, risk readiness and empathy.

Innovativeness refers to having new ideas in relation to certain relevant groups, markets and environments, and can relate to products and services as well as to administration or technological processes (Lumpkin & Dess, 1997; Avlonitis & Salavou, 2007). There are numerous examples of innovativeness in the tourism sector (Bilgihan & Nejad, 2015), which could be manifested in the selection of products that may be of interest to a particular niche. For example, over the last ten years, a number of new forms of tourism have developed, such as adventure tourism, experiential tourism.

Entrepreneur **proactiveness** is a behavioral syndrome that involves recognizing the opportunities that the market provides, boldness aimed at starting an entrepreneurial venture, during the realization of the venture, but also persistence in overcoming the difficulties that may be encountered in realizing the entrepreneurial venture (Lumpkin & Dess, 1996). Cultures that emphasize entrepreneurial initiative by encouraging entrepreneurs to pursue and anticipate opportunities and to participate in new or emerging markets are classified as proactive (Lee & Peterson, 2000).

Autonomy is also present in successful entrepreneurs and presents the ability to make independent decisions and realize their own ideas and visions. This is one of the factors that may be present when a firm engages in new entry (Covin & Wales, 2012). Also, it may help develop new ventures or improve business practices (Albert & Couture, 2013).

Risk orientation is an important component of a strong EO (Lee & Peterson, 2000). Entrepreneurial activity also involves entering an unfamiliar terrain, which also enhances the possibility of making errors in the assessment, for example, that the market will accept a new product or service. Naldi et al. (2007) found that risk taking was a distinct dimension of entrepreneurial orientation in family firms and that it was positively associated with proactiveness and innovation. They also found that family firms took risk to a lesser extent than nonfamily firms.

An entrepreneur is often considered as self-centered personality thinking only of his or her well-being, but many well-known entrepreneurs have been driven by a desire to contribute to the well-being of the society (Montanye, 2006). When it comes to the service sector, especially health sector, an important dimension of entrepreneurial orientation is **empathy**, which is also one of the dimensions of emotional intelligence. It signifies a healthcare professional's ability to understand patient's emotions, which can contribute to the more caring treatment. Service is characterized by intangibility and therefore the perception of the quality of service by the consumer is also based on the emotional response produced by the service. Empathy is very important for successful entrepreneurial activities in tourism sector particularly due to prolonged nature of service encounter.

Within this study we hypothesize:

H1: GLOBE Culture dimensions are predictors of entrepreneurial orientation dimensions.

To the best of our knowledge this is the first study investigating the relationship between all nine GLOBE dimensions and six dimensions of EO, therefore offering significant insight on the impact of culture dimensions on entrepreneurial orientation.

Methodology

Questionnaires

The questionnaire was composed of three sections: i) survey of demographic profile of respondents, ii) entrepreneurial orientation and iii) dimensions of culture. Questionnaire to measure entrepreneurial orientation was reused from the literature study: Hermansen-Kobulnicky and Moss (2004) (Cronbach index greater than 0.9 for all dimensions). This questionnaire uses ratings from 1- strongly disagree to 7 - strongly agree, for assessing the following dimensions of entrepreneurial orientation: proactivity, work ethic, empathetic service provider, innovativeness, autonomy, risk readiness. The questionnaire for measuring social culture is reused from the work: House, Hanges, Javidan, Dorfman and Gupta (2004). Reliability for all dimensions is above 0.5 (House et al., 2004).

This questionnaire uses the ratings in the range 1- strongly disagree to 7 - strongly agree, for assessing the following dimensions of social culture: uncertainty avoidance, future orientation, performance orientation, institutional collectivism, group collectivism, assertiveness, people orientation, power distance.

The questionnaires were distributed to students of tourism, medicine and pharmacy, in dozens of travel agencies, pharmacies and doctors' offices. A total of 250 questionnaires were distributed, of which 207 returned correctly completed questionnaires. All respondents were informed that participation in the survey was anonymous and the goal of the survey was explained. Respondents provided answers using the standard pen and paper method.

Sample structure

Out of 207 respondents, 108 of them were medical and tourism students while 99 were employed in the med-

ical (including pharmacy) and tourism sectors. The sample contained 60 male respondents (29%) and 147 female respondents (71%). There were 135 students and employed persons with the high school degree (62%), 9 of the respondents completed a 2-year college higher education (4.3%), 44 completed a 4-year University education (21.3%) and 19 of them completed masters or PhD education (9.2%). Regarding the age of respondents, 69.1% belonged to the group between 19 and 35 years of age, 21.7% of respondents were in the group between 35 and 45 years year of age, 6.3% between 45 and 55 years of age and 2.9% of respondents above 55 years of age. Hence, over 80% of respondents were under 45 years of age.

Results

Descriptive statistics

Descriptive statistics for the dimensions of culture according to the GLOBE model are given in Table 1. Respondents rate the level of power distance very high (5.65), which means that despite the changes that Serbian society experienced after the socialist period, there was no significant reduction in power distance. The perception of performance orientation is very low (2.81), which indicates that society has not yet transformed in the direction of promoting high performance and rewarding them adequately. Also, the orientation towards the future is low (2.96), which also indicates a lack of strategic planning in our society. Unlike group collectivism, which is relatively high (4.88), institutional collectivism is perceived as very low (3.16), which can be the result of insufficient support from state institutions in many sectors (in the development of entrepreneurship). The reliability of these questionnaires is lower than recommended, but it is acceptable for questionnaires with a small number of items.

The Table 2 shows that the average values of all dimensions of entrepreneurial orientation are very high, which could mean that at the individual level there are favorable conditions for the development of entrepreneurship.

Table 1. Descriptive statistics for the dimensions of culture according to the GLOBE model.

		Min.	Max.	Average	St. dev.	Skewness (St err. 0.169)	Kurtosis (St. err 0.337)	Reliability
Uncertainty Avoidance	UA	1.00	6.33	3.4960	1.20850	-0.253	-0.519	0.54
Future Orientation	FO	1.00	6.60	2.9691	1.11713	0.077	-0.400	0.61
Performance Orientation	PO	1.00	6.50	2.8140	1.32487	0.433	-0.457	0.48
institutional colectivism	IC	1.00	6.67	3.1626	1.20939	0.090	-0.310	0.57
In group collectivism	GC	1.33	7.00	4.8841	1.30160	-0.349	-0.630	0.59
Assertivity	AS	1.33	7.00	4.5411	1.08102	-0.009	-0.343	0.71
Human Orientation	HO	1.00	5.50	3.1171	1.00929	0.117	-0.409	0.65
Gender equality	GE	1.00	7.00	5.6522	1.34734	-1.057	0.957	0.67
Power distance	PD	2.00	7.00	5.6510	1.08239	-0.762	0.232	0.75

Table 2. Descriptive statistics for dimensions of entrepreneurial orientation

Dimension	Abbreviation	Min.	Max	Average	St.dev.	Cronbach alpha.
Proactiveness	Proact	1.00	7.00	5.4348	1.09290	0.632
Work Ethic	WE	1.00	7.00	5.3671	1.32809	0.810
Empathetic service provider	Empat	1.25	7.00	5.4481	1.08583	0.693
Innovativeness	Innovat	1.00	7.00	5.0870	1.21342	0.704
Autonomy	Auton	1.00	7.00	5.3816	1.26827	0.792
Risk Taking	RiskT	1.00	7.00	5.3092	1.30964	0.662

Regression models

Regression model with the dependent variable *proactiveness* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level and the multiple correlation coefficient R = 0.260. However, the model explains only about 7% (R-square 0.067) of the variability in the dependent variable and no significant correlations were observed.

Table 3. Regression models with the EO dimensions as dependent variables and independent variable dimensions of GLOBE culture

		EO Dimension									
		WE		Empat		Innovat		Auton		RiskT	
		Beta	P	Beta	P	Beta	p	Beta	p	Beta	P
1	Constant		0.000		0.000		0.000		0.000		0.000
	UA	-0.173	0.018	-0.056	0.437	-0.064	0.421	-0.126	0.074	-0.190	0.006
	FO	-0.097	0.208	-0.069	0.362	0.009	0.911	-0.024	0.750	-0.013	0.856
	PO	0.155	0.047	0.064	0.399	0.024	0.777	0.080	0.287	0.116	0.113
	IC	0.087	0.205	-0.017	0.804	-0.024	0.751	0.062	0.352	0.080	0.217
	GC	0.224	0.002	0.344	0.000	0.183	0.020	0.332	0.000	0.301	0.000
	AS	-0.245	0.001	-0.316	0.000	-0.266	0.001	-0.276	0.000	-0.275	0.000
	HO	-0.032	0.647	-0.144	0.069	-0.108	0.159	-0.124	0.073	-0.141	0.056
	GE	-0.097	0.186	-0.108	0.133	-0.167	0.037	-0.063	0.372	-0.080	0.249
	PD	0.018	0.819	0.048	0.529	0.125	0.136	0.078	0.296	0.115	0.115

Regression model with the dependent variable *work ethic* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level (Table 3). The multiple correlation coefficient R = 0.531 and the model explains about 28% of the variability in the dependent variable. Beta coefficients of avoidance of uncertainty, performance orientation, group collectivism and assertiveness are statistically significant.

Regression model with the dependent variable *empathy* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level. The multiple correlation coefficient R = 0.554 and the set of predictors explains about 31% of the variability in the dependent variable. Beta coefficients of group collectivism and assertiveness are statistically significant.

Regression model with the dependent variable *innovativeness* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level. The multiple correlation coefficient R = 0.391 and the set of predictors explains about 15.3% of the variability in the dependent variable. Beta coefficients of group collectivism, assertiveness and gender equality are statistically significant.

Regression model with the dependent variable *autonomy* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level. The multiple correlation coefficient R = 0.570 and the set of predictors explains about 32.5% of the variability in the dependent variable. Beta coefficients of group collectivism and assertiveness are statistically significant.

Regression model with the dependent variable *risk readiness* and independent variable dimensions of GLOBE culture is significant at the p = 0.00 level. The multiple correlation coefficient R = 0.597 and the set of predictors explains about 35.6% of the variability in the dependent variable. Beta coefficients of uncertainty avoidance, group collectivism and assertiveness are statistically significant.

Discussion

Previous research investigated the relationship between GLOBE cultural dimensions and entrepreneurship (Castillo-Palacio et al. (2017), as well as the influence of Hofstede's cultural dimensions on entrepreneurship (Block & Walter, 2017). Our previous research demonstrated the relationships between GLOBE dimensions, facets of job satisfaction and the leader-member exchange (Vukonjanski et al., 2012), as well as between GLOBE dimensions, communication satisfaction and emotional intelligence (Nikolić et al. 2014). The relationship between two of the GLOBE cultural dimensions (PO and HO) and two of the EO dimensions (RiskT and Proact) was previously investigated in South Korea and Thailand (Yoo, 2015). However, our study shows the influence between all nine GLOBE dimensions and six EO dimensions in the service sector in Serbia. The results from the statistical analysis are summarized in Figure 1.

The obtained results, in the case of the regression model with work ethic as criterion variable, indicate the negative influence of uncertainty avoidance and assertiveness, and positive influence of performance orientation and in group collectivism. Yoo (2015) showed the positive influence of performance orientation on Risk taking and Proactiveness. A high level of performance orientation implies readiness of the society to reward a high level of performance, which can be one of the driving factors for the high level of

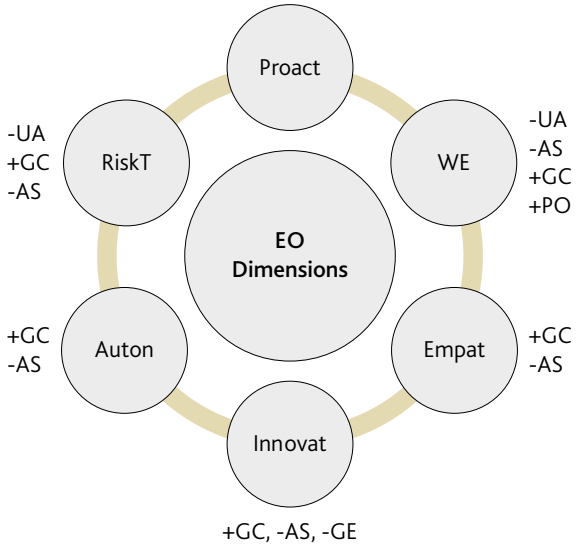

Figure 1. The identified statistically significant influences of dimensions of culture on the dimensions of entrepreneurial orientation (EO)

work ethic. In a society with a high degree of uncertainty avoidance, it is expected that everything is well planned, which can reduce the work ethic of the respondents in a highly individualized service sector (measured in this questionnaire with motivation for work, value, and willingness to meet challenges). Previous research by Engelen, Schmidt & Buchsteiner (2015) found no empirical support for the interaction effect on EO of market turbulence and uncertainty avoidance.

According to the previous GLOBE-related study (Dickson et al., 2000), external influences on organizational culture are multiple and their influences may be complex. One of the specificities of the tourism and medical sectors is the high degree of interconnectivity of providers of partial services, which enable the formation of a complex service. For example, in the tourism sector, it is the connection of employees in the tourism and cultural sector, which is manifested by tourists' visits to cultural institutions - museums, galleries, archeological sites (Hadžić, 2005), and in the medical sector, for example, it can be a conciliatory decision making. It is clear therefore that the respondents' perception of a high level of group collectivism encourages the respondent to express a high level of work ethic orientation. The perception of a high level of assertiveness was followed in our sample by a low level of group collectivism. Such result is understandable, given that a high level of assertiveness in society indicates a high level of rudeness, unkindness and domination. This may discourage an employee from trying to establish a collaborative stakeholder network, so necessary with the provision of high quality service.

The statistical results in the model with the criterion variable empathy showed that there is a positive influence of group collectivism and the negative influence of assertiveness. Previously, Saeed et al. (2014) showed that assertiveness, market size and regulatory quality are no relevant moderators of the EO-performance relationship. High level of empathy reflects the respondent's willingness to develop strong personal relationships with the service user and to focus on meeting his / her requirements, which is an important condition for the service users' perception of the high level of services (Humphrey, 2013). The positive regression coefficient between independent variable group collectivism and dependent variable empathy means that as the level of perceptions of group collectivism increases the perception of entrepreneurial orientation-empathy is also increasing. This is understandable, because a high level of group collectivism also means a willingness to help group members. Entrepreneurs high on empathy will be more successful at motivating and leading their employees and helping their employees to cope with workplace stresses (Humphrey, 2013). The aforementioned characteristics of a society with a high degree of assertiveness "fits" very poorly with empathy, which results in a corresponding regression coefficient being significant and negative.

The regression model in which the criterion variable is innovativeness indicated the positive influence of group collectivism and negative influence of assertiveness and gender equality. High level of innovativeness means the respondents' willingness to engage in innovative activities with a desire to be respected and valued among their colleagues (one of the items was "I want to be known among my colleagues as an innovator"). The high level of group collectivism creates a good environment for a successful innovator (Goncalo & Staw, 2006) in the tourism and medical sectors to be accepted in society and to be appreciated by both their colleagues and service users. On the other hand, a high level of assertiveness (which implies both aggression in the society and a desire for domination) is not a good environment for accepting and respecting very successful people, who may be deterred by the assertive members of the society. Such a situation can influence creative members of an assertive society to reduce their innovative aspirations (a significant negative regression coefficient).

The regression model with the criterion variable autonomy, showed positive influence of group collectivism and negative influence of assertiveness. A high level of autonomy orientation (according to the questionnaire used) means that the respondents have the expectation that their ideas will be accepted and given a chance for their realization. Hence, a high level of group collectivism (which includes the support of colleagues in the workplace but also members of the wid-

er family) (House et al., 2004), allows a good environment for autonomous action. The negative influence of assertiveness on autonomy can be ascribed to the negative effect of increased aggressiveness in the society, similarly to the above discussed effect of assertiveness on innovativeness.

The regression model with risk readiness as the criterion variable showed negative influence of uncertainty avoidance and assertiveness, and positive influence of group collectivism. Kreiser et al. (2010) show that uncertainty avoidance and power distance have a significant negative influence on risk taking. Respondents who perceive a high degree of uncertainty avoidance in the society have a lower degree of risk orientation. One explanation may be that in a company with a high degree of uncertainty avoidance, there is less institutional support (for example, financial) for projects that are rated as risky in terms of performance (it is difficult to obtain favorable loans for small entrepreneurs without a high guarantee on the loans obtained). Thomas & Mueller (2000), as well as Shane (1995) point to a negative correlation between uncertainty avoidance and entrepreneurial activity, considering that a society with a high degree of uncertainty avoidance is not prone to risk-taking activities and that members of such a society have low levels of readiness for changes, which is important for entrepreneurial activities. This can discourage potential entrepreneurs from embarking on an entrepreneurial venture, which can also reduce their willingness to take risks. On the other hand, the perception of a high level of group collectivism can encourage entrepreneurs to start an entrepreneurial venture as they can expect the support of the group (most often families), in the absence of institutional support.

According to our previous study (Nedeljkovic at al. 2018), a high score for the dimension of group collectivism (as it is) in Serbia was noted (mean 5.33), which can positively influence the development of entrepreneurial activities in Serbia.

Conclusion

This study demonstrates for the first time that GLOBE Culture dimensions are predictors of the dimensions of entrepreneurial orientation.

The following significant influences are revealed:

- Uncertainty avoidance, performance orientation, group collectivism and assertiveness are significant predictors of work ethic.
- Group collectivism and assertiveness are significant predictors of empathy.
- Group collectivism, assertiveness and gender equality are significant predictors of innovativeness.
- Group collectivism and assertiveness are significant predictors of autonomy.
- Uncertainty avoidance, group collectivism and assertiveness are significant predictors of willingness to take risks.

Based on the results obtained, we can conclude that group collectivism has a positive effect on all dimensions of entrepreneurial orientation except for proactiveness. Group collecivism implies support from the group, but also from the wider family, which can be a very significant support for starting entrepreneurial activities especially in the societies without clearly defined institutional support for entrepreneurship development. Research findings also indicate a high level of uncertainty avoidance, which is particularly negatively related to risk readiness. The recommendation to strategists and government agencies is to encourage employees through internal entrepreneurship, to encourage new business ideas and to introduce financial support for the development of new ideas, even though they bring a dose of risk in terms of their successful implementation. It is possible that this would reduce the high level of uncertainty avoidance in Serbian society, which is very important for a society's readiness for change. Dealing with change and responding appropriately to changes in the environment is very important to gain competitiveness in the global market. In addition to avoiding uncertainty, assertiveness was identified as a dimension of culture that adversely affects individual dimensions of entrepreneurial orientation. Although assertive behavior in some societies is considered useful in the business environment, we believe that the positive aspects of this dimension of culture are not well known in the Serbian culture. Hofstede's (2001) research on the dimensions of culture in the former Yugoslavia showed that the Serbian society is characterized by extremely strong collectivism and that much attention is paid to interpersonal relations in the work environment, even to the detriment of competitiveness. Therefore, in such society assertiveness may be perceived as harshness in relation to peers, bringing negative effects to the entrepreneurial orientation. We believe that through the education of students, especially in the study programs regarding entrepreneurship, it would be useful to point out the positive aspects of assertiveness, thus reducing the gap in relation to this cultural dimension in the Serbian society.

From the practical viewpoint the results of this study could be valuable for policy makers as well as

for managers. The results obtained are important for defining a cultural framework that can significantly influence the development of entrepreneurial activities, which is of particular importance for transition societies such as Serbian society.

We suggest further evaluation of the influence of cultural dimensions on entrepreneurial orientation in other developing and developed countries, in different sectors of industry, to generate a wider view on the influence of personality dimensions of entrepreneurial orientation.

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