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Spatio-temporal Variations of Tropospheric Nitrogen Dioxide in Turkey Based on Satellite Remote Sensing

Doğukan Doğu Yavaşlı[A]

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Abstract

The satellite observations of NO2 acquire the total tropospheric column over an area while the current ground observations lack spatial and temporal coverage. In this study the Dutch Ozone Monitoring Instrument (OMI) NO2 (DOMINO) data product v2.0 for 2004 – 2019 period was used to analyze the spatial and temporal variations of NO_2 in Turkey. Considering the seasonality characteristics of NO_2, we have used pixel based Seasonal Kendall (S-K) test to investigate the trend of the change. The highest values of NO_2 has been found at the metropolitan areas and perimeter of the high capacity power plants in the observed period. The monthly average concentrations of NO_2 are higher in winter months due to the higher demand of heating and power usage. The S-K trend test results indicate a statistically negative trend at the largest cities such as Istanbul, Ankara and Izmir. However statistically significant positive trend has been found in some areas and Syrian border provinces in particular. Our results show that there is an abrupt change by 2011 in the tropospheric NO2 concentrations, same period when the first Syrian refugees have arrived after the political disorder. The dramatic change at the emission landscape of the NO2 in the region can be explained by changes in population concentration due to political circumstances.

Keywords: NO_2; OMI; DOMINO data; Seasonal Kendall; Turkey

Introduction

Nitrogen oxides (NO_X) (nitrogen monoxide and nitrogen dioxide) forms at high temperatures that can cause molecular nitrogen in the atmosphere to react with oxygen. At room temperatures nitrogen and oxygen do not react each other. Therefore, formation of NO_X can originate naturally from lightning strikes and forest fires or with anthropogenic activities such as burning fossil fuels at high temperatures. Large amounts of NO_X are produced by anthropogenic activities firstly in the form of NO, then it is rapidly transformed in to NO_2 by reaction with ozone (Castellanos & Boersma, 2012). The total global anthropogenic emissions of NO_X are roughly 122 Mt/year however due to short atmospheric lifetime (approximately hours) the concentrations are highly variable in time and space (Crippa et al., 2018).

The effects of high NO_2 levels to health mainly consists of respiratory problems such as coughing, difficulty in breathing, wheezing, colds, flu and bronchitis that makes NO_2 is one of the primary pollutants. On the other hand, NO_2 provides a contributing component for secondary pollutants by forming ozone (O_3) with releasing oxygen atoms when exposed to sunlight (Kharol et al., 2015).

The measurement of atmospheric NO_2 is traditionally established with ground station data. However, air quality stations lack of temporal and spatial coverage, particularly in developing countries such as Tur-

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key. Conversely, remote sensing data provide data for areas without a ground station and more importantly has retrospective view.

The satellite observations of NO_2 acquire the total tropospheric column over an area whereas air quality stations measure its concentration near the ground. Leaving aside lightnings and air transportation, the major sources of NO_2 is located at the land surface and therefore the NO_2 detected by satellites mostly originate from atmospheric boundary layer (Richter et al, 2005).

The first monitoring of NO_2 at troposphere have started with Global Ozone Monitoring Experiment (GOME) on European Remote-Sensing Satellite-2 (ERS-2) satellite in 1995 and it continued with SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) in 2002, Ozone Monitoring Instrument (OMI) aboard Aura satellite in 2004, GOME-2 in 2007 and TROPOspheric Monitoring Instrument (TROPOMI) on board the Copernicus Sentinel-5 Precursor satellite in 2017. Among these, OMI has been observing the atmospheric NO_2 daily since late 2004 at spatial resolution of 13 x 24 km at nadir view increasing in size to 24 x 135 km for largest view angles.

Recently, various studies have been carried out on the satellite observations of tropospheric NO_2 columns. For instance, Richter et al. (2005) presented the tropospheric column amounts of NO_2 obtained from GOME and SCIAMACHY for the period 1996-2004. They have found a significant decrease in Europe and USA with a 50% increase in the industrial areas of China. The NO_2 concentration decrease in Europe has also been noted by Castellanos and Boersma (2012) between the years 2004 and 2010. Their regression models show that most of the metropolitan areas in Europe have a decrease around 20% according to the OMI satellite data. The increase in tropospheric NO_2 concentrations in China has also been noted by Schneider and Van Der A (2012). Their calculations of SCIAMACHY data indicate that the trend in China is between 4 – 19.7 x 10^{15} molecules/cm² per year and there is a strong agreement of NO_2 concentrations at Europe and USA. On the other hand, a more recent study has found that there is a 6% decrease at NO_2 level at China after 2011 according to the OMI data (Irie et al., 2016). Similar results have been found by Cai et al. (2018) for Chengdu–Chongqing Economic Zone in China. Their results indicate high NO_2 concentrations in the northwest of Chengdu and southeast of Chongqing with an inflection point towards a decrease in the year 2011. The change in the tropospheric NO_2 can sometimes be abrupt. For instance, Lelieveld et al. (2015) have found that economic crisis and armed conflicts have urgently shifted the NO_2 emissions in the Middle East. These studies have shown that tropospheric NO_2 concentrations are not only controlled by emission policies to improve air quality but also economic, industrial and other human controlled activities.

Although there are various inventories at global and regional scale and they commonly use regression models for trend analysis, the examination of the trends of the tropospheric NO_2 has never been made for Turkey. Here, we analyze the tropospheric NO_2 over Turkey for the period 2004–2019 using OMI data. We present the spatial distribution characteristics of NO_2 as well as the temporal change over time by a novel approach of using Seasonal Kendall test for each pixel.

Materials and Methods

The DOMINO v2.0 dataset of European Space Agency (ESA) Tropospheric Emission Monitoring Internet Service (TEMIS; www.temis.nl) based on the OMI orbits has been used in this study. DOMINO is a post-processing level 2 data set of OMI, providing geophysical information for each ground pixel observed by the instrument. The NO_2 retrieval algorithm of DOMINO dataset consists of three stages: using Differential Optical Absorption Spectroscopy (DOAS) to obtain NO_2 slant columns from the OMI reflectance spectra, separating the stratospheric and tropospheric contribution to the slant column and converting the tropospheric slant column to a vertical column with the tropospheric air mass factor (AMF) (Boersma et al., 2011). Monthly averages as a unit of 10^{13} molecules/cm_2 have obtained from TEMIS and converted to 10^{15} molecules/cm². The data is filtered with 30% cloud radiance fraction. The dataset includes October 2004 – October 2019 period. The annual averages have been calculated using 12-month calendar year data. The monthly, seasonal and whole period averages have been used to acquire the spatial, annual and seasonal cycle of tropospheric NO_2 concentrations.

The temporal change of NO_2 at the study area has been investigated through seasonal Kendall (S-K) test. The S-K test is a modified case of Mann-Kendall trend test to analyze data for monotonic trends in seasonal data (Mann, 1945; Kendall, 1975; Hirsch et al., 1982). The seasonality refers that the data have variable distributions for different seasons or months of the year.

We have tested each pixel at the study area by two hypotheses with S-K: the H_0, hypothesis regarding there is no trend in the time series and the alternative H_a hypothesis that there is a statistically significant negative or positive trend in the series at 0.01 and 0.05 significance level. The Kendall tau coefficient (τ) has been used to identify rank correlation where the positive τ value indicates an increasing trend as well as a low negative value is an indicator of a decreasing one. The estimate of the trend slope over time has been computed using a generalized version of the Sen slope estimator (Sen, 1968).

We have also used Pettitt's test to the selected areas to test the homogeneity and identify the time when a shift occurs. This test hypothesize that values are independent and identically normally distributed in the null hypothesis and the alternative one assumes that the series has a shift in a given time (Pettitt, 1979).

Results and Discussion

Spatial Distribution of NO_2

Figure 1 gives the overview of the average distributions of the tropospheric NO_2 concentration from 2004 to 2019 over Turkey. The highest concentrations are observed at the most populated and industrialized cities such as Istanbul, Ankara, Izmir, Bursa and Adana as expected. The NO_2 concentrations reach $7x10^{15}$ molecules/cm^2 at Istanbul, the industrialization and urbanization center of Turkey with more than 15 million inhabitants. Other NO_2 hotspots are northern K. Maraş, northwestern Manisa, western Muğla, central Konya and southern Şırnak. These hotspots have coal-fired power plants (Fig. 2).

The NO_2 concentrations in Turkey show large seasonal amplitude with highest values in November, December, January and February and lowest values June, July August (fig. 3). It is well known that because of the excessive use of powerplants and home heating, NO_2 levels increase in northern hemisphere winter months. This seasonal characteristics about the distribution of NO_2 also arise from the hydroxyl radical (OH) and the photolysis frequency of NO_2. Higher winter values are usually associated with the decreasing loss of NO_2 by reaction with OH which is the major NO_X loss process in the lower troposphere. A lower photolysis rate is observed in winter the northern hemisphere that depletes NO_2 due to less sunlight (Xiao et al., 2013). Therefore, in the winter months with less sunlight, NO_2 is removed more slowly from the atmosphere (Saini et al., 2008). The high NO_2 levels in winter is usually associated with anthropogenic activities being the dominant NO_2 source rather than biomass burning or soil emissions (Van Der A et al., 2008).

Temporal Distribution of NO_2

Examining the annual averages of NO2 over Turkey for 2004-2019 period (fig. 4) there are peaks and decreases for various areas in Turkey. In general, the effects of 2008 global economic crisis can be observed between 2009-2011 period in most of the provinces primarily in Istanbul, Ankara and Izmir which can be associated with the decrease in industrial production. This is consistent with Castellanos and Boersma's (2012) results. Same decrease can also be noticed

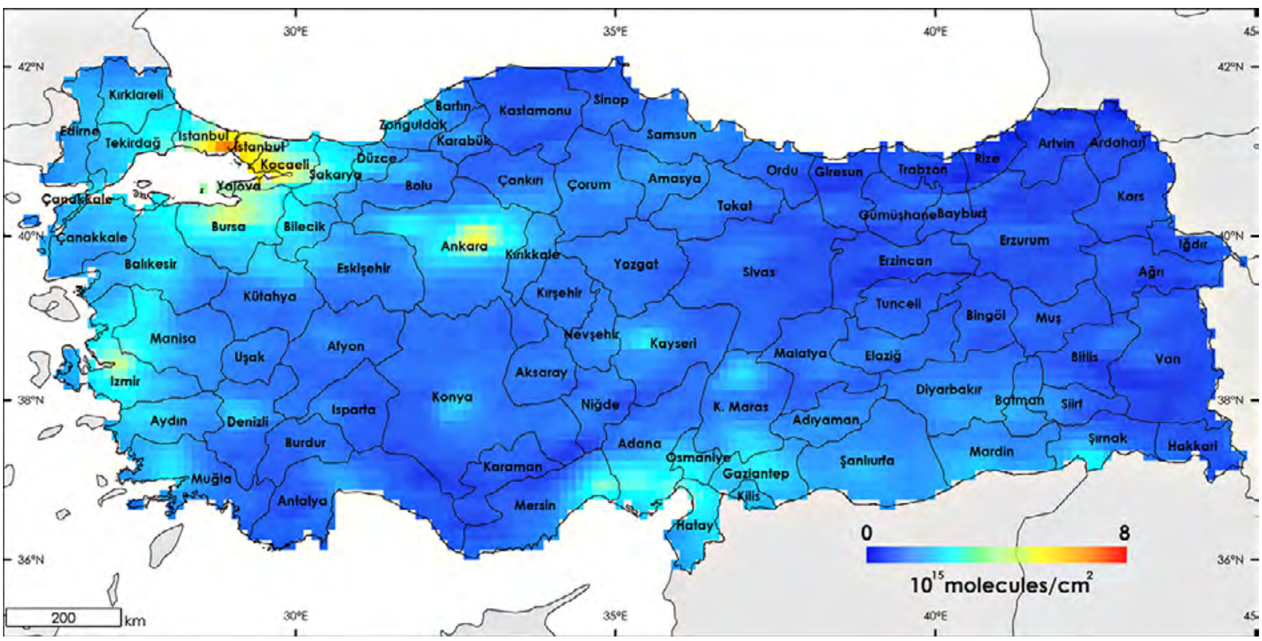

Figure 1. The mean annual tropospheric NO_2 over Turkey for the period 2004 – 2019

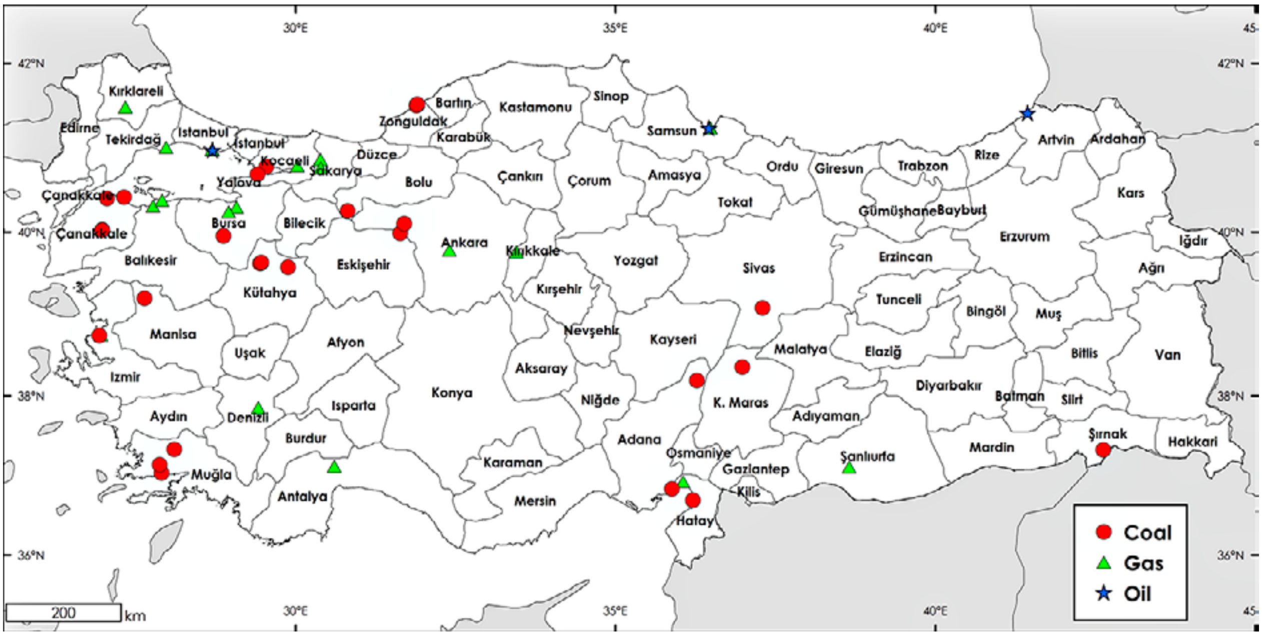

Figure 2. The power plants of Turkey
Source: WRI, 2019

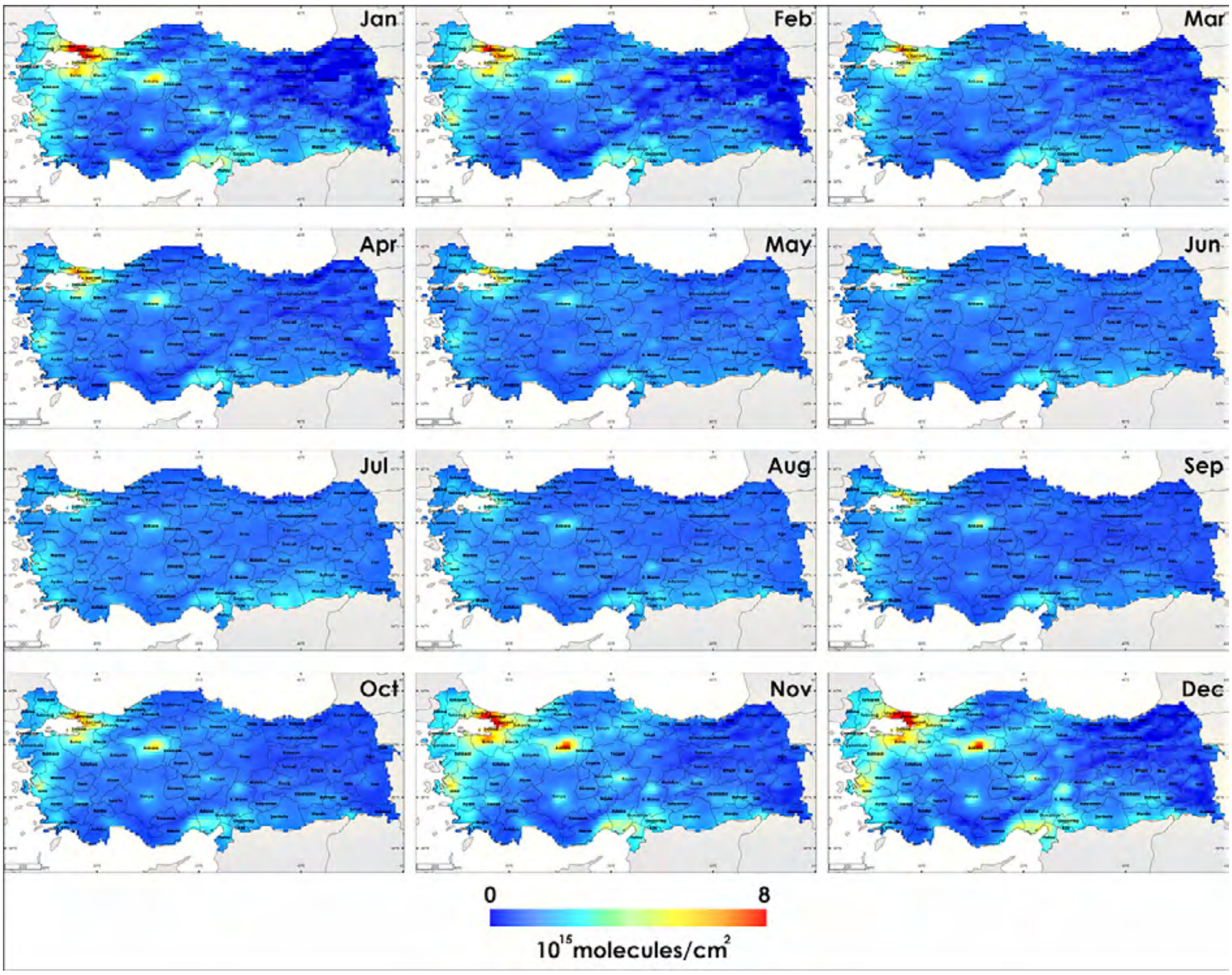

Figure 3. The mean monthly values of tropospheric NO_2 over Turkey for the period 2004 – 2019

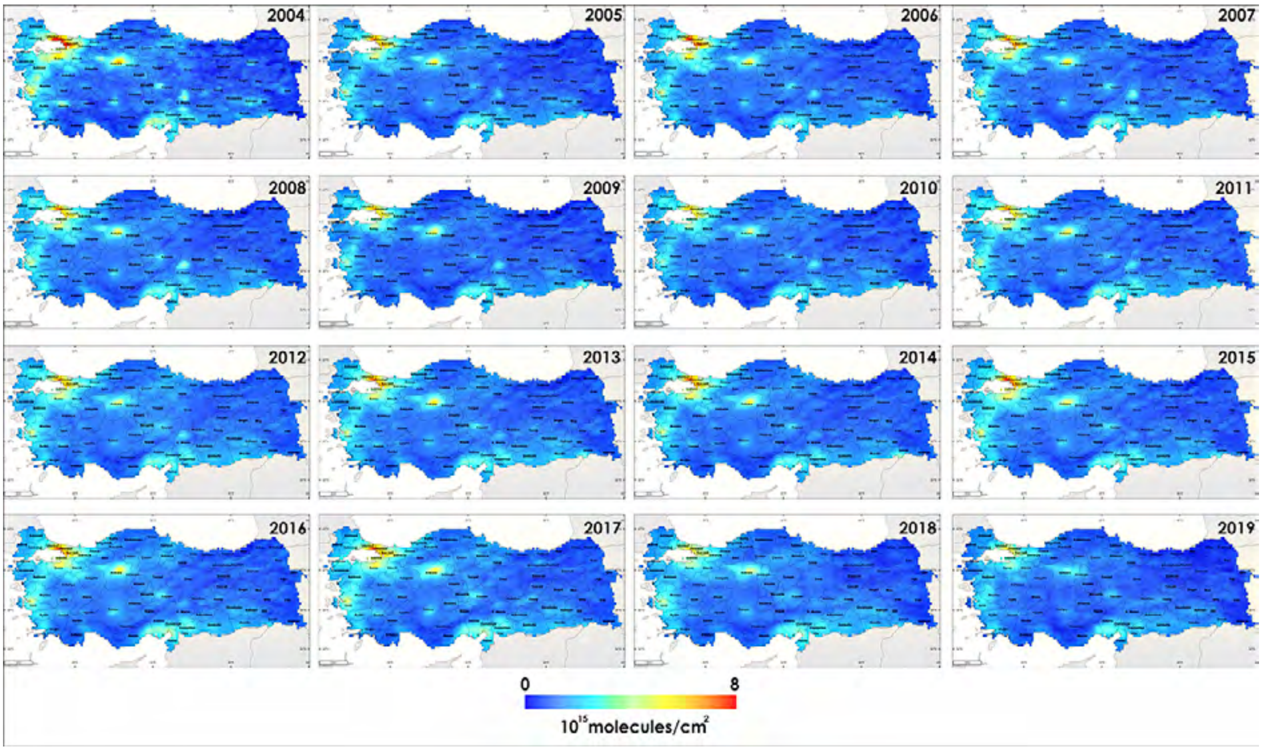

Figure 4. Yearly averages of tropospheric NO_2 over Turkey for the period 2004 – 2019 (please note that the years 2004 and 2009 does not have 12-month data)

at the areas with large fossil fuel power plants such as K. Maraş.

The temporal change of the tropospheric NO_2 has been evaluated using S-K test. Figure 5 shows the τ values as a means to assess the significance of the cross-correlation between the time series and NO_2 concentrations whereas the significance levels of the trends can be examined in figure 6. The highest values of τ is observed particularly at the south provinces of Turkey such as Gaziantep, Şanlıurfa, Kilis referring an increase for NO_2 concentrations. Other high values can be noticed at individual areas such as eastern Sakarya, northern Kırıkkale, southeastern İzmir and northern Çanakkale. These results are statistically significant at 99% level with a positive trend of $0.08x10^{15}$ molecules/cm^2/year according to the p-values and Sen's slope calculations (Fig. 6 and Fig. 7).

When considered from this point of view, the positive trend at the Syrian border provinces (Gaziantep, Şanlıurfa and Kilis) is remarkable. The change NO_2 concentrations in the region have increased $1.2x10^{15}$ molecules/cm^2 in the 15-year period. In order to unveil the reasons for this change and the exact time of the change, we have applied Pettitt's test to the pixel values at these provinces. The test results indicate that 94% of these pixels have a significant change point (or a shift) exists and 79% of it indicates an abrupt change on May 2011. Considering the start of the revolt in Syria in March 2011, the first Syrian refugees have arrived in Turkey on 29th April 2011 (Özden, 2013; Özdemir, 2017). The number of the Syrian refugees were 33,818, 37,385 and 67,753 in 2013 at Gaziantep, Kilis and Şanlıurfa respectively. These numbers have changed to 452,419, 115,599 and 430,049 in 2019 following the same order (table 1) (Directorate General for Migration Management, 2019). Therefore, we attribute the significant positive trend for tropospheric NO_2 in this region to the Syrian refugee influx started in 2011 and correspondingly the increasing number of inhabitants as well as increasing anthropogenic activities. It should be noted that the refugees typically use coal burning stoves since the government and non-governmental organizations provide coal (Leghtas & Hollingsworth, 2017). Considering the percentage of

Table 1. The population change and the number of Syrian refugees in selected cities.

	Population (2004)	Population (2018)	Syrian Refugee (2019)	Percentage of the Refugees to 2018 Population
Gaziantep	1,441,079	2,028,563	452,419	22%
Kilis	114,615	142,541	115,599	81%
Şanlıurfa	1,404,961	2,035,809	430,049	21%

the number of refugees to the population, the increase at Kilis province is more evident.

On the other hand, low τ values can be observed at western Thracian provinces such as Tekirdağ, Kırklareli, Edirne as well as northeastern part of Turkey. Istanbul, Ankara, Izmir, Bursa as the four most populous cities have also negative τ values referring a negative trend for the NO_2 concentrations. The negative trend can be noticed also at northern K. Maraş and southern Şırnak where the Afşin-Elbistan and Silopi coal-fired power plants are located respectively (fig. 2). This negative trend is statistically significant at 99% level with a Sen's slope value of $-0.08x10^{15}$ molecules/cm² year⁻¹ (fig. 6 and fig. 7). The negative trend can be associated with 2008-2009 global economic recession for the large cities and emission controls for the ones with large power plants (Castellanos & Boersma, 2012; Ministry of Environment and Urban Planning, 2009).

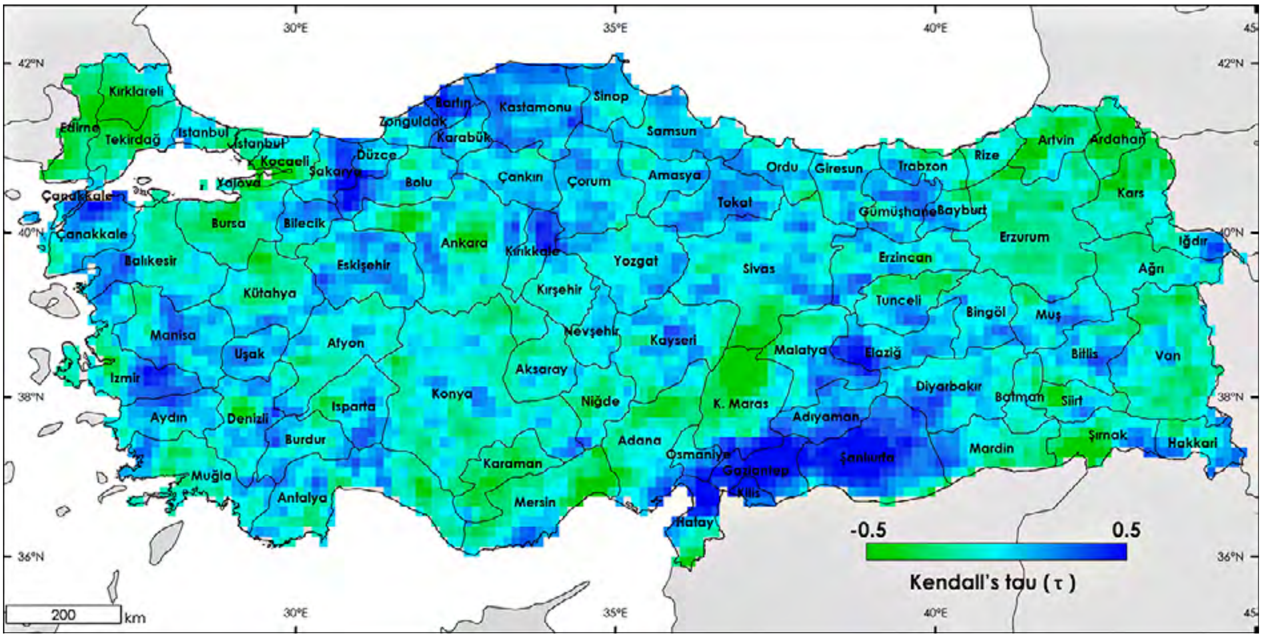

Figure 5. Kendall's tau (τ) values of S-K test

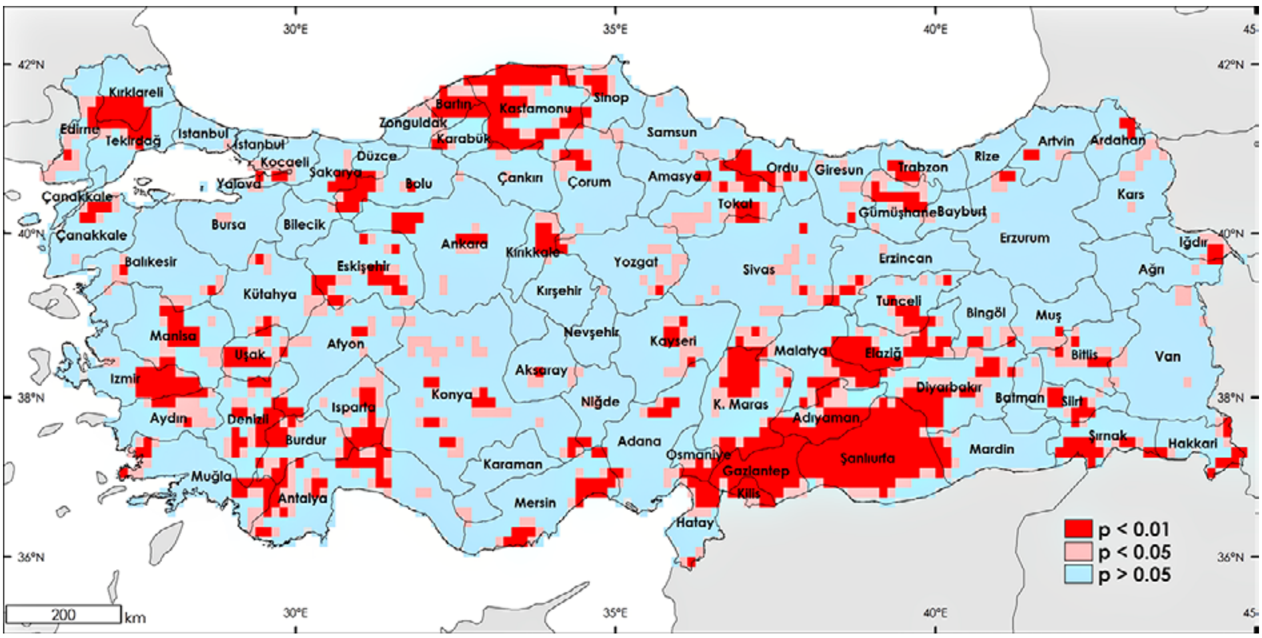

Figure 6. Significance level of the trends

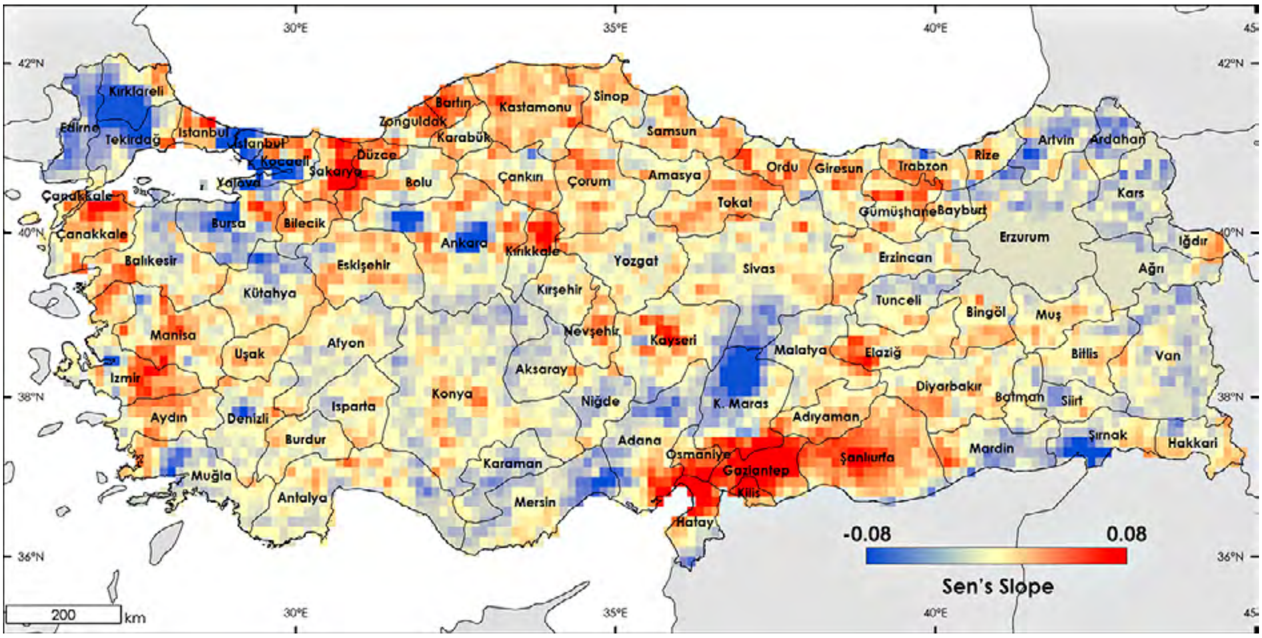

Figure 7. Sen's slope values

Conclusions

Using monthly tropospheric NO_2 column observations from OMI, we were able to present spatio-temporal multi-year changes in NO_2 at Turkey. Considering its seasonality this study analyzed the spatio-temporal distribution in Turkey for a 15-year period with S-K analysis.

The largest cities such as Istanbul, Ankara, Izmir, Bursa and Adana have highest levels of NO_2 in a consequence of anthropogenic activities. Other main sources of NO_2 are mostly located around high capacity powerplants. Regarding the annual cycle of NO_2, the levels are higher in winter months and lower on summers.

The overview of tropospheric NO2 concentrations during the period 2004 – 2019 reveals large changes in Turkey. Most of the large cities and the surroundings of some power plants have a negative trend according to the S-K analysis. On the other hand, the statistically positive trends are mostly observed at the Syrian border provinces such as Gaziantep, Kilis and Şanlıurfa. This has been attributed to the increasing refugee numbers and anthropogenic activities at these provinces after 2011. The Pettitt's test results for the region indicate similar period for an abrupt change.

Since the satellite data offer global coverage, the method used in this study to analyze the observation time series considering its seasonal pattern, can be applied to any region worldwide. The ongoing and planned observations of tropospheric NO_2 with satellites will provide a better understanding of our NO_2 emissions and their spatio-temporal distribution.

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Investigating Micrometeorological Differences between Saline Steppe, Forest-steppe and Forest Environments in Northern Serbia during a Clear and Sunny Autumn Day

Dragan D. Milošević[A, B], Jelena Dunjić[B], Vladimir Stojanović[B]

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Abstract

Saline habitats of the Pannonian plain are specific regarding their extraordinary biodiversity with many endemic species, yet they are among the most threatened European communities with limited spatial distribution. These habitats are present in the Autonomous Province of Vojvodina in the north of Serbia, in the area of Srednja Mostonga, and they are in the procedure of protection as the II category protected area - "*region of exceptional characteristics*". Great variety of rare and endemic species makes this area interesting for recreational and educational activities. In this paper we investigate micrometeorological and outdoor thermal comfort conditions in different natural environments at the area of Srednja Mostonga. This is the first micrometeorological field measurement study conducted in this region. Measurements were performed during the daytime of a sunny autumn day in 2019. The results showed that daytime air temperature was up to 3.4 °C lower in forest compared to steppe, while relative humidity was up to 5-6% higher in forest than in steppe with up to 3.2 m/s lower wind speeds in forest than in steppe area. Micrometeorological values were similar between forest-steppe and steppe. However, the outdoor thermal comfort conditions expressed via Humidex showed that 'some discomfort' was most often observed in forest-steppe during 27% of measurement time, followed with 13% of 'some discomfort' observed in steppe and only 1% of 'some discomfort' was observed in forest. Accordingly, during the warmest daytime hours outdoor activities could be performed in forest, while early morning and evening hours could be spent in steppe and forest-steppe areas of Srednja Mostonga.

Keywords: temperature; humidity; Humidex; saline steppe; forest-steppe; forest; Serbia

Introduction

Saline habitats such as saline steppes and marshes of Pannonian plain in Serbia are strongly impacted by Pannonian climatic conditions characterized by extreme temperatures and aridity in summer. These areas are characterized by lower salt content, but higher alkalinity, and they have been present in the Carpathian Basin since the last Ice Age. These habitats have specific vegetation, with salt resistant plants, and they occur only in a few other countries in Europe (e.g. Hungary, Austria, Bulgaria, Romania, Slo-

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vakia). They are considered to be among the most threatened European communities, due to their limited geographical distribution. Molnár et al. (2012) predicted transformation and fragmentation of saline habitats in Hungary, as well as decline of their resilience and recovery potential. Even though alkali plant communities are relatively poor regarding the species, their combinations are very specific and diverse. Saline habitats with their mosaic structures give the basis for extraordinarily rich flora and fauna, which contain endemic species (Šefferová Stanová et al., 2008).

Even though saline habitats are of great importance and should be priority areas for protection as recommended by the European Union (e.g. Directive 92/43/EEC), that wasn't the case in Serbia until recently. In Vojvodina Province in northern Serbia, especially in Bačka region, there are large, yet fragmented areas of saline habitats (e.g. saline steppes, forest-steppes, forests) with rare and endemic wild species of national and international importance. Therefore, Institute for Nature Conservation of Vojvodina Province initiated protection of "Srednja Mostonga", as the natural area of II (second) category - *region of exceptional characteristics* (IUCN Category V: Protected Landscape/Seascape). Parts of the area of "Srednja Mostonga" have been singled out as an International Important Plant Area (IPA) and International Important Bird Area (IBA), as stated by the Ministry of Environment of the Republic of Serbia.

The main reasons for this initiative are many issues threatening saline habitats such as: agricultural activities, forest degradation, littering as well as climate change which affects fragile habitats like these. On the other hand, the conservation of the saline habitats could contribute to a number of positive activities and be beneficial for surrounding local communities. Protection initiatives are important for realization of sustainable tourism goals (Stojanović et al., 2018). Rare and endemic wild species which are internationally recognized (IPA and IBA areas) make this area interesting for ecotourism, which focuses on educational, cultural and community beneficial activities (Šiljeg et al., 2019). Since touristic activities based on natural resources often mean spending a great amount of time outdoors, they are strongly dependent on climatic conditions (Mihăilă & Bistricean, 2018), and comfortable climatic conditions could enhance them. Scott et al. (2011) emphasized the importance of the climate conditions for the tourism sector, both destination management and visitors. Basarin et al. (2014) analyzed bioclimate of two special nature reserves in Serbia based on measurements from nearby stations and came to similar conclusions.

Measurements of microclimatic conditions in different natural saline habitats aims to contribute to the micrometeorological and outdoor thermal comfort assessment in order to make suggestions about the most suitable period for exploring or visiting these areas. The most important meteorological parameters influencing human outdoor thermal comfort are: air temperature, humidity, wind speed and global radiation. Combining the effect of air temperature and humidity on humans can be assessed with thermal comfort indices, such as Humidex (Masterton & Richardson, 1979). This index was used to analyse thermal comfort conditions in numerous natural and urban areas (Błażejczyk & Twardosz 2010; Orosa et al., 2014; Ramezani & Fallahzadeh, 2014; Mekis et al. 2015; Tahbaz, 2018; Geletič et al. 2018; Garcia, 2019), due to its higher accessibility of input data when compared to other indices.

The main aims of this paper are threefold. Firstly, we wanted to perform the first field micrometeorological measurements in various natural environments of Srednja Mostonga consisting of saline steppe, forest-steppe and forest environments. Secondly, we wanted to investigate micrometeorological conditions and outdoor thermal comfort in their natural environments during a clear and sunny autumn day. And thirdly we wanted to assess and quantify micrometeorological and outdoor thermal comfort differences between saline steppe, forest-steppe and forest as the basis for sustainable natural protection and tourism activities.

Study area, data and methods

Study area

Srednja Mostonga (3,131 ha) is located in the northern part of Serbia (Vojvodina Province) on the territory of three municipalities: Apatin, Sombor and Odžaci. This area is highly influenced by saline soils due to high groundwater levels and continental climate. For this exact reason, the area of Srednja Mostonga has never been plowed in the past. The natural habitats are well preserved throughout this area unlike its surroundings where such features are permanently lost. Therefore, Srednja Mostonga has been proposed for protection based on the conservation study, which was written in 2018 by the experts of Institute for Nature Conservation of Vojvodina Province.

There are 27 habitats of high priority protection in the area of Srednja Mostonga. Next, 17 habitats are within the priority NATURA 2000 internationally significant habitats (Conservation study, 2018). In

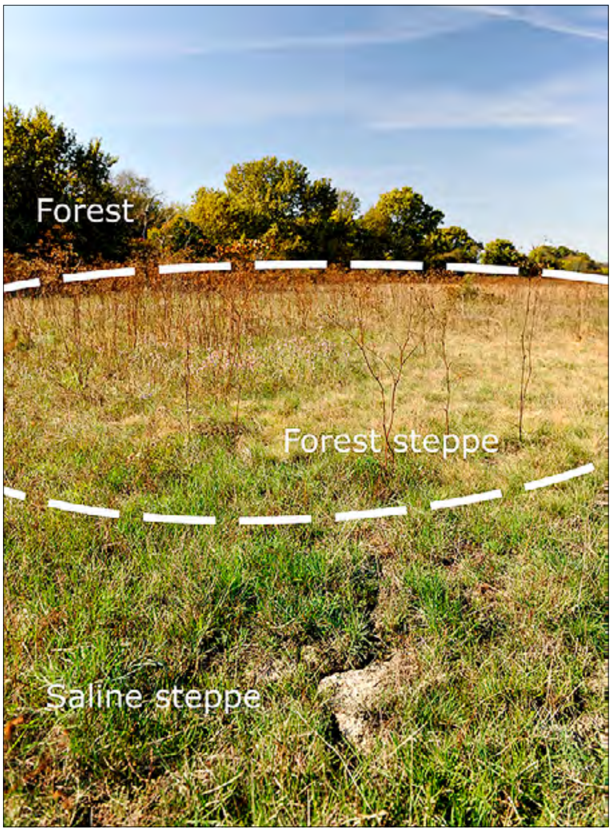

Figure 1. A range of habitats in „Srednja Mostonga": saline steppe, forest steppe and oak forest on the saline soils
Photo: V. Stojanović

the triangle of the villages of Srpski Miletić, Bogojevo, Karavukovo – Donjaslatina location, there is a relatively small area characterized by more of habitats, ranging from saline to oak forests on the saline soils (Figure 1).

General long-term climate characteristics of the area of Srednja Mostonga can be assessed with data from meteorological station of Sombor (45° 46' N 19° 09' E, 88 m a.s.l.). This is the closest official meteorological station to the area of interest (25.3 km away). Unfortunately, there is no permanent meteorological station deployed in Srednja Mostonga area, which is a drawback if we want to access the climate change effects in this protected natural area in the future. Fortunately, Sombor meteorological station is located in a natural surroundings bordering the suburban area. This region has a Cfb climate (temperate climate, fully humid, and warm summers, with at least four $T_{mon} \geq + 10$ °C), according to the Köppen-Geiger climate classification (Kottek et al. 2006). The mean monthly air temperature ranges from −0.1 °C in January to 21.9 °C in July. The mean annual precipitation is 612 mm (Figure 2). Average wind speeds are from 1.7 m/s for SSW direction to 3.1 m/s for N direction. Data is obtained from Republic Hydrometeorological Service of Serbia for the 1981-2020 period.

We have performed the first micrometeorological measurements in Srednja Mostonga. The measurements were performed during a clear and sunny day of 21st October 2019 which could be representative of an ideal day for touristic activities in the area. October is characterized by decrease in precipitation and increase in relative humidity with average maximum temperatures (T_{max}) reaching 18.1 °C (Figure 2) and

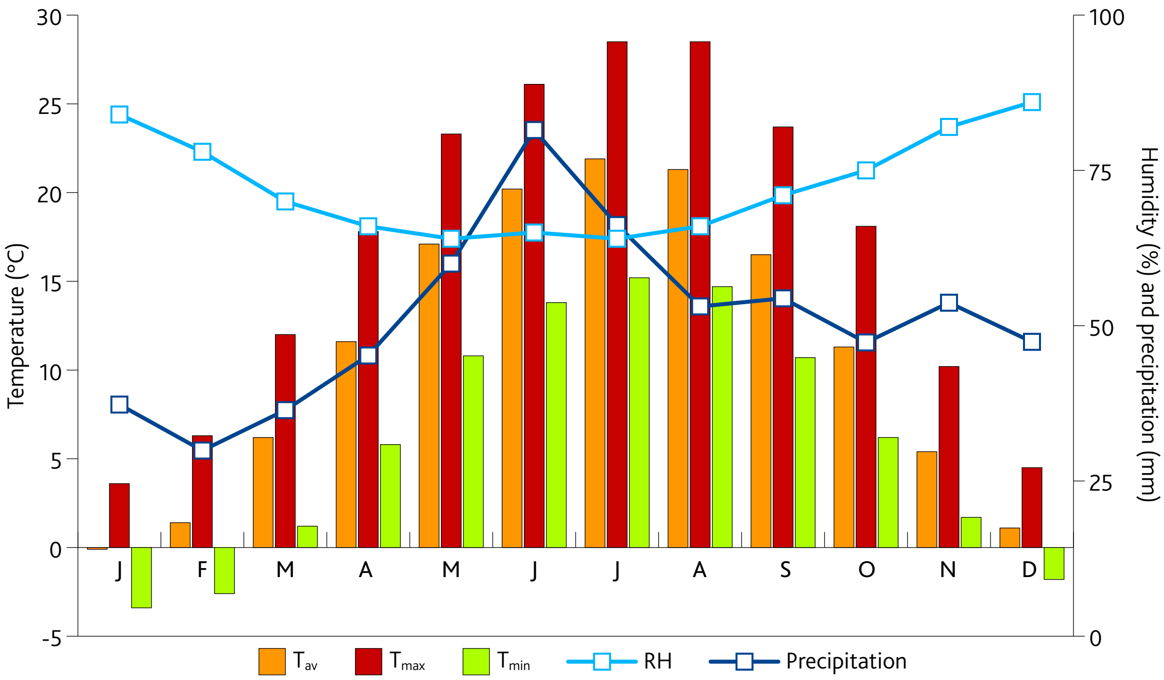

Figure 2. Climate data from Sombor meteorological station for the normal climatological period 1981-2010. Data obtained from Republic Hydrometeorological Service of Serbia. NOTE: Black rectangle shows the month in which we have performed measurements

this month could be ideal for tourism (Eslami & Tirandaz, 2011) due to comfortable air temperature during the midday hours with lower T_{max}.

Data and Methods

For the present study, we have performed field micrometeorological measurements at three locations: saline steppe, forest-steppe and forest (Figure 3). The measurement campaign started at about 10:00 AM and lasted until about 3:30 PM on a clear and sunny autumn day (21st October 2019). We have selected morning and midday hours to perform the measurements because during these hours with low wind speeds and lack of cloud cover, specific micrometeorological conditions in each investigated environment can be expected to develop and prevail. Furthermore, outdoor activities in this area are generally performed during the selected hours.

We used three mobile Kestrel 5400 Heat Stress Trackers (Figure 4) to measure air temperature (T_a), relative humidity (RH), wind speed (v) and globe temperature (T_g) with one-minute measurement resolution. The measurements were performed at approximately 1.1 m height representing the center of gravity of the human body for standing subjects (ISO 7726 1998). The accuracy of instruments comply with ISO 7726 (1998) standards for sensor measurement range and accuracy (Table 1). In further analysis we used T_a,

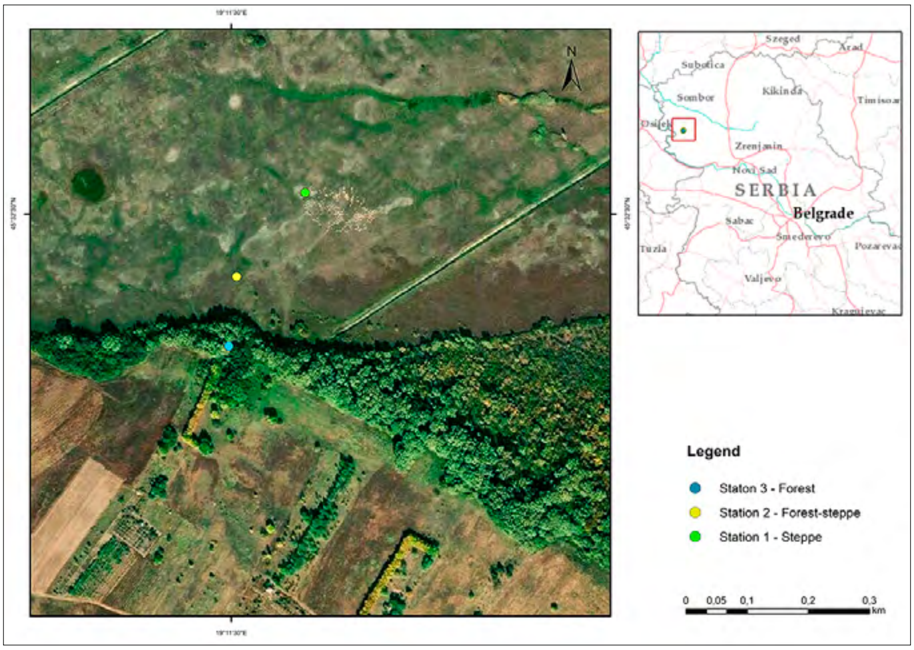

Figure 3. Measurement sites in Srednja Mostonga (Serbia) with the position of stations in saline steppe, forest-steppe and forest on 21st October 2019

Figure 4. Instrumental set-up of the meteorological stations in: saline steppe, forest-steppe and forest (from left to right)
Photo: V. Stojanović

Table 1. Sensor specifications for Kestrel 5400 Heat Stress Tracker used for the micrometeorological measurements

Sensor	Accuracy (+/-)	Resolution	Range	Notes
Air temperature	0.5 °C	0.1 °C	-29.0 to 70.0 °C	Airflow of 1 m/s or greater provides fastest response and reduction of insolation effect. For greatest accuracy, avoid direct sunlight on the temperature sensor and prolonged sunlight exposure to the unit in low airflow conditions.
Relative humidity	±2%RH	0.1 %RH	10 to 90% 25°C non-condensing	To achieve stated accuracy, unit must be permitted to equilibrate to external temperature when exposed to large, rapid temperature changes and be kept out of direct sunlight. Calibration drift is typically less than ±0.25% per year.
Wind speed	Larger of 3% of reading, least significant digit or 20 ft/min	0.1 m/s	0.6 to 40.0 m/s	25 mm diameter impeller with precision axle and low-friction Zytel® bearings. Startup speed stated as lower limit, readings may be taken down to 0.4 m/s

RH and *v* data and omitted T_g due to numerous missing values. We have analyzed data from 11 AM to 3 PM, and omitted the first 30 to 45 minutes of measurements due to the acclimatization of the instruments. The recorded values were averaged at 5-min intervals and used in the further analysis.

Based on T_a and *RH*, we have calculated Humidex, a biometeorological and outdoor thermal comfort index, developed by Masterton and Richardson (1979). The advantage of using this index is that only two meteorological elements are needed for calculation making the index widely understood by the public. The disadvantages are that wind speed and mean radiant temperature are not included in the calculation.

Humidex (H) calculation was based on the Masterton and Richardson (1979) formula:

$$H = T_{AIR} + \frac{5}{9}\cdot\left(6.112\cdot 10^{\frac{7.5\cdot T_{AIR}}{237.7+T_{AIR}}}\cdot\frac{r_H}{100} - 10\right)$$

However, the calculation procedure itself was performed in Excel using formula transcribed by Vysoudil et al. (2016):

$$H = \frac{POWER\left(2.71828, 23.58 - \frac{4044.2}{235.6+T_{air}}\right)}{100\cdot\left(\frac{RH}{100}-10\right)\cdot\frac{5}{9}+T_{air}}$$

The range of Humidex values and the associated degree of comfort is given in Table 2. It can be seen that there is no discomfort when Humidex is less than 29. If Humidex is from low 30s to high 30s, certain types of outdoor exercise could be performed at a slower pace or modified, depending on the age and health of the individual, physical condition, clothes characteristics, and other weather conditions. Great discomfort with possible dangerous health consequences can happen when Humidex values are above 40. All unnecessary activities should be stopped in such conditions (McGregor et al., 2015).

Table 2. Humidex values and degrees of comfort

HUMIDEX values	Degree of comfort
Less than 29	no discomfort
30 to 39	some discomfort
40 to 45	great discomfort, avoid exertion
Above 45	dangerous
Above 54	heatstroke imminent

Results and discussion

We have observed micrometeorological differences between saline steppes, forest-steppes and oak forest in Srednja Mostonga region during the sunny autumn day. The highest T_a are noticed in more open areas of forest steppe and steppe, while the lowest T_a are observed in oak forest, as expected (Table 3). Although the forest area is small and it is a fragment of previously much larger forested area, it is still able to lower T_a up to 3.4 °C (Figure 5) when compared to steppe area during the afternoon hours. Similar results were obtained by Erdős et al. (2014) in southern Hungary. Differences in mean T_a between forest and forest-steppe are 1.3 °C. On the contrary, small T_a differences (< 0.5 °C) are obtained between forest-steppe and saline steppe (Figure 5). This is because the forest-steppe is more similar to steppe than to forest area, because it does not contain trees, yet higher and lower grass species. It is discussed among the researchers that altered microclimatic conditions within the forest patches (Tuff et al. 2016) and forest fragmentation is an important driver of biological impoverishment worldwide (Haddad et al. 2015). Due to that, it is important to preserve, improve and responsibly manage small forest fragments in Srednja Mostonga in order to save and improve its biodiversity and usage in the future. In order to do it, we need more measurement campaigns of air temperature and other parameters in fragmented forests, which was rarely done before (Arroyo-Rodríguez et al. 2017).

Highest *RH* is noticed in the forest as the most vegetated and "coldest" measurement location, while *RH* was lowest in forest steppe (Table 3). Maximum *RH* differences were up to 5-6% between steppe and two other locations (Figure 6). Similar results were obtained by Chen et al. (1993) and Magnago et al. (2015) who pointed out that relative humidity was lower at forest edges compared to the forest interior. This can be problematic because the combination of lower humidity and increased air temperatures can contribute to tree mortality at forest edges (Kapos, 1989; Laurance et al. 2001) and this should be taken into account when managing Srednja Mostonga region.

The measurement day was characterized by low wind speeds at all three locations (Table 3). The v was highly variable, yet the wind averaged over measurement period followed the pattern with the highest v in steppe and the lowest in forest. Forest-steppe had higher v compared to forest, and values were similar as in steppe. The largest differences were obtained between steppe and forest with up to 3.2 m/s higher v in steppe (Figure 7). Similar results were obtained

Table 3. Statistical characteristics of T_a, RH, v and Humidex at three measurement locations in Srednja Mostonga during 21st October 2019 (period 11 AM to 3 PM)

Station	Ta	RH	v	Humidex
Average values				
I saline steppe	24.8	50.2	2	27.9
II forest steppe	25.3	48.4	1.5	28.4
III forest	24.0	50.4	0.6	26.7
Max. values				
I saline steppe	29.3	59.6	3.9	32.7
II forest steppe	29.4	59	3.5	33.2
III forest	27.4	61.4	1.7	30.4
Min. values				
I saline steppe	20.5	38.4	0	22.7
II forest steppe	20.7	37.3	0	23.1
III forest	19.6	41.3	0	21.8
St. Deviation				
I saline steppe	2.1	6.4	0.7	2.1
II forest steppe	2.2	6.1	0.7	2.3
III forest	2.0	5.8	0.4	2.2

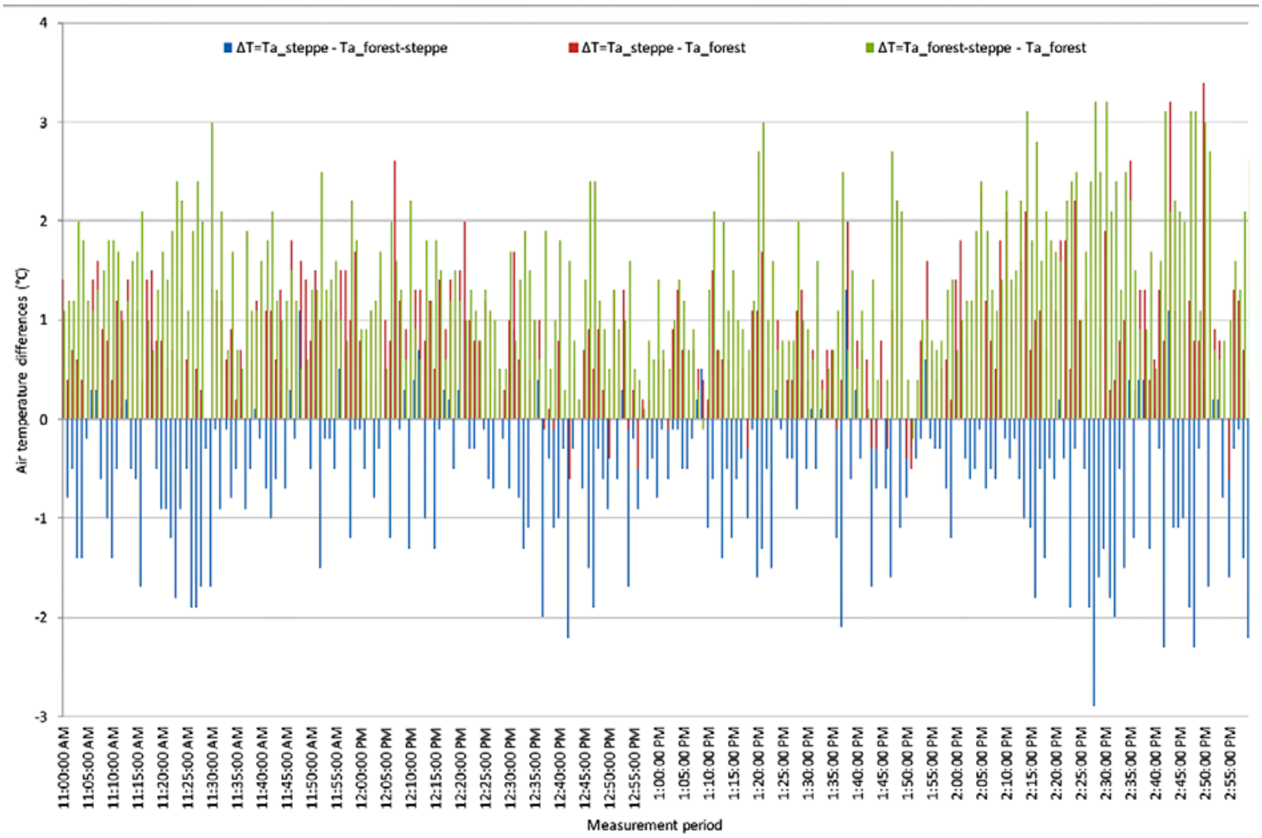

Figure 5. Air temperature differences between stations in steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019

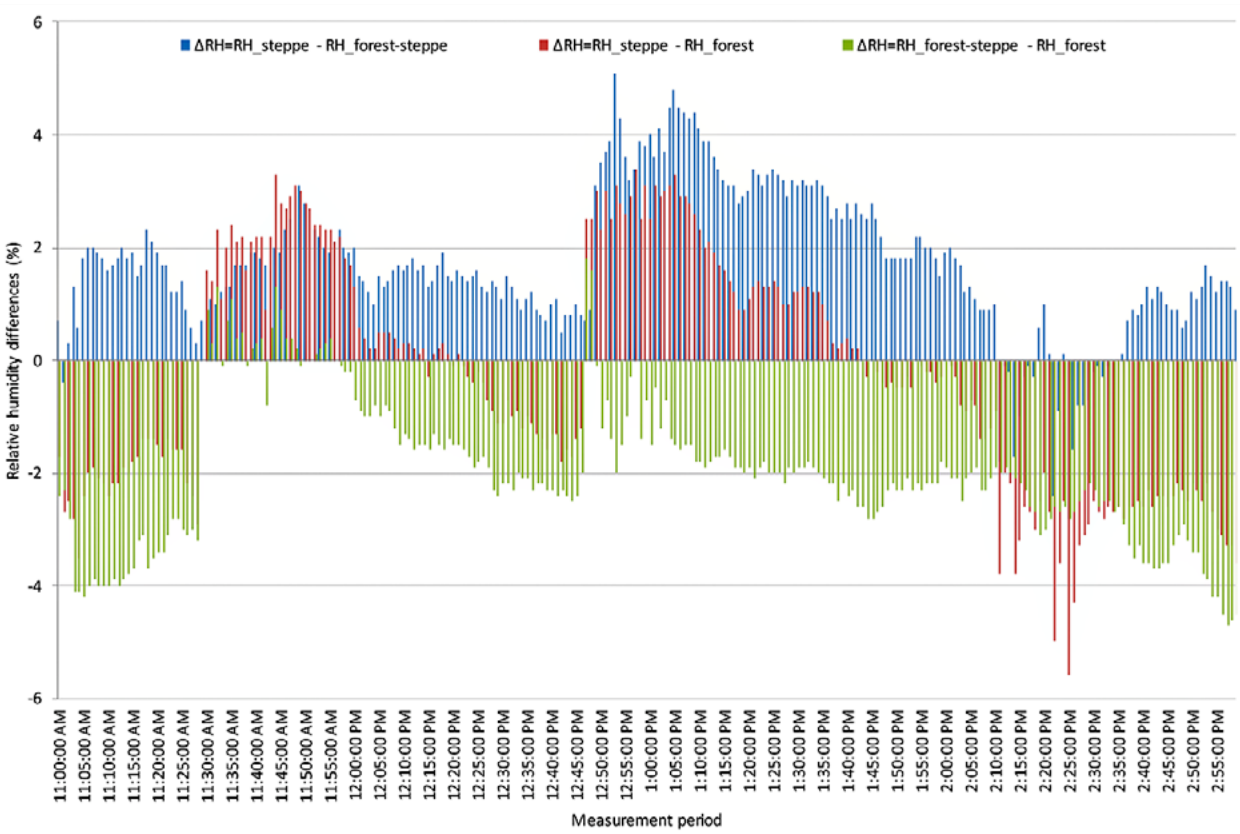

Figure 6. Relative humidity differences between stations in steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019

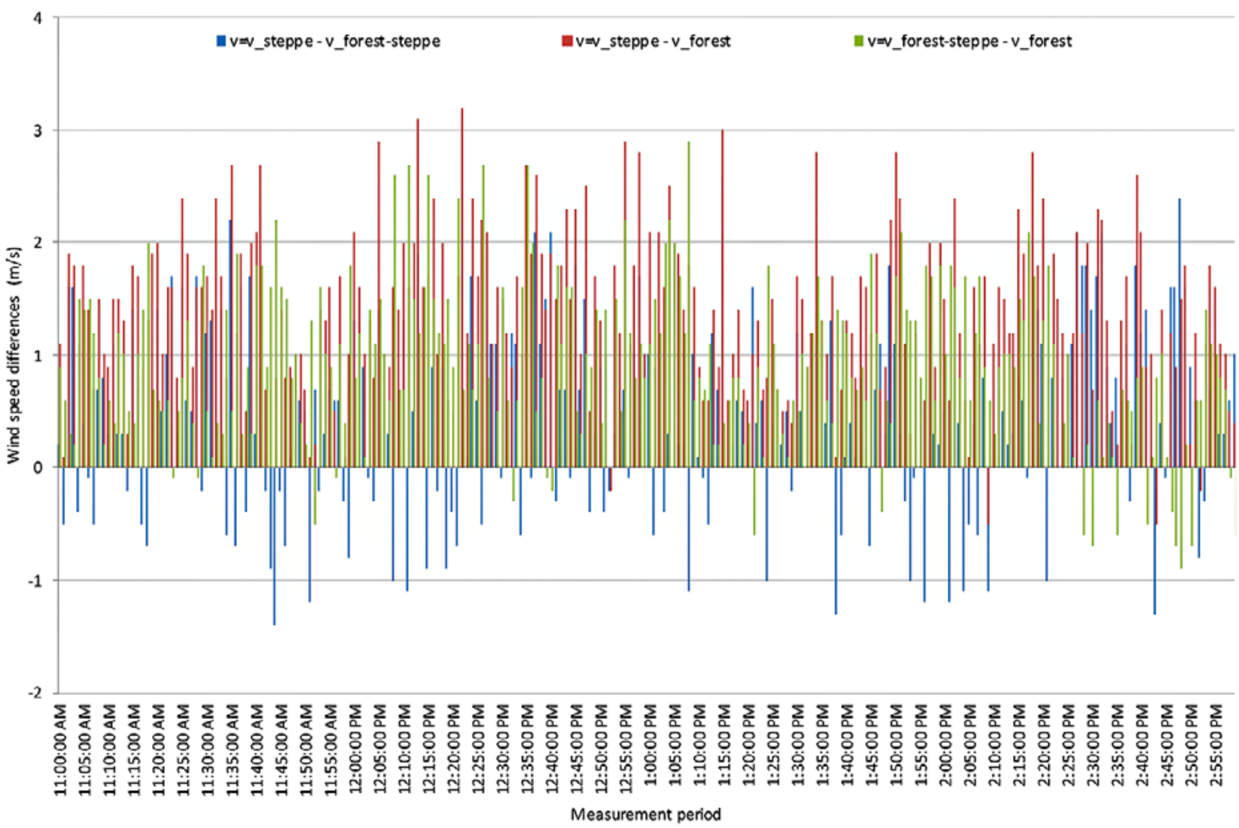

Figure 7. Wind speed differences between stations in steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019

by Davies-Colley et al. (2000) who pointed out that v was higher in pasture than in forest with the ratio of wind in forest to that in pasture (Mean ± SE) averaged 10 ± 3% in summer. Schindler et al. (2012) noticed that the interactions between airflow and trees and forest stands are quite diverse and include the reduction in near surface wind speed and production of turbulence by trees. As a consequence, near-surface wind conditions affect physiological processes in trees, their growth and survival (Ennos 1997; Eugster 2008). Accordingly, it is important to study the interactions between wind and forests in order to preserve its health and ecosystems services.

Analysis of the outdoor thermal comfort with the usage of Humidex showed that its lowest values are in the forest making it the most comfortable area for human activities (Table 3, Figure 8). On the contrary, forest-steppe and steppe have higher Humidex values. Forest-steppe location had on occasions Humidex values higher by 5 degrees compared to forest and steppe (Figure 8). Furthermore, some discomfort (Humidex between 30 and 39) was noticed during 13% of meas-

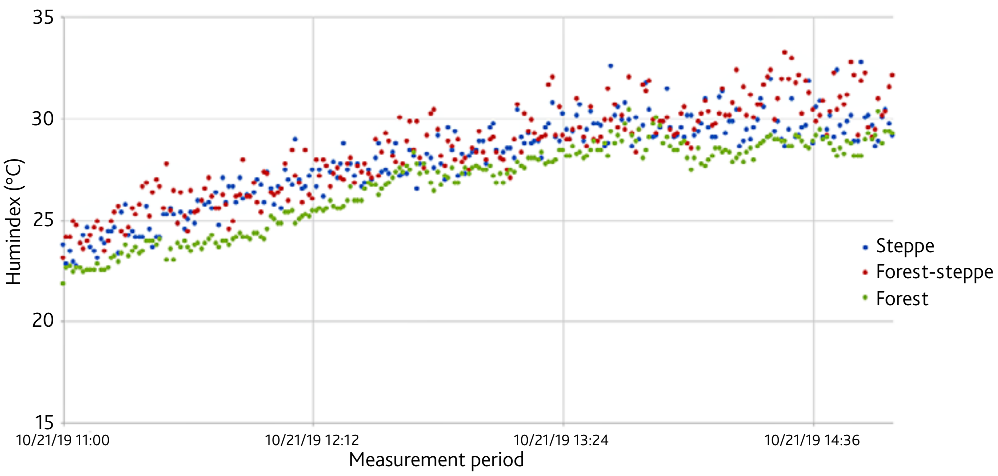

Figure 8. Humidex values in saline steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019 (period 11 h – 15 h)

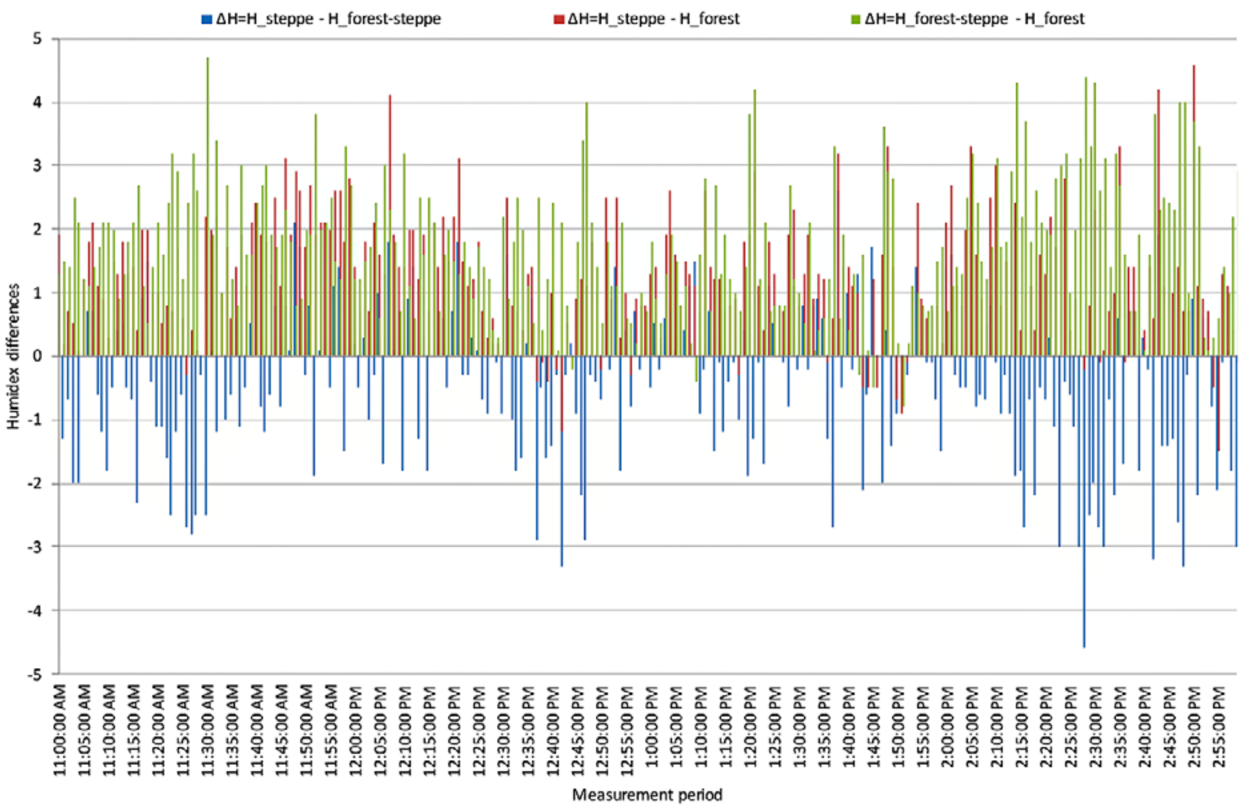

Figure 9. Humidex differences between stations in steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019

urement time in steppe and 27% in forest-steppe making them less comfortable areas for outdoor touristic activities. In contrast, only 1% of measurement time in forest was characterized by some discomfort (Figure 9). Similarly, Kamoutsis et al. (2007) noticed that forest areas had a more comfortable climate with more frequent occurrence of "comfortable" weather compared to the nearby urban area. Even in the urban areas, high green coverage and low sky view factor lead to lower Humidex values (Charalampopoulos et al. 2013).

These results are important when planning tourist activities in these diverse natural areas. For example, during the warmest daytime hours touristic activities should be performed in forest, while early morning and evening hours (Figure 8) should be spent in steppe and forest-steppe. Although Humidex does not incorporate wind speed and mean radiant temperature into thermal comfort and heat stress assessment, its simplicity makes it easier to use by numerous practitioners which is an advantage when compared to other more complex indices.

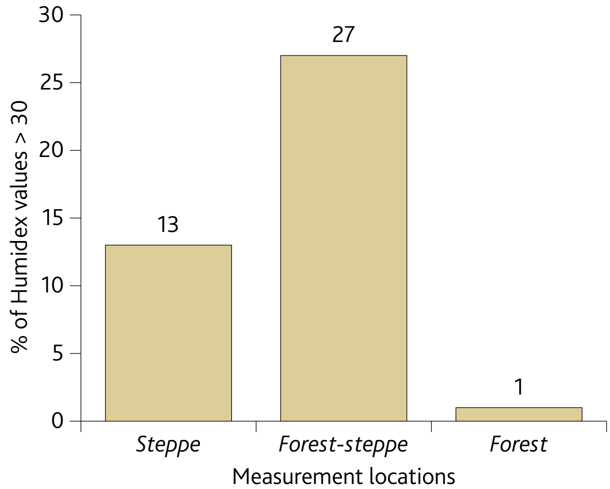

Figure 10. Frequency (%) of Humidex values above 30 representing at least some discomfort in steppe, forest-steppe and forest in Srednja Mostonga on 21st October 2019

Conclusions

The area of Srednja Mostonga, soon to be protected as the "*region of exceptional characteristics*", with its specific vegetation represents rather rare and significant habitat for the number of species. Since this area consists of rather vulnerable habitats, activities of any kind must be well planned and properly managed. In order to provide useful information for both destination management and interested visitors, we conducted initial measurements of microclimatic conditions in the area of Srednja Mostonga. Microclimatic measurements were performed in three different types of saline habitats (saline steppe, forest-steppe and forest) due to their different vegetation structure which affects microclimatic conditions.

The results of the initial short-term measurements showed that there are certain differences between microclimatic conditions in three different sites, even though the measurement stations were located at relatively short distance. Vegetation structure influences differences in air temperature, relative humidity and wind velocity, which affects thermal comfort. At the same time microclimatic conditions are affecting fragile saline species and habitats, by determining their ecological valences. Nature based recreational, educational and touristic activities require comfortable outdoor thermal conditions. In this study we used Humidex index for outdoor thermal comfort assessment. The results of outdoor thermal comfort assessment showed that the most comfortable thermal conditions are in the forest area during the entire measurement period, while the values of Humidex showed slight discomfort in saline steppe and forest-steppe areas in the afternoon warmest hours. Maximum Humidex values show up to the 2.8 degrees difference between forest (30.4), saline steppe (32.7) and forest-steppe areas (33.2). This information indicates that the activities in the investigated sights should be organized according to the most comfortable period of the day. For example, in the morning hours thermal conditions are more favorable at steppes and forest-steppes, and during the warmest period of the day, the conditions are more comfortable in the forest.

Micrometeorological measurements of this kind provide valuable information for tourism zoning and visitors distribution according to the most comfortable hours of the day, which contributes to sustainable management of tourism activities. Since this study is the first micrometeorological field measurement conducted in this region, even though it was a short-term measurement, it gave important insights into micrometeorological differences between different natural environments. In order to contribute to long-term strategic planning of the activities and their sustainable management, longer measurements during different seasons, measurement of nighttime meteorological values and soil temperatures (e.g. Lehnert et al., 2015) would be beneficial.

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Regional Inequalities in the Visegrad Group Countries, Serbia and Croatia

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Abstract

The paper discusses the evaluation of regional inequalities in the V4 countries, Serbia and Croatia. The gross birth rate, the unemployment rate, the average monthly gross earnings, the gross domestic product per capita in purchasing power parity and dwellings completed per 1000 inhabitants were selected as a set of evaluation indicators and, to determine the level of regional inequalities the Gini Coefficient and the Coefficient of Variation in two variants were used – in all the counties as well as after excluding the capital cities. The integrated indicator of socio-economic status based on the above-specified indicators revealed the prevailing dichotomy of the prosperous west vs. the problematic east in the majority of the countries, the most significantly in Slovakia. This country together with Hungary recorded (mainly thanks to the significant effect of the capital city) the most significant inequalities while the less significant ones were in the Czech Republic, Serbia and Croatia. The strong effect caused by the capital city was confirmed almost in all the countries except for Poland. The level of the dependence between the socio-economic status of the countries and the level of their inequalities was confirmed only partially.

Keywords: Croatia; regional inequalities; Serbia; socio-economic status; Visegrad Group countries; west-east dichotomy

Introduction

A growing spatial inequality is the chief present-day problem of socio-economic development from the geographic and economic point of view. In the recent years, disparities have become a great point of interest of geographical and economic sciences, as manifested by the fast-growing number of publications on the subject (Czyż & Hauke, 2011).

The seriousness of the matter is proven not only by the widespread academic discussion, but it is also perceived by the general public and, its intensification is looked at as something negative. This view of regional inequalities is one of the main reasons for the research.

This paper focuses on the evaluation of regional inequalities in six selected countries. The first four ones – the Czech Republic, Poland, Slovakia and Hungary have been closely cooperating for nearly 30 years as the Visegrad Group countries (abbreviated to the V4 countries). Since 2004, they have been the EU members. The remaining two countries, Serbia and Croatia, were a part of Yugoslavia in the 1990s. Croatia became the EU Member State in 2013 and Serbia is a candidate country. The development trajectories of the evaluated countries vary, however, each of them went or is going through an intensive transformation process that commenced in the 1990s. This process revealed the real economic performance of the countries and their regions that manifested itself as various levels of forming regional inequalities.

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Theoretical Background

In the broadest sense, disparities are understood as a divergence or inequality of characters, phenomena or processes, the identification and comparison of which make some rational sense (cognitive, psychological, social, economic, political) (Kutscherauer et al., 2010). It is an inequality or a divergence caused by essential tendencies in the development of the society which is a significant level of its variability resulting in uneven development (Hučka et al., 2008).

There are two essential approaches to their evaluation, a positive and a negative one (Majerová, 2012). Kutcherauer and Hučka (2011) designate the negative approach as a 'disparite approach' that sees regional inequalities as weaknesses. It is reckoned as a dominant approach while numerous authors recommend introducing measures to stop their increase (Gurgul & Lach, 2011), because differences in regional development are not favourable for the socio-economic development of the whole country, and what is more, they are damaging (Czyż & Hauke, 2011). On the other hand, excessive endeavours to reduce inequalities may lead to overall stagnation of socio-economic development of the whole country (Blažek & Csank, 2007).

Regional inequalities started to fully manifest themselves in the countries of Central and Eastern Europe ('CEE') because of political and economic changes in the early 1990s. As quoted by Lackenbauer (2004), until then, the countries have lost out on at least half a century of 'normal' economic development. The nature of their growth caused serious structural deformations in their economies that made them highly ineffective when compared to Western Europe. The transformation from centrally-planned economy to western-style democracy and market economy caused the dramatic development of changes in their economic, social, ecologic and spatial development (Miljanović et al., 2010).

At the beginning of the transformation process, the countries shared remarkably similar low level of inequality. As the time went, the situation dramatically changed and inequality diverged considerably (Ivančev et al., 2010).

According to Monastiriotis (2013), the changes in the early 1990s encouraged the polarization trend when central places (mainly capitals and their hinterlands) were growing faster, benefiting from the concentration of financial and political capital, a higher share of FDI and sufficient qualified workforce as well as the basic trend of East-West dichotomy supported by differences from the point of proximity to the 'Western core' (the so-called blue banana).

In this context, Lackenbauer (2006) points out to two types of winners, represented by metropolitan regions (mainly capitals) and the regions neighbouring the old EU Member States, and two types of losers, that are rural and declining industrial areas as well as regions in Eastern peripheries.

Similarly, Kisiała and Suszyńska (2017) drew attention to the trend of increased interregional inequalities in initial phases of national economy growth and consequent interregional convergence. According to them, this mutual dependence may be explained by the fact that, in insufficiently developed countries, there were few regions that would be proud of having attributes of so-called 'growth poles'. In these areas, it was possible to monitor growing productivity and increased pace of growth compared to the other regions in the country thanks to a high concentration of production factors, better technical equipment and workforce offer. These growth poles were the metropolitan areas in the majority of developing countries, often also the regions of their capitals. According to Domański (2011), these areas are the most obvious winners of the post-socialist transformation. They benefit from the development of advanced producer services and the location of new manufacturing plants, being the most attractive place for both, foreign investments and the growth of small- and medium-sized indigenous firms. Partners for cooperation can be more easily found here, so large investors are more likely to become regionally embedded.

The initial divergence caused by faster growth of economically strongest regions manifested itself first as spatial polarization. Along with gradual growth of economies in transforming countries, the processes of spreading growth impulses to other regions should lead to spatial balance and the elimination of inequalities (Bogumił, 2009; Gurgul & Lach, 2011; Smętkowski, 2014; Kisiała & Suszyńska, 2017; Fecková Škrabuľáková et al., 2019).

Transformation steps, the gradual progress of CEE countries and their approach to the economic levels of the former EU-15 countries in the first decennium of the 21st century remarkably accelerated due to their accession to the EU. Both, direct and indirect impacts of their accession to the EU, as well as favourable world economic environment until the economic crisis in 2008 are considered by Smętkowski (2014) as the main accelerators of their development.

The financial and economic crisis slowed development down in almost all the countries and the first indications of a return to economic growth were observed in 2012 and 2013. As referred by Klamár et al. (2019b), in Slovakia, the years of economic crisis meant the stagnation or the decrease of inequalities and since 2013 their gradual increase has been observed.

Methodology

In assessing regional inequalities, it is necessary to solve several methodological problems. It is necessary to define the observational level of the evaluated territorial units, determine the choice of adequate indicators for the assessment as well as to select the appropriate statistical tools for their measurement (Matlovič & Matlovičová, 2005, 2011).

When selecting appropriate hierarchical level of compared territorial units, the lower level of the observational unit, the more growing problem of the availability and relevance of observed data and time series (Klamár, 2016). In international comparisons, mainly levels NUTS 2 and NUTS 3 are used. While Eurostat evaluates the majority of indicators on level NUTS 2, level NUTS 3 describes the monitored problem in details; however, less statistical data are available. Also, this paper uses level NUTS 3, and in the case of the Czech Republic there are 14 counties, in Slovakia 8, in Hungary 20, in Poland 73, in Croatia 21 and in Serbia 30 (5 counties were without input data), that were jointly marked as counties for sake of the better comparison (in the Czech Republic and Slovakia they are called 'kraje', in Poland – 'podregiony', in Hungary – 'megyék', in Serbia – 'okruzi', in Croatia – 'županije').

Another step was to choose evaluation indicators and that was alike influenced by data availability. Five indicators were chosen for the evaluation purposes, namely the gross domestic product per capita in purchasing power parity (PPP) (adjusted by the price level indices in the particular country), the gross birth rate (abbreviated to: birth rate), the unemployment rate, the average monthly gross earnings (abbreviated to: monthly earnings) and dwellings completed per 1000 inhabitants (abbreviated to: dwellings completed.) These indicators were for 2018 (only GDP per capita in PPP – 2016 and monthly earnings in Croatia – 2017) and had the same weight in evaluation. The selection of the indicators was conditioned by already mentioned availability of data from the evaluated counties on the NUTS 3 level (counties) as well as by their informative capability in relation to economic, social and demographic development. The most crucial and complex indicator is the economic indicator the gross domestic product per capita that characterizes the economic prosperity or the underdevelopment of a region from the point of its production potential. It is suitable to evaluate the maturity of economics and the intensity of regional development. Another indicator is the average monthly gross earnings reflecting the disposable resources to satisfy the basic life needs and to assure consumer standards. The economic indicator with a remarkable social subtext is the unemployment rate representing the share of disposable registered number of the unemployed to the number of economically active inhabitants. The gross birth rate is an important demographic indicator that shows the reproduction vitality and the perspective of individual regions. Quality and available housing shown by the dwellings completed per 1000 inhabitants is an important factor influencing workforce mobility.

For purposes comparison, the monthly earnings in the Czech Republic, Hungary, Poland, Croatia and Serbia were converted to euro using the average annual exchange rate in the monitored period. The issue of the selection of indicators of regional inequalities is discussed in detail for example in the work of Ancuța (2012).

In order to make the first evaluation of indicators we used the integrated indicator – socio-economic status (e.g. in the work of Klamár et. al., 2019a), the construction of which came out of the point method. The basis for the comparison of each indicator was its highest level achieved in any of the counties. The highest value was 100 points, this was the basic quantity when compared to other counties, and it was used for comparisons of values achieved in every indicator in other counties. The value per each county was the result of addition of values per individual indicators (max. 500 p.). In this part of the analysis, we defined the first hypothesis **H1** in which we presumed that the counties in the western parts of the evaluated countries have a higher level of socio-economic status than the counties in the eastern parts. On the map of socio-economic status, we marked the numbers of the counties in the highest quartile with a circle and in the lowest one with a square (Fig. 1 in the annex).

The next step was to choose statistical tools to measure inequalities. There are more indexes which can be used, e.g. the coefficient of variation, the Gini coefficient, the Theil index, the Hoover index, the Atkinson index, the real convergence method, etc. The most frequently used are the coefficient of variation and the Gini coefficient that are used individually or jointly by numerous authors and that were also used in this paper (coefficient of variation – CV, Gini coefficient – IG). The coefficient of variation is a relative measure of dispersion derived from the standard deviation σ (the ratio of the standard deviation and the mean)

$$CV = \frac{\sigma}{\overline{x}} = \frac{\sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}}}{\overline{x}}$$

where n is the total number of territorial units, x_i is the value of the indicator x in territorial unit i and is the arithmetic mean of the indicator x.

An advantage of the coefficient of variation is the fact that it is not dependent on the measured values of the input indicators. It enables mutual comparison of variability of variable and different values (Michálek, 2012). The drawback of the coefficient of variation is that the result value depends of mean and causes the loss of sensitiveness to extreme values (Rusnák, 2012).

The second statistical measure was the Gini coefficient, which originated as a tool to measure income inequality. It ranges between 0 (absolute equality) to 1 (absolute inequality).

$$IG = \frac{1}{2n^2 \cdot \overline{x}} \cdot \sum_{i=1}^{n} \sum_{j=1}^{n} (x_i - x_j)$$

where n is the total number of territorial units, x_i is the value of the indicator in the i-territorial unit, x_j is the value of the indicator in the j-territorial unit and is the arithmetic mean of the indicator x.

An advantage of the Gini coefficient is its independence of mean and rather low sensitivity to extreme values (Cowell & Flachaire, 2007 In Nosek & Netrdová, 2010). Its only drawback is that it does not comply with the decomposability condition i.e. the calculated value of the Gini coefficient in a country as a whole is different from the total value of the Gini coefficients calculated per individual counties in the country.

In this part, we define hypothesis **H2**, in which we presume the lowest level of inequalities in the countries in the gross birth rate as the only non-economic indicator and hypothesis **H3**, in which we presume that the level of regional inequalities is lower in terms of average monthly gross earnings in the evaluated countries than the unemployment rate, just like it was pointed out by Puljiz and Maleković (2007) in Croatia.

Apart from the analysis carried out as described above, we also evaluated regional inequalities using both said coefficients from the point of importance of their capitals (Lackenbauer, 2006; Bogumił, 2009; Monastiriotis, 2013; Smętkowski, 2014; Illieva, 2015 etc. pointed out to the importance of their influence to regional inequalities in the CEE countries). That is why we have excluded the counties of the capital cities from the evaluation so that it was possible to define the level of inequalities without their impact. We have made hypothesis **H4**, in which we presume a significant decrease of regional inequalities in the observed countries after the exclusion of their capital cities.

As the last step, we evaluated the level of dependence between the socio-economic status of the evaluated countries and the level of their inequalities. The socio-economic status of the countries was evaluated using the set of the same five indicators (however, on the national level in this case), while applying the point method again. The socio-economic status was consequently correlated with the level of regional inequalities in two variants – all the counties and without their capitals. To define dependence, we used the regression and the correlation analysis where the socio-economic status of a country was an independent variable and the size of regional inequalities (in both variants) was a dependent variable. The suitability of the linear regression model was verified by ANOVA (Analysis of Variance) in the program STATISTICA, where the null hypothesis Ho was tested: 'The model is not appropriate for use'. The F value represented test characteristics, whose significance was given by the p-value indicating the smallest possible level of significance for rejection of the null hypothesis. When the p-value was ≤0.05, the null hypothesis was rejected at a given significance level α = 0.05. Regarding the fact that strict criteria to classify the values of the Pearson correlation coefficient into separate groups according to the level of dependence intensity do not exist, we relied on established practice and the data character (e.g. works by Gregorová & Fillová, 2004; Chajdiak, 2009). The Pearson correlation coefficient R was the rate to appraise the power of linear dependence, the absolute values of which approaching to 1 indicated the growth of power of the relation between country's socio-economic status and the size of its regional inequalities. To the contrary, the more R-values approached to 0, the more grew the independence between the evaluated indicators.

Despite the fact that the Pearson correlation coefficient is suitable and a frequently used coefficient to express the intensity of linear dependence, we miss similar indexes to express the strength of dependence in non-linear regression models (also regarding the intricacy of the regression function). The Pearson correlation coefficient to the power of two makes the coefficient of determination. The coefficient of determination R^2 expressed as a percentage of the variation of the dependent variable explained by the variation in the independent variable. At this stage, we defined hypothesis **H5** saying that the level of regional inequalities grows together with the decrease in the socio-economic status of the countries. This hypothesis is based on the work of Szörfi (2007), who stated that the size of regional inequalities as well as their growth was higher in the least developed countries.

Results

In the first part of the analysis we used the point method that revealed the spatial distribution of prosperous and lagging counties (Fig. 1, tab. 4 in the annex) using the integrated indicator socio-economic status arising from five indicators (Fig. 2-6 in the annex). We presumed that the counties in the western parts of the countries would have a higher level of socio-economic status than the counties nearby the eastern borders. Thus, hypothesis **H1** was confirmed only partially. The most significantly it was confirmed in **Slovakia**, where the economically strongest counties, Bratislava county (370.0 p.) and Trnava county (258.6 p.), are located on the west of the country and, the weakest ones are on the east or the south-east (Banská Bystrica – 177.0 p., Prešov – 187.4 p.). This west-east polarization is strongly reinforced by the eccentric location of the capital city Bratislava on the west. In the **Czech Republic**, the capital city Prague is centrally located and is slightly oriented to the west. In this area, there are also strong counties such as the Capital City of Prague (370.6 p.), Central Bohemian county (284.7 p.) and Plzeň (281.9 p.). Despite the fact, that economically weaker counties are situated on the northeast (Olomouc, Moravian-Silesian), the west-east gradient is disturbed by Karlovy Vary and Ústí nad Labem counties on the north-west. As to **Hungary**, economically strong counties create a continuous stretch from the Capital City of Budapest (264.9 p.) to the west (Győr-Moson-Sopron – 296.9 p., Komárom-Esztergom – 233.3 p.). In this country, rather north-south and north-southeast gradient was confirmed with economically weak counties neighbouring Croatia (Baranya – 155.8 p.) and Romania (Békés – 155.2 p., Szabolcs-Szatmár-Bereg – 156.1 p.). The predominant west-east dichotomy can be observed in **Croatia**, where the counties located to the west of the Capital City of Zagreb county (260.0 p.), towards the coast create an economically prosperous part of the country (mainly Zadar county – 218.7 p. and Istria – 213.2 p.) and to the east, there is one lagging behind (Vukovar-Srijem – 147.7 p., Virovitica-Podravina – 149.8 p.). In **Serbia**, there is a dominant northwest-southeast orientation, where there are prosperous counties such as the Capital City of Beograd county (189.9 p.) and the South Bačka (178.8 p.) on one side, and, on the other side are the economically weakest counties not only in Serbia, but also in all the evaluated countries (Zaječar county – 99.1 p., Rasina – 115.6 p., Bor – 117.3 p.). In **Poland**, the location of prosperous counties is significantly associated with the counties of big cities such Warszawa (449.4 p.), Wroclaw (387.5 p.), Poznań (381.5 p.), Kraków (359.0 p.) and Trójmieski (334.3 p.). The lagging regions are located in the peripheral areas among them and their highest concentration is observed at the eastern borders (e.g. Chelmsko-Zamojski county – 159.3 p., Przemyski – 171.9 p., Krośnienski – 173.2 p.). Despite this fact, the west-east dichotomy is very weakly identifiable.

Level of Regional Inequalities

Building on the results of the Gini coefficient and the coefficient of variation (tab. 1) it is evident that the **Czech Republic** has the lowest level of regional inequalities considering all the indicators. A very low level was found both in the birth rate (IG – 0.029, CV – 0.058) and in the monthly earnings (0.043; 0.103). Relatively high balance among the Czech counties was confirmed by the GDP per capita in PPP (0.134; 0.376) and the unemployment rate (0.153; 0.289), while the highest inequalities were in the dwellings completed (0.195; 0.367). A low level of inequalities was also observed in **Serbia**, in two indicators it had the second lowest value after the Czech Republic (monthly earnings – 0.050; 0.100 and unemployment rate – 0.184; 0.351) and in another two indicators at least in one coefficient (completed dwellings – 0.577 and GDP per capita in PPP – 0.341). The highest inequalities, compared to the other countries, were only in the birth rate (0.078; 0.143). A little higher level of inequalities was observed in its neighbour, **Croatia** having comparable or only a little higher values than the Czech Republic in two indicators, the GDP per capita in PPP (0.156; 0.334) and the birth rate (0,050; 0,092), and only in case of dwellings completed it had second highest inequalities after Hungary (0.391; 0.812). Only a little higher level of inequalities was in **Poland**, where only the GDP per capita in PPP showed the second highest level of inequalities after Slovakia (0.195; 0.425). The highest inequalities were proven in **Hungary** and **Slovakia**. Both countries showed the highest or the second highest level of inequalities in almost all the indicators (Hungary in three indicators, Slovakia in four).

An overall comparison of the regional inequalities using the individual indicators in the evaluated countries reveals that it was definitely the gross birth rate that had the lowest level of inequalities in all the countries (tab. 1), and so the validity of hypothesis **H2** was fully confirmed. Even the validity of another hypothesis **H3** was fully confirmed, because the higher level of inequalities in the unemployment rate than in monthly earnings in all the countries was observed. The most significant difference was in Croatia (difference 4.8-times in IG and 4.3-times in CV) and the lowest was in the Czech Republic (IG – 3.6-times, CV – 2.8-times).

Table 1. Regional inequalities in the selected countries including the capital city and without it

		All counties						Without the capital city						Difference (%)					
		CZ	HU	PL	SK	RS	HR	CZ	HU	PL	SK	RS	HR	CZ	HU	PL	SK	RS	HR
Birth rate	IG	0.029	0.053	0.067	0.076	0.078	0.050	0.024	0.054	0.066	0.061	0.074	0.047	-17.2	1.9	-1.5	-19.7	-5.1	-6.0
	CV	0.058	0.098	0.120	0.145	0.143	0.092	0.048	0.100	0.119	0.118	0.138	0.088	-17.2	2.0	-0.8	-18.6	-3.5	-4.3
Monthly earnings	IG	0.043	0.071	0.065	0.073	0.050	0.055	0.023	0.056	0.060	0.030	0.039	0.043	-46.5	-21.1	-7.7	-46.6	-22.0	-21.8
	CV	0.103	0.139	0.125	0.160	0.100	0.109	0.045	0.102	0.113	0.076	0.070	0.078	-56.3	-26.6	-9.6	-52.5	-30.0	-28.4
Unempl. rate	IG	0.153	0.282	0.241	0.274	0.184	0.264	0.145	0.286	0.235	0.263	0.187	0.248	-5.2	1.4	-2.5	-4.0	1.6	-6.1
	CV	0.289	0.536	0.433	0.543	0.351	0.472	0.274	0.543	0.422	0.517	0.354	0.444	-5.2	1.3	-2.5	-4.8	0.9	-5.9
GDP per cap. (PPP)	IG	0.134	0.187	0.195	0.223	0.168	0.156	0.056	0.138	0.174	0.089	0.139	0.122	-58.2	-26.2	-10.8	-60.1	-17.3	-21.8
	CV	0.376	0.421	0.425	0.560	0.341	0.334	0.103	0.274	0.344	0.180	0.260	0.239	-72.6	-34.9	-19.1	-67.9	-23.8	-28.4
Dwellings completed	IG	0.195	0.410	0.302	0.316	0.316	0.391	0.194	0.416	0.289	0.210	0.316	0.398	-0.5	2.2	-4.3	-33.5	0.0	1.8
	CV	0.367	0.845	0.648	0.695	0.577	0.812	0.375	0.883	0.621	0.445	0.583	0.846	2.2	4.5	-4.2	-36.0	1.0	4.2

Source: own elaboration, Note: CZ - Czech Republic, HU - Hungary, PL - Poland, SK - Slovakia, RS - Serbia, HR - Croatia; green colour – two lowest levels of inequalities, orange and light orange colours – two highest levels of inequalities, green numbers with a minus – decrease in inequalities, red numbers – increase of inequalities

The capital cities of the CEE countries have, as mentioned above, a significant impact on the intensity of regional inequalities, and that is the focus of the following analysis. We observed a decrease in inequalities in all the evaluated countries after excluding the capital city, with regard to the majority of the indicators (tab. 1). The most significant it was in the **Czech Republic** and **Slovakia**. The effect of a capital city manifested itself the most in GDP per capita in PPP, where there was a decrease in IG as much as by 58.2% (CZ) or 60.1% (SK) and in CV (72.6%, 67.9%) and in the monthly earnings (IG – 46.5%, 46.6%; CV – 56.3%, 52.5%). A slighter decrease of inequalities was also observed in the birth rate (IG – 17.2%, 19.7%; CV – 17.2%, 18.6%), in Slovakia, there was also a more significant decrease in completed dwellings (IG – 33.5%, CV – 36.0%). Therefore, the capitals, Prague and Bratislava, have a significant impact on the level of regional inequalities in these countries and after their exclusion, the Czech Republic even more confirmed its position of a country with the lowest inequalities and Slovakia, a country with the highest inequalities, became a country with the second lowest level. The second group is formed by **Hungary**, **Serbia** and **Croatia**, where there was a perceptible decrease of inequalities after excluding Budapest, Beograd and Zagreb in two indicators on a comparable level: GDP per capita in PPP (IG – 26.2% HU, 17.3% RS, 21.8% HR; CV – 34.9%, 23.8%, 28.4%) and monthly earnings (IG – 21.1% HU, 22.0% RS, 21.8% HR; CV – 26.6%, 30.0%, 28.4%). As for the remaining indicators, the difference was only up to 6.1%. The given findings show a lower impact of these capital cities on regional inequalities than in the case of Prague and Bratislava. Hungary remained, even after the exclusion of the capital, a country with high inequalities, in Serbia and Croatia no notable change was monitored and remained in the position of the countries with the medium level of inequalities. The lowest decrease of inequalities was noticed in **Poland** where, after the exclusion of Warszawa, the decrease was max. by 10.8% (IG) and 19.1% (CV) in GDP per capita in PPP. Concerning the rest of the indicators, the change was up to 9.6%. In comparison, it would mean that Poland was one of the countries with the highest inequalities in as many as three indicators (GDP per capita in PPP, monthly earnings, birth rate). In this case, the strong influence of the polycentric structure of settlements in Poland with numerous big cities as well as the size of the country itself was confirmed. Now, we can affirm only limited validity of hypothesis **H4**, while the dominant effect of the influence of a capital city was confirmed notably in the economic indicators such as GDP per capita in PPP and monthly earnings and in the case of the countries, it was in the Czech Republic and Slovakia.

Table 2. Socio-economic status (points) in V4 countries, Serbia and Croatia

	Birth rate (‰)		Month. earnings (€)		Unempl. rate (%)		GDP per capita in PPP (€)		Dwellings compl.		SES (points)
CZ	10.73	**100.0**	1 313	**100.0**	3.07	**100.0**	25 642	**100.0**	3.19	**66.1**	**466.1**
HU	9.19	**85.6**	1 035	**78.8**	3.71	**82.7**	19 572	**76.3**	1.81	**37.6**	**361.0**
PL	10.11	**94.2**	1 135	**86.4**	5.80	**52.9**	19 965	**77.8**	4.82	**100.0**	**411.3**
SK	10.59	**98.6**	1 013	**77.2**	5.04	**60.9**	21 245	**82.8**	3.50	**72.6**	**392.1**
RS	9.16	**85.4**	582	**44.3**	12.70	**24.2**	11 310	**44.1**	2.59	**53.7**	**251.7**
HR	9.04	**84.2**	1 113	**84.7**	11.10	**27.7**	17 799	**69.4**	2.48	**51.5**	**317.5**

Source: own elaboration, Note: CZ - Czech Republic, HU - Hungary, PL - Poland, SK - Slovakia, RS - Serbia, HR - Croatia; SES – Socio-economic status

The last step was to evaluate the level of dependence between socio-economic status and the level of their regional inequalities using five monitored indicators (tab. 1). The highest level of socio-economic status was observed in the Czech Republic (466.1 p.), the next were Poland (411.3 p.) and Slovakia (392.1 p.), followed by Hungary (361.0 p.), Croatia (317.5 p.) and the lowest level was noticed in Serbia (251.7 p.) (tab. 2).

The measure of dependence between the socio-economic status of the countries and the level of their regional inequalities was investigated using the Pearson correlation coefficient R that was calculated for all the counties in the countries both including and excluding their capitals. The obtained data (tab. 3) prove that the inequalities in the monthly earnings, the unemployment rate and the GDP per capita in PPP (for all the counties) almost do not correlate with the level of socio-economic status of the countries and the linear regression model for their territorial expression is not suitable. In all three indicators, there were values very close to zero, which implies that **H5** was not confirmed.

The inequalities noticed in the birth rate were increasing along with the decreasing level of socio-economic status. It was likely in dwellings completed where, along with the decrease of inequalities, the level of socio-economic status rose. The suitability of the regression model was not confirmed despite moderate high correlation. Therefore, hypothesis **H5** was neither accepted nor refuted with regard to the suitability of the model.

The level of dependence predominantly increased after excluding the capital cities. In general, we can state that no significant correlation dependence between the socio-economic status and inequalities in monthly earnings and the unemployment rate was proven. The inequalities in the birth rate, the GDP per capita in PPP and dwellings completed negatively correlated with the level of socio-economic status. The highest levels of correlation were observed in the regional inequalities in the birth rate, where the absolute value of the Pearson correlation coefficient R exceeded 0.64. Despite higher values of R, even in this case it is not possible to accept hypothesis **H5** and pronounce a definite conclusion about at least a part of the evaluated indicators, because even in relatively high correlation, the model was not suitable for the use. The decreasing character of the regression line in all the indicators (in case of exclusion of the capitals) implies that the level of inequalities grows together with the decrease of socio-economic status.

Table 3. Rate of dependence between socio-economic status of the countries and their regional inequalities

		All counties		Without the capital city	
		R	R2	R	R2
Gross birth rate	IG	-0.5580	0.3114	-0.6404	0.4101
	CV	-0.5315	0.2825	-0.6461	0.4174
Average monthly gross earnings	IG	0.0438	0.0019	-0.2173	0.0472
	CV	0.2596	0.0674	-0.1084	0.0117
Unemployment rate	IG	-0.1370	0.0188	-0.1860	0.0346
	CV	-0.1202	0.0144	-0.1652	0.0273
GDP per capita in PPP	IG	-0.0244	0.0006	-0.4558	0.2078
	CV	0.4078	0.1663	-0.4151	0.1723
Dwellings completed per 1000 inhabitants	IG	-0.5889	0.3468	-0.5947	0.3537
	CV	-0.4248	0.1804	-0.4801	0.2305

Source: own elaboration

Discussion

The country with the lowest regional inequalities is the Czech Republic and that was confirmed by all the indicators. By contrast, Hungary and Slovakia showed the highest level. Poland presented a medium level of differences. Similar conclusions were published by Smętkowski (2014), who also confirmed the lowest level of inequalities in the Czech Republic; Poland and Hungary were the countries with a medium level of inequalities and Slovakia was the one with the most significant differences and polarization thanks to fast growth of Bratislava. The named author also pointed out to the size of inequalities after the exclusion of the capital cities where there was the most notable decrease of inequalities in Slovakia and lower in Poland thanks to its polycentric system of settlement. Similarly, some other works such as by Lackenbauer (2006), Monastiriotis (2013), Matlovič et al. (2018), Marošević and Sekur (2018) indicated the importance of a capital city from the point of inequalities within the meaning of their decrease after excluding the capital city.

According to Lackenbauer (2006) inspired by works of Gorzelak (1996) and Enyedi (1996), the fact that metropolitan regions of their capital cities (except from Poland) are a part of a so-called 'Central European boomerang' creating the most advanced part of the CEE countries, has a vast influence on the level of regional inequalities in the V4 countries. It is the axis of Gdansk-Poznań-Wroclaw-Praha-Brno-Bratislava-Vienna-Györ-Budapest that integrates the economically most advanced counties of the V4 countries. Even a so-called 'Central European eastern wall', whose regions (the easternmost regions of Poland, Slovakia and Hungary) are typical for slower growth, poorer education level, infrastructure, foreign capital as well as underdevelopment of neighbouring countries (Belarus, Ukraine, Romania) confirms the identified west-east dichotomy.

Uniformly, Matlovič et al. (2018) identified the existing west-east dichotomy mentioned in the submitted paper (hypothesis H1) also via west-east gradient when evaluating the V4 countries. It was the most notable in Slovakia, less in the Czech Republic and Hungary and least strong in Poland. This decrease in economic status was similarly mentioned by Blažek and Csank (2005), Lang (2015), Kebza et al. (2015), Klamár (2016) and Kubeš and Kebza (2018).

In the case of Serbia and Croatia, the second and third lowest level of inequalities were demonstrated, even after the exclusion of their capitals, their level remained medium. In the case of Serbia, their lower level of inequalities is rather surprising, because a number of authors such as Mijačić and Paunović (2011), Lukić and Stoilković (2017) drew attention to their high rate compared to the other EU countries. The identified inequalities have their grounds in decreased economic efficiency in the northwestern-southeastern direction (in all the indicators), which is consistent with the works by Mijačić and Paunović (2011), Jakopin (2014) and Joksimović and Golić (2017). This originated in the late transformation process in the country (Winkler, 2012), unfavourable demographic trends, small scale industrial production, high unemployment rate and inadequate infrastructure (Joksimović & Golić, 2017) which manifested itself in the higher poverty risk rate in Europe (24.3%) as well as in the low Competitiveness Index Europe 2020 (Jakopin, 2014).

Croatia had a little higher level of inequalities, however, in the GDP per capita in PPP and the birth rate it had the second lowest inequalities after the Czech Republic. Đokić et al. (2015) state that Croatia is a remarkably heterogeneous country with high regional inequalities in economic and social development, while they refer to the works of Puljiz and Maleković (2007), who identified significant inequalities in the unemployment rate and slightly from the point of income (these differences also affirmed the results of the submitted paper – hypothesis H3). In compliance with the work by Marošević and Sekur (2018), we also identified the strong position of the capital, Zagreb, from the point of inequalities, however not that significant as in the case of Prague or Bratislava (tab. 1). The identified inequalities arise from the fact that economically prosperous counties are located to the west from Zagreb, to the coast and along it. To the east in direction to the borders with Serbia are concentrated those underdeveloped ones (apart from the birth rate, it was confirmed in all the indicators).

Conclusion

In the overall evaluation of regional inequalities, it is evident that the lowest level was proven in the Czech Republic that also had the highest level of socio-economic status. The second highest inequalities were found in Serbia followed by Croatia, despite the fact they had the lowest or the second lowest level of socio-economic status. To the contrary, the highest inequalities were demonstrated in Slovakia and Hungary. From the point of individual indicators, the univocally lowest values of inequalities were observed in the gross birth rate as the only non-economic indicator. Almost in all the evaluated countries (apart from Poland – polycentric character of settlement) a strong influence of their capital cities was found regarding the level of inequalities, the most significant cases being Prague and Bratislava. After their exclusion, the inequalities in Slovakia even decreased to the second lowest level after the Czech Republic. The identified inequalities in the evaluated countries are to a large extent influenced by the dichotomy between prosperous west and problematic east and that was most notable in Slovakia; it was also proven in the Czech Republic and Croatia, in Hungary it was rather north-southern and north-southeastern direction and in Serbia in a northwestern-southeastern direction. In Poland, its polycentric settlement and the presence of more big cities did not make the development in the west-east direction possible, however, less developed counties were more concentrated at the eastern border. The described facts also had an impact also on the evaluation of the dependence between the socio-economic status of the countries and their regional inequalities. The decreasing character of the regression line and relatively strong correlation in the indicators - the birth rate and dwellings completed - in both cases, and in inequalities in GDP per capita in PPP after excluding the capitals, pointed out to the fact that the level of inequalities decreases together with growing socio-economic status. A definite confirmation of the hypothesis could not be stated regarding the suitability of the model. In other inequality rates, the hypothesis was not confirmed.

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Annex

Table 4. List of counties (NUTS 3) and the level of their socio-economic status (points)

POLAND		Points	58	Włocławski	168.3	112	Szabolcs-Szatmár-Bereg	156.1
1	City of Łódź	226.6	59	Elbląski	185.7	113	Bács-Kiskun	204.3
2	Łódzki	197.7	60	Olsztyński	201.3	114	Békés	155.2
3	Piotrkowski	208.4	61	Ełcki	170.4	115	Csongrád	190.4
4	Sieradzki	187.2	62	Słupski	207.2	SERBIA		Points
5	Skierniewicki	189.3	63	Trójmiejski	334.3	116	Capital City of Beograd	189.9
6	Ciechanowski	194.4	64	Gdański	259.7	117	West Bačka	118.9
7	Ostrołęcki	196.4	65	Starogardzki	203.7	118	South Banat	140.5
8	Capital City of Warszawa	449.4	66	Płocki	230.1	119	South Bačka	178.8
9	Radomski	188.4	67	Siedlecki	214.2	120	North Banat	121.2
10	Warszawski-wschodni	244.6	68	Nowotarski	198.2	121	North Bačka	144.1
11	Warszawski-zachodni	301.2	69	Szczecinecko-Pyrzycki	161.5	122	Central Banat	135.1
12	City of Kraków	359.0	70	Inowroclawski	172.9	123	Srem	142.0
13	Krakowski	236.2	71	Świecki	188.2	124	Zlatibor	148.4
14	Nowosądecki	200.9	72	Chojnicki	200.7	125	Kolubara	138.8
15	Oświęcimski	192.9	73	Żyrardowski	224.7	126	Mačva	131.7
16	Tarnowski	188.2	SLOVAK REPUBLIC		Points	127	Moravica	138.4
17	Częstochowski	190.0	74	Bratislava	370.0	128	Pomoravlje	120.9
18	Bielski	230.4	75	Trnava	258.6	129	Rasina	115.6
19	Rybnicki	221.6	76	Trenčín	214.7	130	Raška	151.2
20	Bytomski	187.4	77	Nitra	205.2	131	Šumadija	138.9
21	Gliwicki	232.0	78	Žilina	219.7	132	Bor	117.3
22	Katowicki	252.1	79	Banská Bystrica	177.0	133	Braničevo	127.9
23	Sosnowiecki	198.7	80	Prešov	187.4	134	Zaječar	99.1
24	Tyski	259.4	81	Košice	195.7	135	Jablanica	118.0
25	Bialski	184.1	CZECH REPUBLIC		Points	136	Nišava	138.7
26	Chełmsko-zamojski	159.3	82	Capital City of Prague	370.6	137	Pirot	119.6
27	Lubelski	235.3	83	Central Bohemian	284.7	138	Podunavlje	114.2
28	Puławski	178.7	84	South Bohemian	255.8	139	Pčinja	128.9
29	Krośnieński	173.2	85	Plzeň	281.9	140	Toplica	120.5
30	Przemyski	171.9	86	Karlovy Vary	219.9	141	Kosovska Mitrovica	-

31	Rzeszowski	234.0	87	Ústí nad Labem	214.7	142	Peć	-
32	Tarnobrzeski	190.3	88	Liberec	242.4	143	Kosovo	-
33	Kielecki	184.9	89	Hradec Králové	260.3	144	Kosovo-Pomoravlje	-
34	Sandomiersko-Jędrzejowski	173.8	90	Pardubice	263.8	145	Prizren	-
35	Białostocki	225.6	91	Vysočina	248.0	CROATIA		Points
36	Łomżyński	187.2	92	South Moravian	261.8	146	Primorje-Gorski kotar	192.6
37	Suwalski	185.1	93	Olomouc	237.5	147	Lika-Senj	185.5
38	Pilski	201.5	94	Zlín	248.5	148	Zadar	218.7
39	Koniński	205.2	95	Moravian-Silesian	225.3	149	Šibenik-Knin	169.8
40	City of Poznań	381.5	HUNGARY		Points	150	Split-Dalmatia	188.4
41	Kaliski	230.6	96	Capital C. of Budapest	264.9	151	Istria	213.2
42	Leszczyński	243.7	97	Pest	234.8	152	Dubrovnik-Neretva	202.3
43	Poznański	324.0	98	Fejér	216.4	153	Capital City of Zagreb	260.0
44	Koszaliński	217.2	99	Komárom-Esztergom	233.3	154	Zagreb	180.5
45	City of Szczecin	269.8	100	Veszprém	213.4	155	Krapina-Zagorje	164.5
46	Szczeciński	200.2	101	Győr-Moson-Sopron	296.9	156	Varaždin	177.2
47	Gorzowski	205.9	102	Vas	214.2	157	Koprivnica-Križevci	173.9
48	Zielonogórski	209.1	103	Zala	185.4	158	Međimurje	192.5
49	City of Wrocław	387.5	104	Baranya	155.8	159	Bjelovar-Bilogora	156.9
50	Jeleniogórski	179.1	105	Somogy	171.1	160	Virovitica-Podravina	149.8
51	Legnicko-Głogowski	240.3	106	Tolna	205.3	161	Požega-Slavonia	154.8
52	Wałbrzyski	170.9	107	Borsod-Abaúj-Zemplén	184.4	162	Slavonski Brod-Posavina	152.1
53	Wrocławski	260.3	108	Heves	205.1	163	Osijek-Baranja	157.1
54	Nyski	171.0	109	Nógrád	150.3	164	Vukovar-Srijem	147.7
55	Opolski	201.3	110	Hajdú-Bihar	180.8	165	Karlovac	161.5
56	Bydgosko-Toruński	227.1	111	Jász-Nagykun-Szolnok	173.3	166	Sisak-Moslavina	151.6
57	Grudziądzki	186.4						

Source: own elaboration, Note: order number of the county serves for its identification in Figures 1-6

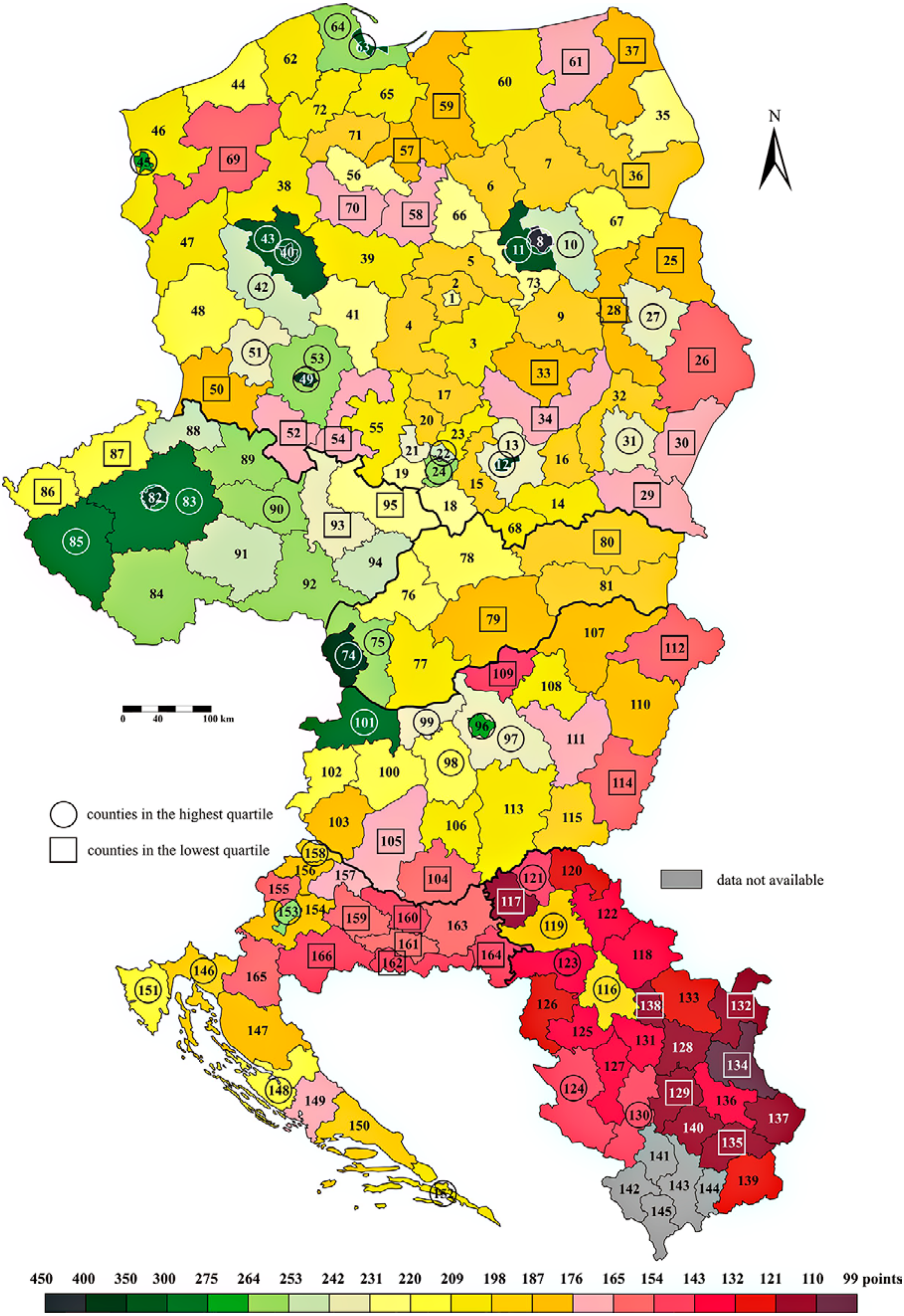

Figure 1. Socio-economic status in counties in V4 countries, Serbia and Croatia (2018)
Source: our processing, tab. 4

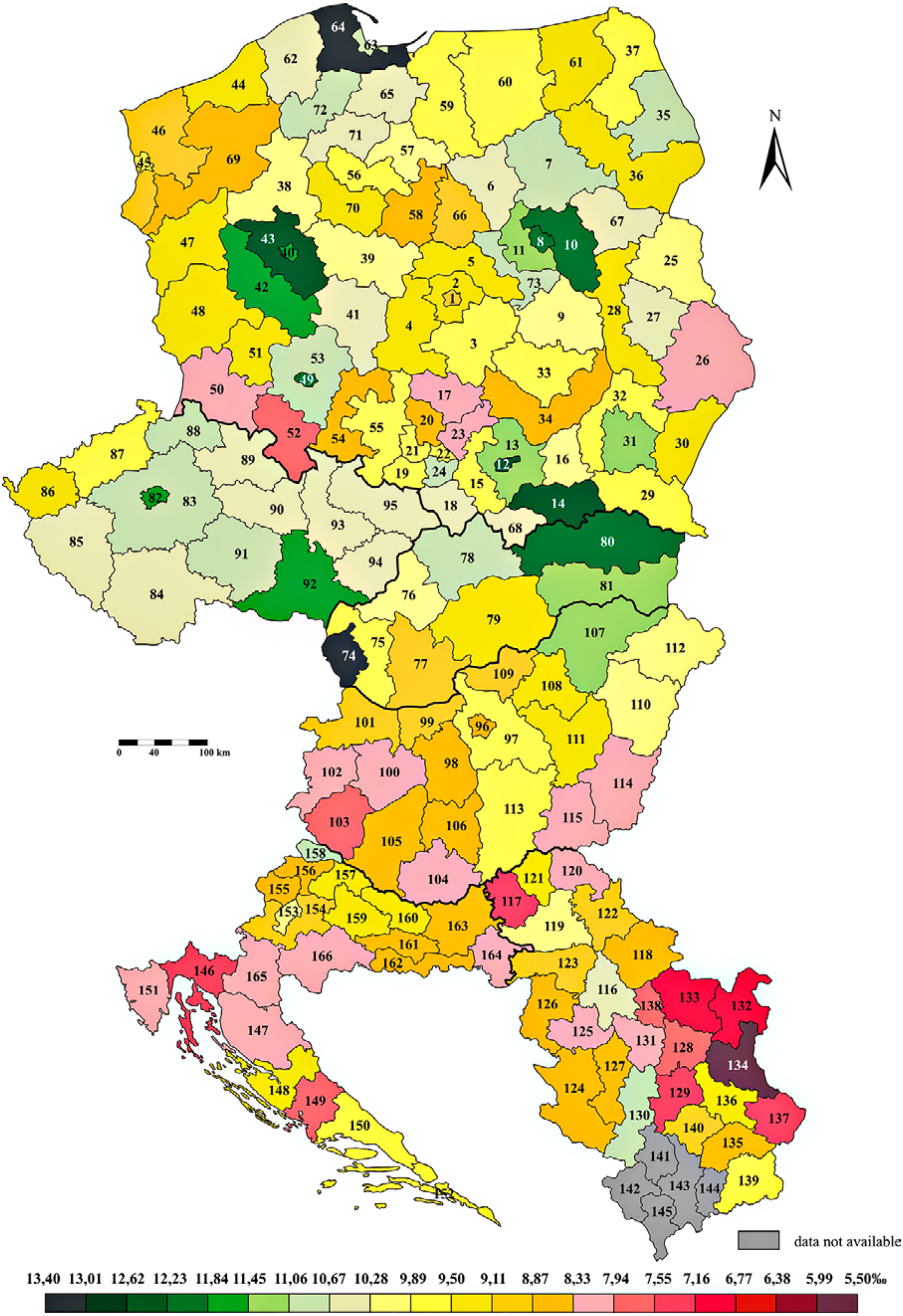

Figure 2. Gross birth rate in counties in V4 countries, Serbia and Croatia (2018)
Source: *http://bdl.stat.gov.pl* *(PL)*, *http://datacube.statistics.sk* *(SK)*, *http://vdb.czso.cz* *(CZ)*, *http://www.ksh.hu* *(HU)*, *http://data.stat.gov.rs* *(RS)*, *http://www.dzs.hr* *(HR)*

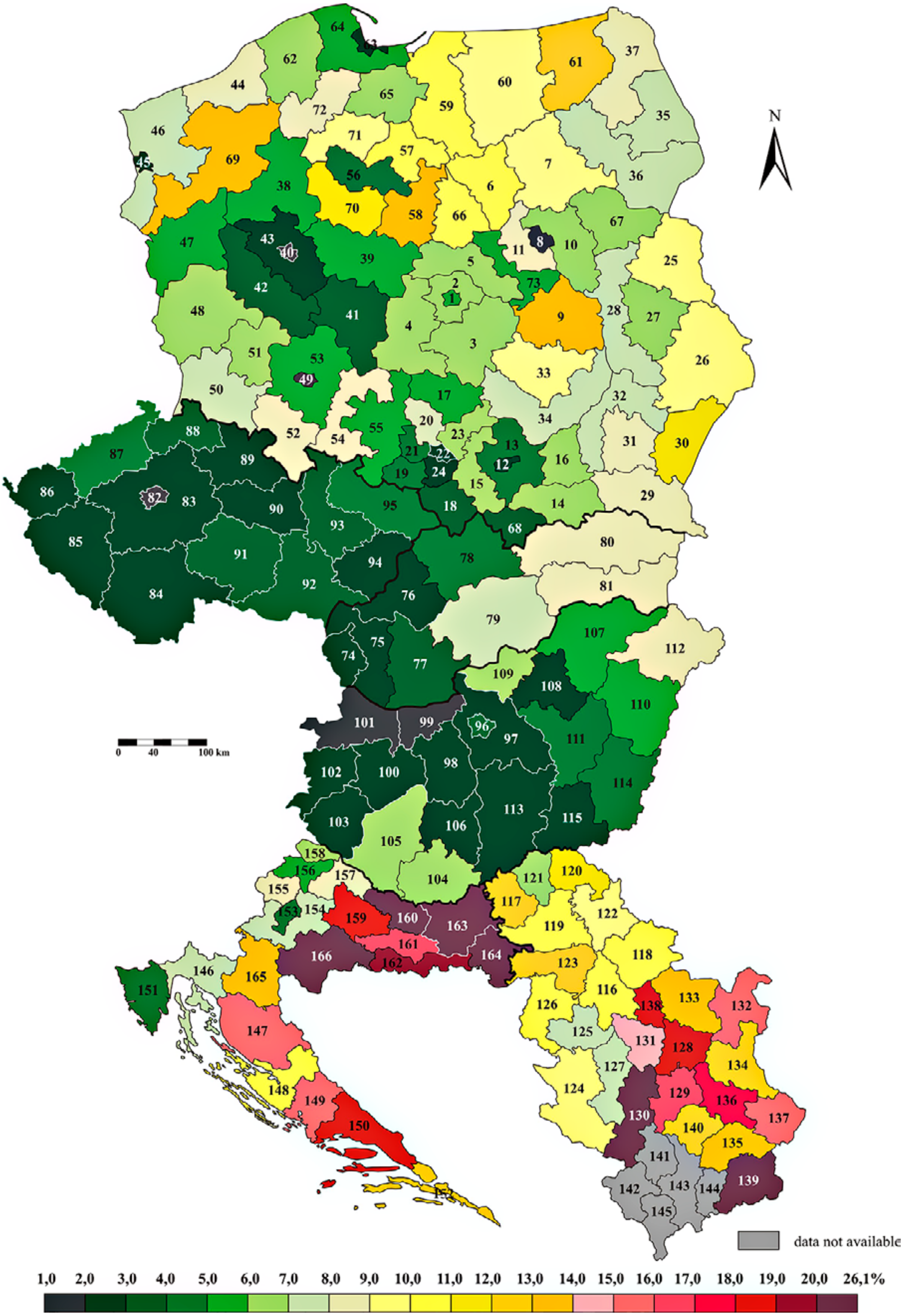

Figure 3. Unemployment rate in counties in V4 countries, Serbia and Croatia (2018)
Source: http://bdl.stat.gov.pl (PL), http://datacube.statistics.sk (SK), http://vdb.czso.cz (CZ), http://www.ksh.hu (HU), http://data.stat.gov.rs (RS), http://www.dzs.hr (HR)

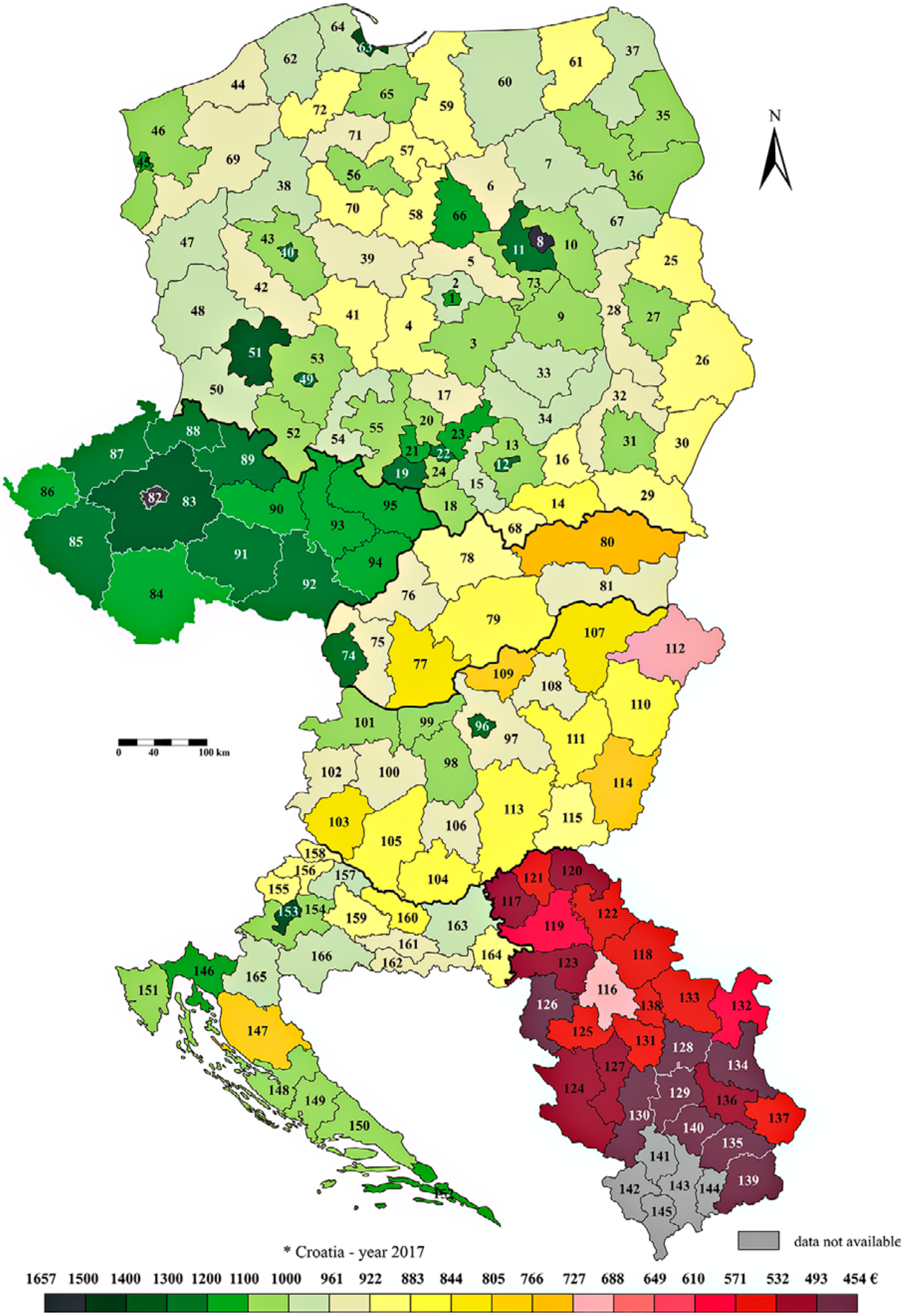

Figure 4. Average monthly gross earnings in counties in V4 countries, Serbia and Croatia (2018)*
Source: *http://bdl.stat.gov.pl (PL), http://datacube.statistics.sk (SK), http://vdb.czso.cz (CZ), http://www.ksh.hu (HU), http://data.stat.gov.rs (RS), http://www.dzs.hr (HR)*

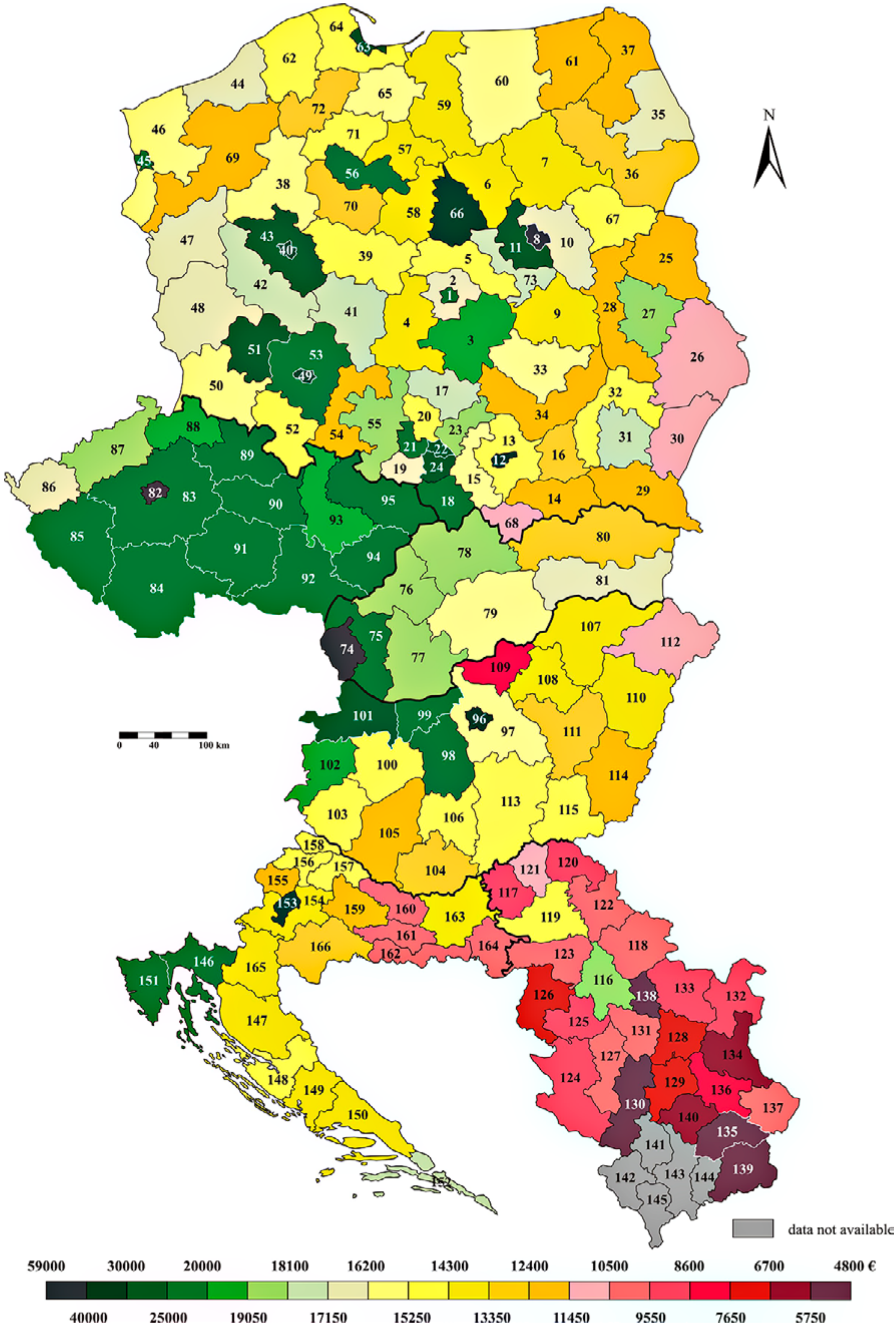

Figure 5. GDP per capita in PPP in counties in V4 countries, Serbia and Croatia (2016)
Source: https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (PL, SK, CZ, HU, RS, HR)

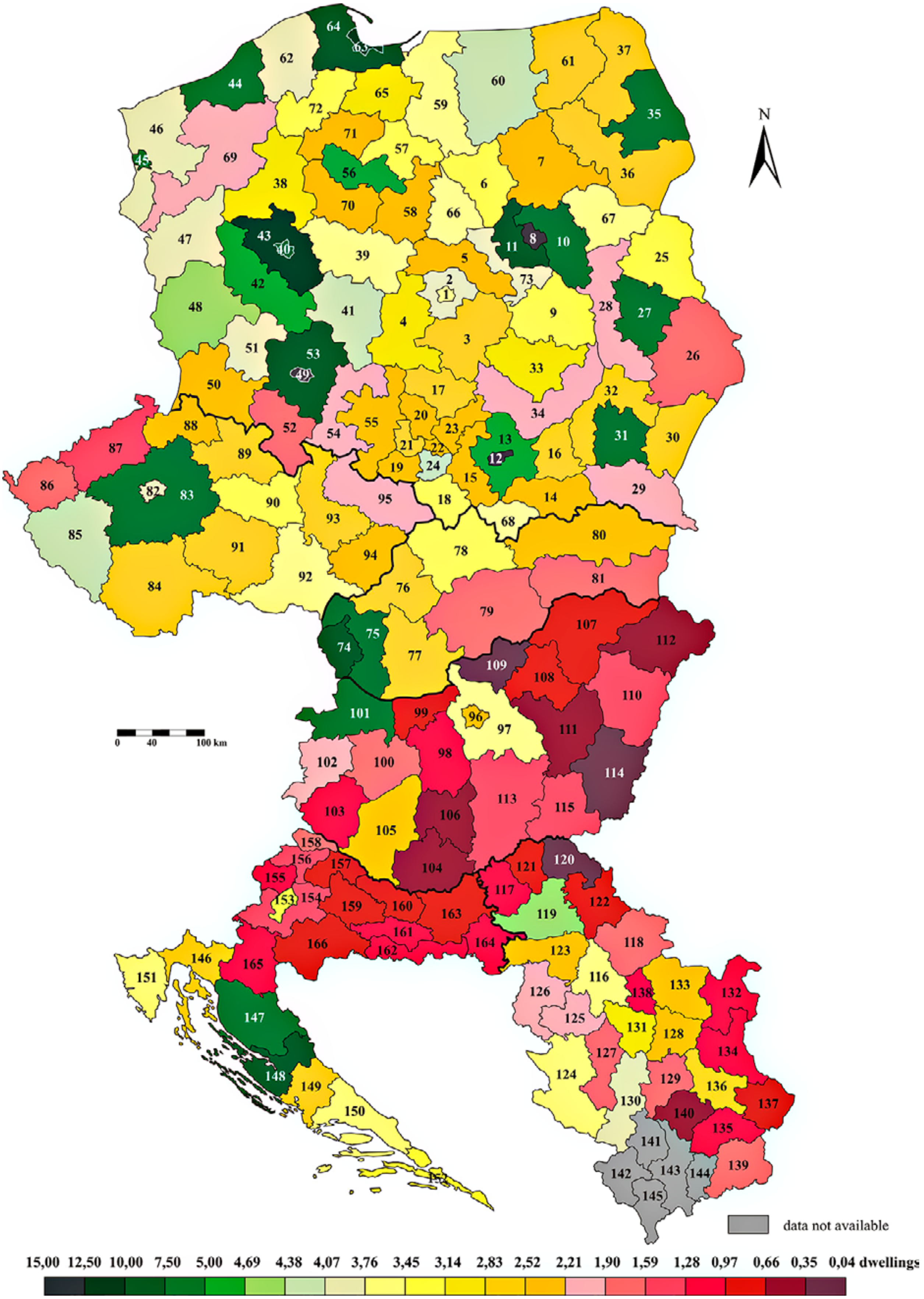

Figure 6. Dwellings completed per 1000 inhabitants in counties in V4 countries, Serbia and Croatia (2018)
Source: *http://bdl.stat.gov.pl (PL), http://datacube.statistics.sk (SK), http://vdb.czso.cz (CZ), http://www.ksh.hu (HU), http://data.stat.gov.rs (RS), http://www.dzs.hr (HR)*

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Environmental Consequences of the Urban Sprawl in the Suburban Zone of Nitra. An Analysis Based on Landcover Data

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Abstract

One of the most important territorial processes in the highly urbanised continent of Europe is suburbanisation, urban sprawl which occurs in a gradual manner over long periods and is not perceived as dramatic. Nevertheless the built-up urban areas and the urban lifestyle occupy step by step the periurban territories. Urban sprawl affects the essential environmental, economic and social functions of the impacted settlements. In the last decades these processes reached the less urbanised Central European region, leading to very fast and less planned changes in its settlement system. The research deals with these processes in the Central European non-metropolitan areas, around regional centres, and with their environmental impacts. The aim of this paper is, based on theoretical and empirical knowledge, to point out to spatial patterns of urban sprawl and suburbanisation in functional urban areas (FUA). This paper examines the urban sprawl and its impacts in Slovakia in the case of Nitra Functional Urban Area, in the agglomeration of an economically growing regional centre. The research is based on standard geographical methods including field research. Desktop and field empirical researches were conducted, with different methods such us GIS analysis of land use change. The analysis shows then to what extent cities and urban areas grow, from which one can conclude to how landscape surrounding the urban residential areas has changed, how the proportion of non-permeable surfaces increased, basically influencing the runoff of precipitation. The data demonstrate, moreover, how artificial patches and barriers fragment landscape more and more, endangering thereby biodiversity and decreasing green surfaces. The examination covers the 2000-2018 period, using the CORINE CLC 2000, 2006, 2012 and 2018 databases. Thereby the authors are able to examine changes in a longer period of almost two decades, and three internal periods. All this is compared to the demographic changes of the urban area of Nitra as well, in order to see to what extent the change in the number of population contributes to the transformation of land cover and thereby to environmental impacts. The characteristic features of Nitra and its hinterland within this are analysed, then the Nitra FUA and within that the suburban zone is examined in detail. Nitra and its area feature high enlargement dynamics looking at the whole of the period, compared to other FUAs. It is typical almost everywhere that the enlargement of areas surrounding cities is more intensive than the growth of the city itself, which demonstrates general suburbanisation.

Keywords: Suburbanisation; urban sprawl; land cover change; environmental impact; Slovakia; Nitra

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Introduction

One of the important features of the urban development and urbanisation processes is that the space of the city, moreover the areas used as urban space are growing, spreading and this process is also changing the use of areas and landscape, which were previously in rural and close-to natural condition (EEA report, 2006, 2016; Enyedi, 2012; Ilbery, 1999; Kovács, 2014; Sturm & Cohen, 2004; Van den Berg, 1982).

The growth of the population of cities and urban regions is fast in Europe, and the demand for space by new residential places and other functions is very rapidly increasing. We can refer to the Marshall's equation, according to which a 3% population increase will determine a 9% increase in area used by urban functions (Gardi, 2017). The rapid changes of 'urban metabolism' pose a challenge for spatial planning and urban development that are often unable to control processes even in the developed countries, not to mention the least advanced ones, and so the environmental impacts are intensifying. Johnson (2001) and Kahn (2000) summarised environmental impacts of urban sprawl which had been identified in the literature. On the basis of this, the environmental impacts are the following: loss of environmentally fragile lands; reduced regional open space; greater air pollution; higher energy consumption; decreased aesthetic appeal of landscape; loss of farmland; reduced diversity of species; increased runoff of stormwater; increased risk of flooding; excessive removal of native vegetation; monotonous (and regionally inappropriate) residential visual environment; absence of mountain views; presence of ecologically wasteful golf courses; ecosystem fragmentation.

Literature offers two directions for finding the answers to the issue: a) one that keeps the tendency of suburban development (Van der Valk & Faludy, 1992) but controls that more adequately with the tools of planning; and b) one that recommends the more practical and denser building up of urban spaces, with a more effective use of the space (compact city theory) (Breheny, 1992). We cannot make a stand in this issue but it is a fact that planning based on better recognition may reduce the negative environmental impacts of urban sprawl.

Residential suburbanisation and urban sprawl are currently the most important urbanisation processes in European post-socialist countries, especially in Central Europe (Bajmóczy, 2012; Csapó–Balogh, 2012; Hirt, 2007, 2012; Karwińska et al., 2018; Kubeš, 2013, 2015; Leetmaa–Tammaru, 2007; Tímár & Váradi, 2001). In addition to the large number of case studies we also find works that compare the processes in the West and the East (Szirmai, 2011). The European, especially Central European and Southeast European researches have primarily focused on the suburban zones of the capital cities (Kovács et al., 2019; Lennert et al., 2020; Slaev et al., 2018), and paid little attention to the processes of the rural centres (Kubeš & Nováček, 2019). The specific features of the urban network of this macro-region make the survey of this set of cities important, especially of the dynamic elements thereof, exploring the special characteristics (Hardi, 2010, 2012; Hardi & Nárai, 2005).

Over the past decade and a half, peri-urban development has enormously changed the traditional cultural landscape, land use, and settlement functions of villages around regional centres (EEA report, 2006), and around many other cities in Central Europe (Antrop, 2004, 2005; Székely–Michniak, 2009). This process has intensified in the former socialist countries after the 2000's and it led to a number of problems, which became apparent during the eighties and nineties in Western countries, and in the fifties-sixties in the USA. The urban sprawl took place without effective control and planning. The extent of spatial growth often exceeds the rate of population growth; it is taking place even in the lack of population growth (urban sprawl). The administrative areas of several settlements are affected by these processes; thus, the lack of coordination is often characteristic (Ehrlich et al., 2012).

Urban sprawl causes numerous landscape-ecological problems. Spatial planners, self-governments and building officials who should regulate the residential suburbanisation are still quite passive in this question, as are local citizens (Kubeš, 2015). Suburbanisation brings irreversible changes in the landscape. An increasing number of publications analysed the environmental, ecological and agricultural consequences of population, suburbanisation, the land take, land consumption of this process, but mainly in the cases and by authors of the USA and East-Asia. The subjects of these works cover several disciplines and professions from urban planning to microbiology. We see that in American literature environmental and climate change issues dominate the research of the phenomenon of suburbanisation.

On the other hand, the European, especially the Central European literature (Kubeš, 2013) focuses on the transformation of the physical and functional spatial structure; housing structure/policy/market; social spatial structure of the city and of the suburbs. The environmental impacts of suburbanisation are under-explored and only a few works deal with it (e.g. Čepelová & Münzbergová, 2012; Repaská et al., 2017; Vaszócsik, 2017).

Residential suburbanisation significantly changes the morphology of the target settlements, their proportions, base plan and villagescape, and the typical means of land use in the inner areas. This will lead to the transformation of the traditional land- and villagescape.

The aim of this paper is, based on theoretical and empirical knowledge, to point out to spatial patterns of urban sprawl and suburbanisation in functional urban areas (FUA).

This paper examines the urban sprawl and its impacts in Slovakia in the case of Nitra Functional Urban Area, in the agglomeration of an economically growing regional centre. The transformation of the landscape is caused as a consequence of the environmental impacts of suburbanisation (increased proportion of non-permeable surfaces, decreasing green surfaces...), but is also due to population changes. The paper is meant to highlight that researchers have to focus not only on the big cities, capitals but on the smaller cities, towns as well, because these urban areas, despite the small scale population growth (sometimes declining population), could reach a significant change in the landscape and in the share of natural/built-up areas.

Urbanisation, suburbanisation and urban sprawl in Slovakia

The suburbanisation phase in Slovakia is characterised by a kind of belatedness compared to the processes in Western Europe. Industry and service sector made cities grow large (more jobs = increase in population), housing blocks were built (uniformity and large series production). Real estate prices in the rural areas and accommodation prices in the cities were the same. Suburbanisation processes appeared in Slovakia after 1989. The state offered attractive financing solutions, and so the residents bought land plots and houses from credit in the peri-urban areas and the countryside. The countryside offered cheaper land and cleaner environment than cities did. The inhabitants preferred detached houses offering more private life, instead of the apartments in the pre-fabricated housing blocks. Outmigration to the countryside and the urbanisation of the rural areas started.

The most important process in urbanisation was urban sprawl in the 20th century. As a definition, it is an economic and socio-spatial process when urbanised areas spread to formerly rural areas around the proper core, creating low-density urban fabric. It may cover many aspects from suburbanisation to decentralisation, from desurbanisation to rurbanisation and the emergence of edge cities (Kocsis, 2015). Thus, it seems to cover too much, but on the other hand, it has a strong explanatory power in interpreting the processes. It enables to link and separate processes. Because of its strength, it is to be found in most places, but as a major process, it is the first to be distorted by policy-makers and local features. Socialism brought about significant alteration in the process inasmuch as many scholars even denied the very existence of the urban sprawl, especially suburbanisation, which was regarded as a negative process. Dense, compact developments, such as housing estates, were favoured and the size of the capital city was seen as too big for the country, thus policies thwarted any significant development in most of the settlements of the agglomeration. Nonetheless, the processes continued, although in an almost unrecognisable way. The actual forms changed, but the driving forces and the desires of the strata remained continual within the strict constraints of the socialist system. The middle-class out-newcomers were replaced by lower class newcomers; it was a process that further propelled the process and led to substantial transformation of the core in the 1960s and 1970s. The process of suburbanisation sped up in the 1990s and flooded farther areas in the early 2000s.

At the beginning of the first stage of urbanisation (i.e. 1869-1918), at the time of the first modern census in 1869, the territory of Slovakia had a predominantly rural character. The degree of urbanisation achieved only 10.1%. In this period, cities with population over 50,000 inhabitants were still absent. Only two cities had higher population than 20,000 inhabitants – Bratislava and Košice. In the years 1948-1989 the urbanisation process occurred simultaneously with the industrialisation process. The number of inhabitants living in the cities increased from 857,000 to almost 2,990,000. The degree of urbanisation increased from 24.9% in 1950 up to 56.7% in 1989. Among others, the integration process – the attachment of communes to cities – considerably contributed to this growth. Within the given urbanisation stage, cities achieved the highest intensity of growth in 1970–1980, while the dynamics of urbanisation in the last decade was sensibly reduced. Only in this stage, the category of big cities was formed; 11 cities had higher population than 50,000 inhabitants (Slavík et al., 2011).

Intense change occurred after 1989 when there was also a change in the values of the society. By the transformation of the economy to market conditions, there was not only restriction of industrial production, but also housing in towns and cities. Mortgage loans appeared which enabled also the population of middle-class society to buy their own family houses and estates. Cheaper estates in cleaner environment of rural areas resulted in the depopulation of towns and cities. There was an intense movement of population to the countryside. The unpreparedness of a large part of rural population to changes and the dynamics of these changes opened the gap between the technical and economic aspects of modernisation and between the cultural and social processes. New relationships between town and countryside began, which started the so-called urbanisation of the countryside by immigrated population from the towns. In many rural villages, the original architecture, indigenous traditions, and indigenous culture began to vanish as well as the bonds of a man to his residence and rural "genius loci" (Repaská, 2012).

Since 1989, the process of suburbanisation has reached to the post-socialist cities and markedly influences also the cities of Slovakia (Bratislava and Košice) (Czaková, 2010; Dická, 2007; Gajdoš & Moravanská, 2013; Slavík et al., 2011). After the year 2000, this process began to show also in large cities of Slovakia (Nitra, Prešov) (Ferťalová & Sedláková, 2006; Repaská, 2012; Repaská et al., 2015;). For the given cities, the authors analysed residential suburbanisation using mainly the dynamics of population growth and net migration as indicators. All analyses corroborated a certain time shift in suburbanisation. On the basis of the intensity of the observed indicators in Nitra city the authors arrived at the identification of the suburban zone. This is usually formed by only a narrow or mosaic ring of communes in the immediate hinterland.

Research on "cross-border suburbanisation" has intensified, especially in the selected locations of Bratislava, Hungary and Austria (Baj, 2010; Hardi, 2010; Jagodič, 2010; etc.).

Suburbanisation around Nitra

The city of Nitra is administratively incorporated into the district of Nitra, which is one of the districts of the Nitra self-governing region. Nitra is a regional city, it has an important transit position in the centre of Western Slovakia and it has good transport links to Bratislava, Banská Bystrica and Komárno. It is connected to the D1 highway Trnava– Bratislava by the R1 expressway. The airport in Nitra-Janikovce allows air connections with the region and in 1998 it gained the status of an international airport for non-scheduled air transport. Nitra has 76,655 inhabitants (31.12.2018) and it is the 5th largest city in Slovakia. The total area of the city is 100.48 km², the population density is 801.40 inhabitants/km². The city concentrates 47.6% of the population of the district, 11.3% of the population of the region and 1.4% of the population of Slovakia.

The important location of Nitra conditioned the development of central functions of the city (cultural, educational, service etc.) that are also reinforced in the contemporary period. In the landscape structure, we observe the loss of agricultural land and growth of commercial areas which is connected also with an increase in car and public transport in the city. The construction of commercial buildings was most often carried out "on a green field". In this way, there has been a significant change in land use at the expense of its agricultural function. In the socialist period before 1989 with a centrally managed economy in Nitra, retail was concentrated mainly in the city centre and in housing estates, where it was easily accessible to residents. After the advent of the market economy after 1989 and the change in the socio-economic situation, ownership relations changed, business development, restitution and privatisation took place. It was under this influence that commercialisation began to manifest in the territory of the city of Nitra, which initially affected the inner parts of the city through the emerging smaller retail outlets. Later, multifunctional buildings with a larger number of retail outlets and services, as well as supermarkets (mainly with foodstuffs), were established in the area of housing estates. The year 2006 was characterised by the arrival of multinational retail chains. Shopping centres with their own marketing concepts entered the city of Nitra. In the vicinity of already built and existing commercial buildings, the residential construction also strengthened, through which the residential suburbanisation, which is reflected in the construction of residential areas, also intensified. Residential suburbanisation began in the city of Nitra after 2000 (Repaská, 2012), when the city registered a decrease in population. While 87,575 inhabitants lived in Nitra in 2000, in 2018 there were only 76,655, which is a decrease by 12.5% (Fig. 1).

This decrease was caused mainly by the total decrease of population with a significant share of emigration. While in 2000 the proportion of emigrants from the city was 10.9‰, in 2018 it rose to 21.7‰. The survey of suburbanisation going on the city of Nitra was realised through a few indicators: *Population decline in the city, population increase in the countryside,*

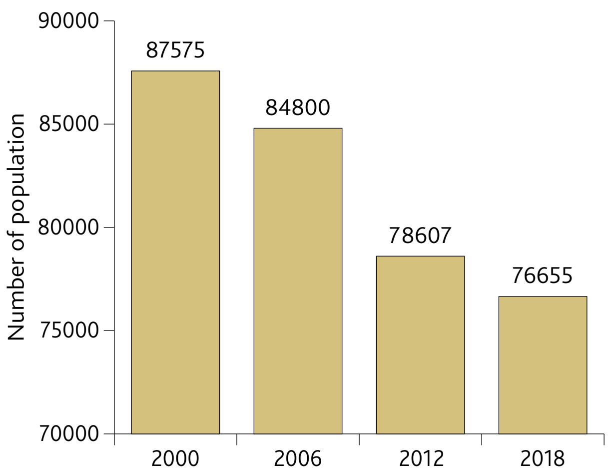

Figure 1. Population dynamics in Nitra city
Source: own work, based on data of Slovak Statistical Office

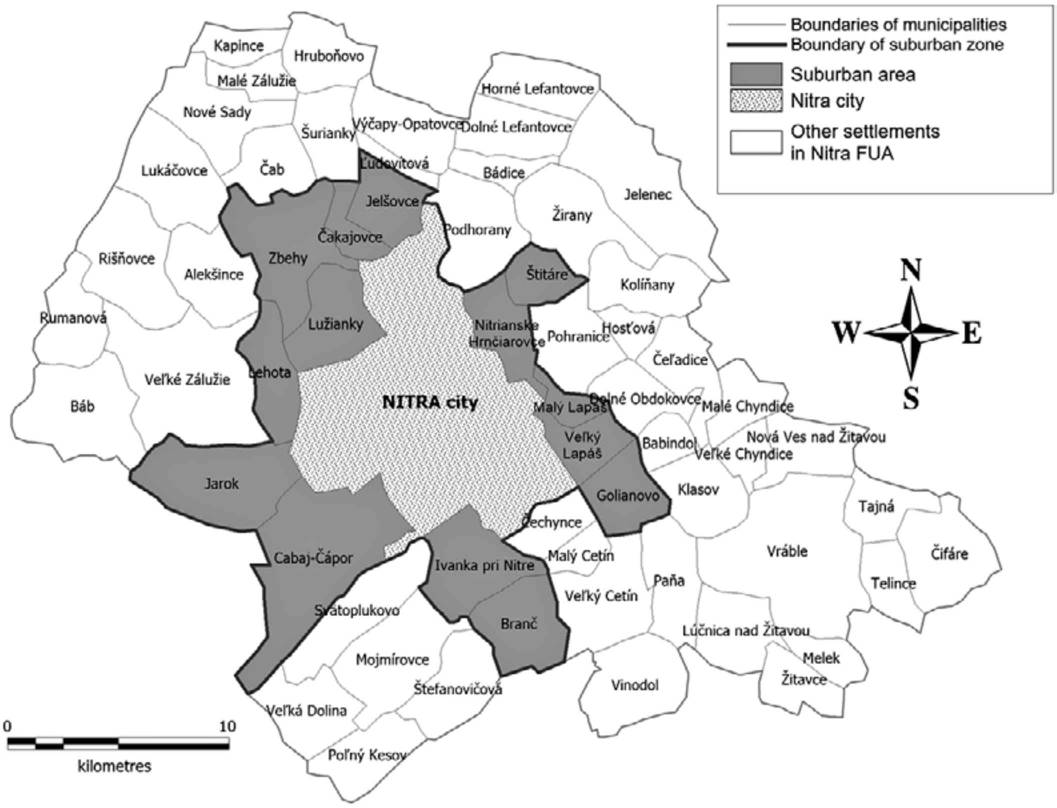

Figure 2. The Structure of the Territory of Nitra Functional Urban Area*
Source: own work
** According to Urban Atlas*

negative migration balance in the city, positive migration balance in the villages. Population decline in the city, population increase in the countryside, negative migration balance in the city and positive migration balance in the villages are no evidences for the process of suburbanisation, only assumptions thereof. A population decline in cities can also be the consequence of the change in the number of births. The negative and positive migration balance shows moving from city to city, from village to village, from city to village and from village to city. The direction of the process of suburbanisation, on the other hand, is a one-way direction from the city to the village. Thus, the *proportion of in-migrants from Nitra in the respective village* was the indicator used to survey migration from the city to the village, only. The proportion of newcomers from Nitra must be higher than the proportion of in-migrants coming from other settlements. According to Repaská (2012), the suburban zone of Nitra City consists of 14 rural villages that surround the city from all cardinal points (Fig. 2).

Between 2000 and 2018, the biggest increase in population was recorded by the municipality of Malý Lapáš (175%), the lowest increase (7%) was in the municipality of Zbehy. In the suburban zone of Nitra city the increase of population is 35%, Nitra showed a decrease of the population by 12% (Fig. 3–4).

The positive migration balance in the municipalities of the suburban zone and the negative migration balance in the city of Nitra point to an increase in the number of inhabitants in rural municipalities at the expense of depopulation of Nitra city.

The migration of the population to the rural municipalities was influenced mainly by cheaper real estate prices; the important factor was the proximity of Nitra city and its good transport accessibility and the attractiveness of the hill Zobor too.

According Repaská et al. (2015), in the municipalities of the suburban zones a decrease of arable land and the expansion of land for constructions took place. In the suburban villages of Nitra detached single unit houses, detached houses, duplexes, and atrium houses are represented. In the villages of the suburban area, the increase in housing units from 2000 to 2018 was most pronounced in the village of Malý Lapáš, where it reached almost 150% (Fig. 5).

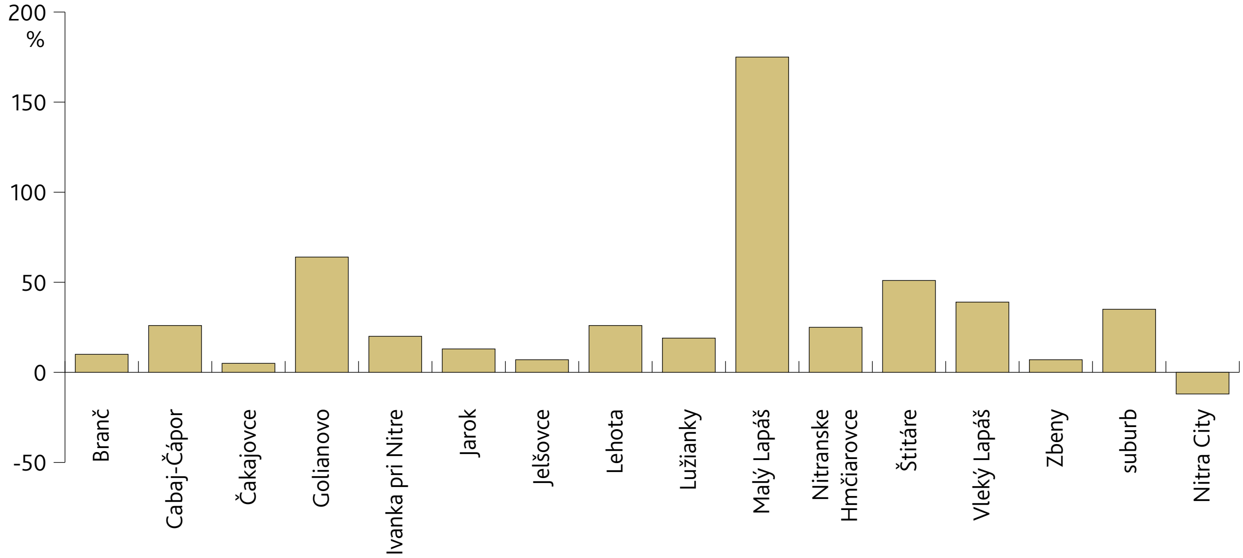

Figure 3. Increase/decrease in the number of population in the suburban area of Nitra city from 2000–2018
Source: own work, based on data of Slovak Statistical Office

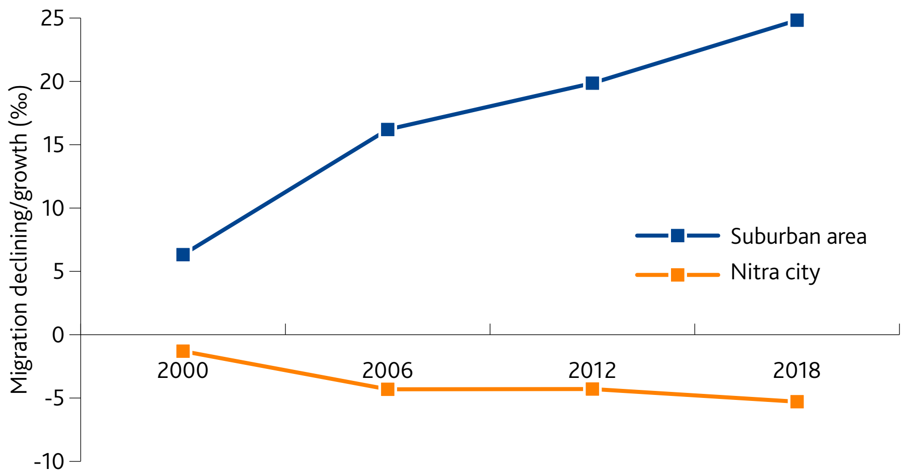

Figure 4. Migration decrease in Nitra city and the migration increase in the suburban area of Nitra city in 2000–2018
Source: own work, based on data of Slovak Statistical Office

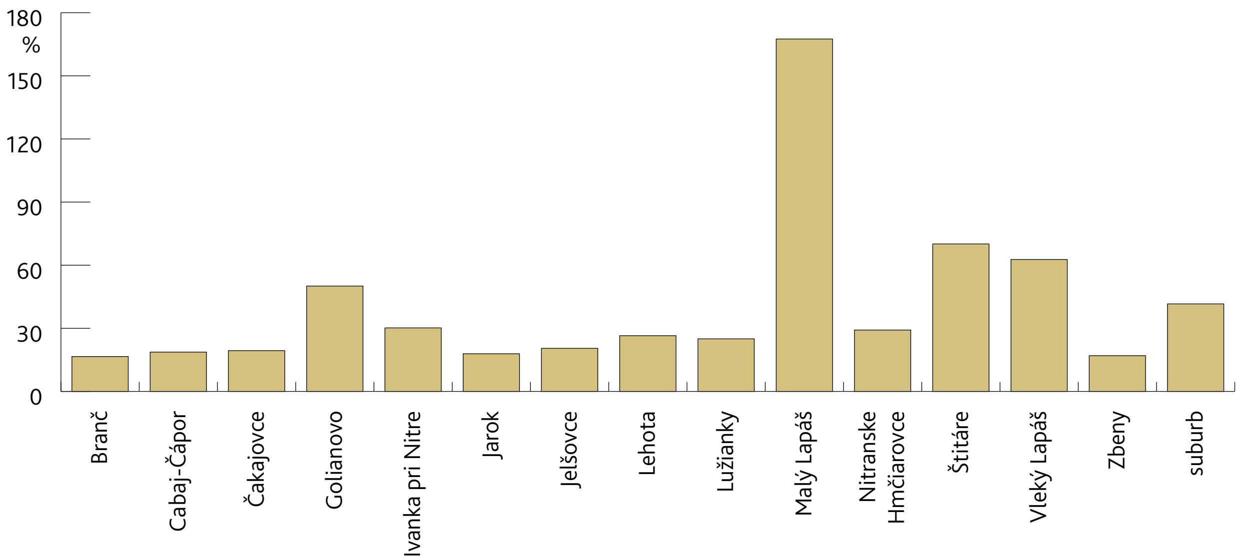

Figure 5. Increase in the number of houses in suburban area of Nitra city
Source: own work, based on data of Slovak Statistical Office

Material and methods

Examination of landcover change caused by suburbanisation and urban sprawl

The spatial unit for assessing the spatial structures of urban sprawl and suburbanization are functional urban areas (FUAs).The European Union and the OECD have jointly developed a methodology to define functional urban areas in a consistent way across countries. FUAs are defined in several steps. First, a population grid makes it possible to define 'urban centres' independently from administrative or statistical boundaries. An urban centre is a pure grid-based concept, a cluster of contiguous cells of high density and with more than 50,000 inhabitants. This means that an urban centre inside a large local unit and one spread out over multiple local units could be easily identified using the same approach, something which is very difficult to do with definitions relying only on local unit data. Subsequently, in this sense, urban centre is adapted to the closest local units to define a city. Next, commuting flows are used to identify which of the surrounding, less densely populated local units were parts of the city's labour market (commuting zone). Commuting flows are based on travel to work i.e. the travel that employed residents in a local unit make to reach the place of work. However, commuting flows also capture some of the flows to access education, health, culture, sports or shops. FUAs are a powerful tool to compare socio-economic and spatial trends in cities and to design urban development policy. Based on the above, we chose FUA to assess the spatial structures of urban sprawl and suburbanization in Slovakia. Although the major concept of functional urban regions (FUR) is quite popular in Slovakia (Bezák 2000, Bezák 2014), we chose OECD and EU regionalisation for research. This paper forms the basis for the development of other similar papers in the individual countries of Central Europe. Therefore, it is essential that an international categorisation is used that is comparable to other countries in Central Europe that the authors will be working on in the future. The region of Nitra FUA and the region of Nitra FUR are not same; Nitra FUA contains 62 municipalities and Nitra FUR 71 municipalities.

Changes in land cover can show visible and generally the impacts of the new built areas and loss of the green territories and it summarises the main effects on the landscape. That is why this methodology is popular among the authors dealing with the impacts of urban expansion and landscape change (Ahrens-Lyons 2019; Feranec et al., 2007; Feranec et al. 2009; Hu et al. 2017; Lennert et al. 2020; Oueslati et al 2015). At European level there are various datasets which can be used as a starting point to explore the spatial patterns of urban sprawl and suburbanisation in functional urban areas[1] (FUA). In the urban sprawl literature one of the most widely used databases is the Corine Land Cover (EEA 2006; EEA 2016) which geographical coverage extends to 39 EEA member and collaborating countries. Another dataset is the Urban Atlas (UA) which contains land use and land cover data for 695 FUA's throughout Europe. These two datasets have standard mapping methodology and nomenclature, which makes the comparative analysis of different FUA's in various countries possible. The verification and qualitative evaluation of the Urban Atlas layers in Slovakia was developed by Szatmári, Kopecká and Feranec (2019).

In their analysis the authors used the Corine Land Cover and Urban Atlas products of the Copernicus Land Monitoring Service. Corine is an acronym which means 'Coordination of information on the environment', and it is part of the European environmental monitoring system. The programme started in 1985, and it provides a common methodological framework to collect and analyse environmental data. The Corine Land Cover (CLC) and Land Cover Change (CHA) datasets are available from 1990 to 2018 at five dates: 1990, 2000, 2006, 2012 and 2018.

CORINE CLC database classifies, on the basis of satellite photos, 0.1 hectare units of the surface into 44 various land cover categories, depending on what is most typical of the surface of the respective square. These categories range from 'Continuous urban fabric' to 'Sea and ocean', and include artificial, agricultural, natural and wetlands categories. There are 11 categories that can be taken as 'ARTIFICIAL SURFACES'.

- Continuous urban fabric (1.1.1)
- Discontinuous urban fabric (1.1.2)
- Industrial or commercial units (1.2.1)
- Road and rail network and associated land (1.2.2)
- Port areas (1.2.3)
- Airports (1.2.4)
- Mineral extraction sites (1.3.1)
- Dump sites (1.3.2)
- Construction sites (1.3.3)
- Green urban areas (1.4.1)
- Sport and leisure facilities (1.4.2)

For their survey the authors selected those land cover categories that best characterise the phenome-

[1] A functional urban area consists of a city and its commuting zone. Functional urban areas therefore consist of a densely inhabited city and a less densely populated commuting zone whose labour market is highly integrated with the city (EUROSTAT 2016, 27).

non of urban sprawl. They examined the changes of 'Discontinuous urban fabric' (1.1.2); 'Industrial, commercial and transport units' (1.2 contains categories 1.2.1-1.2.4) and 'Sport and leisure facilities' (1.4.2).

The change of 'Discontinuous urban fabric' (Most of the land is covered by structures, buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces) is mostly due to the enlargement of residential areas where the constructed units do not make contiguous spaces like in inner cities. Accordingly, they can also be seen as the change of settlement patches. The category 'Industrial, commercial and transport units' typically marks the locations of residential areas, infrastructure elements situated outside closed settlement parts (road, railways etc.), and shopping centres, warehouses, factories. These well demonstrate the fragmentation of landscape around settlements, because especially due to the linear infrastructure they make significant barriers in the landscape, compared to the size of the areas covered, and even their patches more remote from settlements considerably disintegrate landscape that typically used to be land of agricultural production.

The examination of the category 'Sport and leisure facilities' (1.4.2) was found important because it is part of the spread of urban lifestyle that occupy ever larger parts of former agricultural, semi-natural and natural areas that are cut out for the population pursuing an urban lifestyle and transformed into park forests, sport fields etc.

Although categories 1.3 are also taken as 'artificial surface', they were not examined, because mines and working areas are to a large extent independent of urban spaces, and so they do not characterise adequately the phenomenon of urban sprawl. The category 'Continuous urban fabric' (1.1.1) was not examined, either. This category refers to the inner, most closed, mostly contiguous areas of towns and cities. The proportion of these in the settlements examined is negligible, typical of the big cities in the first place and their spread takes place within the city, which makes them less relevant from the aspect of urban sprawl.

The analysis shows then to what extent cities and urban areas grow, from which one can conclude to how the urban residential areas have changed, how the proportion of non-permeable surfaces increased, basically influencing the runoff of precipitation. The larger the proportion of such surface, the larger the share of the precipitation flowing off, and the smaller the proportion and quantity of water filtering into the soil. This increases the threat of floods, the pollution of waters, and decreases the amount of subsoil water and evaporation. The data demonstrate, moreover, how artificial patches and barriers fragment landscape more and more, endangering thereby biodiversity and decreasing green surfaces.

The authors' examination covers the 2000-2018 period, using the CORINE CLC 2000, 2006, 2012 and 2018 databases. Thereby they are able to examine changes in a longer period of almost two decades, and three internal periods. All this is compared to the demographic changes of the urban area of Nitra as well, in order to see to what extent the change in the number of population contributes to the transformation of land cover and thereby to environmental impacts.

In the territory of Slovakia, the Urban Atlas database designates eight functional urban areas (FUAs) (Fig. 6). The characteristic features of Nitra and its hinterland within this are analysed, then the Nitra FUA and within that the suburban zone is examined in detail.

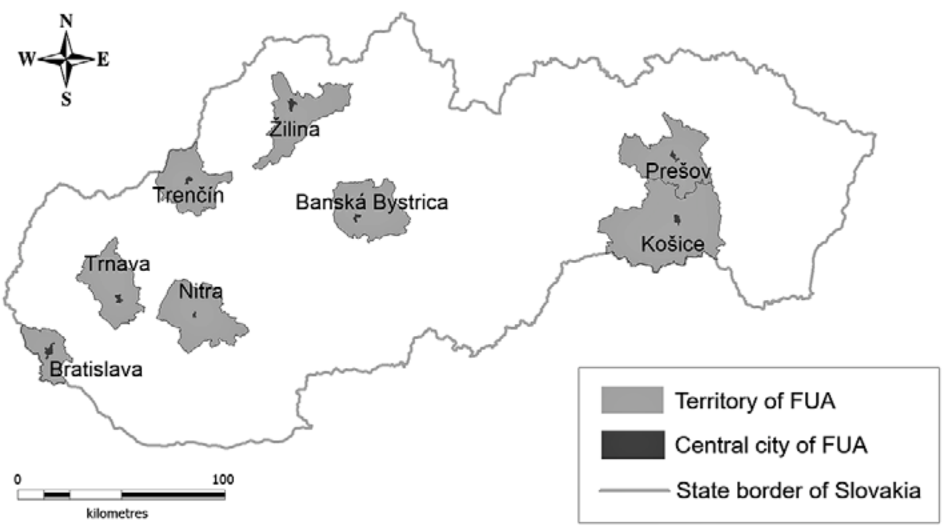

Figure 6. Overview map about the Slovak FUA's locations
Source: Own elaboration based on the data of the Urban Atlas.

Results

In 2000, 25,861.4 hectares from the territory of Slovakia were covered by artificial surface types (i.e. 5.3% of the territory of the country), which grew to 28,850.6 hectares (i.e. 5.9% of the territory of the country) by 2018, which is a growth of 11.6% in 18 years. In the territories of FUAs the share in this period grew on the average from 8.1% to 9.4%, which is an increase by 16.6% (Fig. 7).

Nitra and its area have a visibly higher proportion of built-up areas compared to other FUAs. The proportion of artificial areas is close to the figures of Bratislava, i.e. the highest among the cities, apart from the capital city, and follows Zilina as regards the extent of growth. If we look at the respective FUAs from the aspect of how the proportion of built-up areas changed in the territory of the central city and the other parts

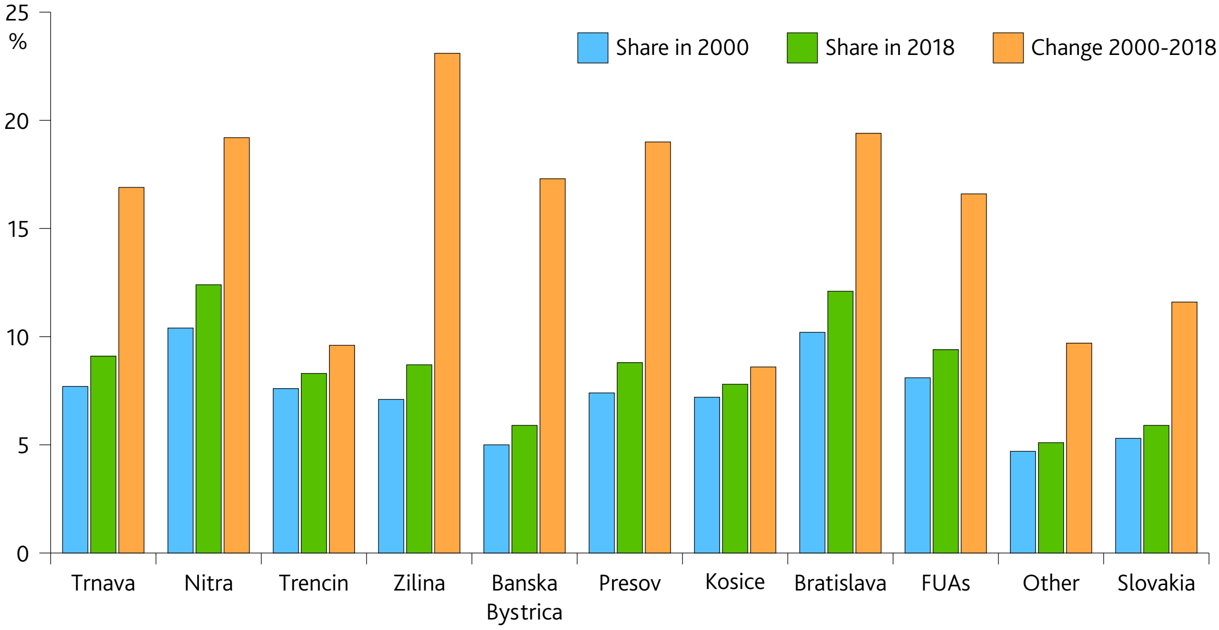

Figure 7. Proportions of the surface coverage categories examined and the extent of change from 2000 to 2018 in Slovakia, in the territories of the respective FUAs, in the average of the FUAs and in areas outside the FUAs
Source: own work based on EU Copernicus data.

Table 1. Extension of examined land cover categories in the territories of FUAs, and its change

FUA		Coverage (ha)		Change (%)			
		2000	2018	2000-2018	2000-2006	2006-2012	2012-2018
Trnava	City	144.9	186.7	28.8	22.2	2.7	2.7
	Other*	424.0	478.6	12.9	8.1	3.7	0.7
Nitra	City	269.7	310.8	15.2	10.1	1.0	3.6
	Other	643.2	777.5	20.9	6.3	4.8	8.5
Trencin	City	156.3	173.3	10.9	3.3	3.3	4.0
	Other	356.7	389.2	9.1	3.0	5.0	0.9
Zilina	City	222.9	238.6	7.0	3.7	2.9	0.4
	Other	352.3	469.6	33.3	29.4	2.6	0.4
Banska Bystrica	City	200.2	222.8	11.3	7.5	3.5	0.0
	Other	218.5	268.3	22.8	7.0	14.6	0.1
Presov	City	201.8	227.3	12.6	6.1	4.2	1.9
	Other	477.2	580.9	21.7	15.4	3.5	1.8
Kosice	City	603.8	620.7	2.8	-0.3	1.3	1.8
	Other	690.2	784.4	13.6	11.2	1.3	0.9
Bratislava	City	1,003.1	1,123.5	12.0	9.5	0.1	2.2
	Other	1,024.9	1,297.2	26.6	8.3	11.1	5.2

**Other: the commuting zone of the FUA; Source: own work based on EU Copernicus data.*

Table 2: Changes in the population and surface coverage in different zones of Nitra FUA

	Area, km²	Population		Relative change 2000-2018				Absolute change 2000-2018		
		2000	2018	Population	Artificial coverage	From which		Artificial coverage	From which	
						Discontinuous urban fabric (1.1.2)	Other examined surfaces		Discontinuous urban fabric (1.1.2)	Other examined surfaces
		Number of inhabitants		%				ha		
NITRA FUA	870.4	162,095	161,120	-0.6	19.2	15.5	48.4	175.4	126	49.4
Nitra city	100.47	87,575	76,655	-12.5	15.2	10.0	36.1	41.1	21.5	19.6
Other*	769.93	74,520	84,465	13.3	20.9	17.6	62.3	134.3	104.5	29.8
Suburbia**	183.9	22,149	28,218	27.4	45.9	43.7	72.5	83.7	73.7	10
Slovakia	49036	5,343,645	5,443,120	1.9	11.6	9.6	22.1	2,989.2	2,081.1	908.1

**= commuting zone of the NITRA FUA;*

***=suburban settlements within the commuting zone*

Source: own work, based on data of Slovak Statistical Office.

of the FUA, it is Nitra again that is characteristically different from the other Slovak urban areas (Table 1).

Nitra and its area feature high but not the highest enlargement dynamics looking at the whole of the period, compared to other FUAs. It is typical almost everywhere that the enlargement of areas surrounding cities is more intensive than the growth of the city itself, which demonstrates general suburbanisation. A characteristic feature of Nitra is that while in the first half of the 2000s growth was relatively high everywhere, especially in territories around the city, and growth slowed down by the third period, Nitra showed a rapid growth within 2012 and 2018 too, in fact, the enlargement of both the city and its environs was the highest among all FUAs, even preceding the capital city.

If the internal changes in the total of the Nitra FUA are examined, one can see that the enlargement of artificial areas was significant in the recent decades. Parallel to an increase of the built-up areas by 19.2%, the number of population decreased by 0.6%. Significant differences can be seen, however, if the data of 1) the central city (Nitra), 2) other parts of the FUA, and 3) the suburban zone within the FUA are separately analysed (Table 2).

One can clearly see the spatial rearrangement of the population within the FUA. The population of the city continuously declined in the examined period (from 87,575 to 76,655), as did that of the FUA as a whole (from 162,095 to 161,120 inhabitants). The population of areas outside the city significantly grew (from 74,520 to 84,465 inhabitants), within that suburban area increased their population from 22,149 to 28,218. Previous surveys prove that approximately half of the increase had come from other cities, the other half from other regions of the country, also, when comparing the data of the settlements we must also take into consideration some migrations of other (rural to rural) direction within the FUAs.

The dynamism of the growth of artificial surfaces (Fig. 8), however, exceeds to a large extent the growth of the number of population in all observed territorial units. In fact, in the cities we can register a rapid territorial increase besides falling population numbers. This is true not only for the residential zones but also for other artificial categories. As regards the central city, it must be emphasised that significant industrial investments were made that occupied territories of former agricultural lands.

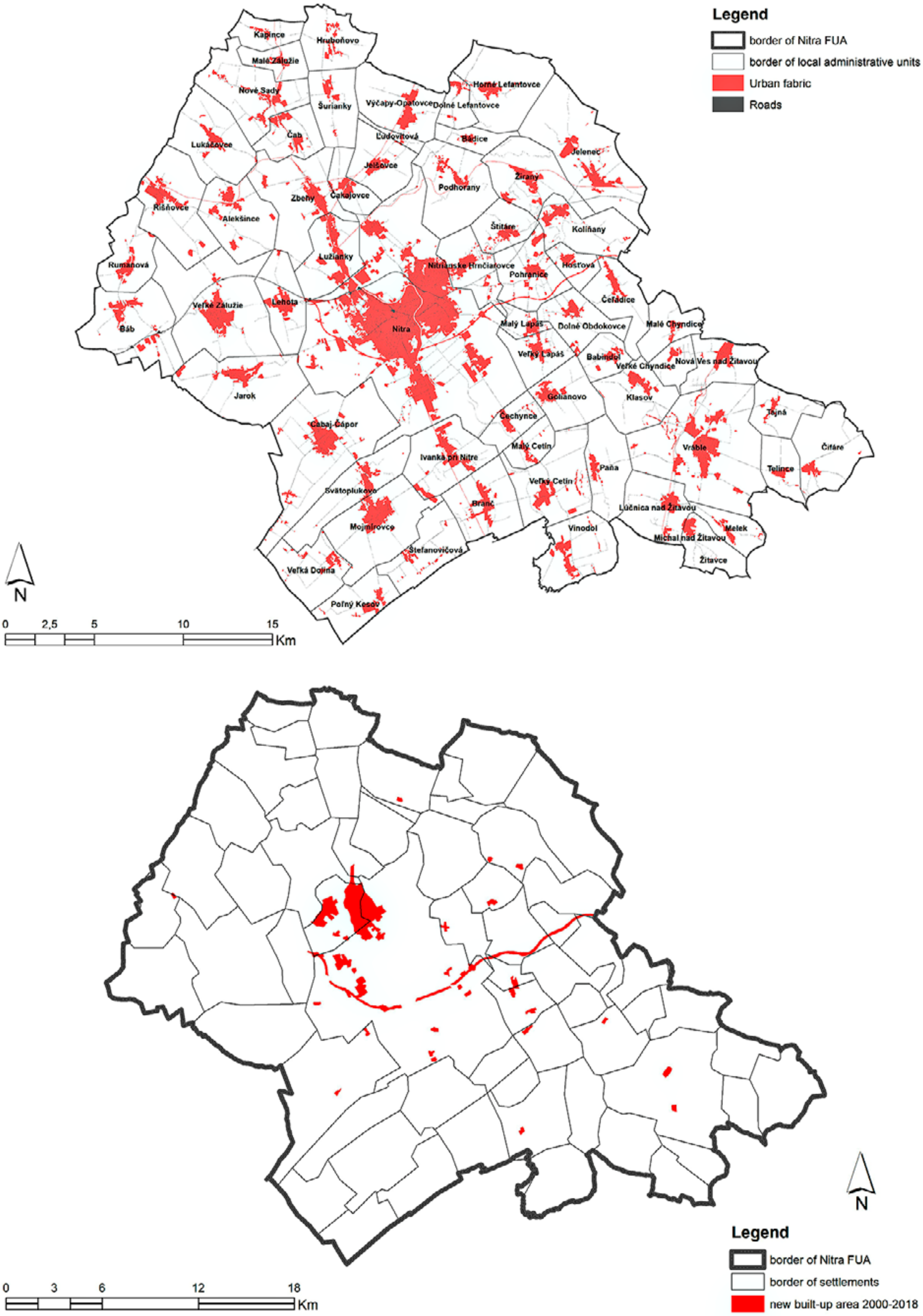

Figure 8. Urban fabric areas in 2018 and Changes in the extension of artificial surfaces in the Nitra FUA (2000–2018)
Source: own work based on EU Copernicus data.

Discussion

Nitra is an important industrial centre in Slovakia. It is a typical Central European industrial centre where growth is primarily due to the expansion of automotive industry. Growing industry attracts a large number of migrants from other parts of the country and even from abroad. It is visible that in the 2000s the city and its suburbia entered the period of suburbanisation, and the central city has been losing its population, parallel to the rapid growth of a suburban zone outside the city. At the same time we can witness the traditional suburbanisation tendency of growing industry attracting inhabitants from other rural areas, who settle down either in the city or in the suburban zones around it.

The authors' in-field experiences show that this results in a spectacular territorial expansion and the transformation of the landscape, the villagescape. It is typical that a large part of the newly settling in-migrants buy newly built homes in residential places created in villages around the city. These new residential zones are usually created by the transformation of agricultural areas. While the construction of detached houses was typical in the beginning of the period, in the last decade terraced houses built for commercial/investment purposes are typical. This increased the density of population and the proportion of built-up parts of the land plots also in suburban areas, while the average size of land plots decreased and there are less and less green surfaces. Exceptions from this are residential areas with higher prestige, which usually occupy hillside areas of higher elevation, and are often enlarged to the detriment of pastures and semi-natural areas, creating homes with a larger proportion of green surfaces on larger land plots. This is also indicated by a paper by the authors Izakovičová, Mederly and Petrovič (2017). According to the authors, urbanisation is typified by conversion of productive agricultural land and semi-natural ecosystems into built-up area accompanied by the negative ecological impacts of habitat deterioration and fragmentation. The rapidly changing consumption patterns of luxury living, transportation and leisure have increased the negative consequences on ecosystems and these compound the negative environmental trends.

Looking at the data of surface coverage the assumption can be justified that during urban sprawl and suburbanisation the increase of artificial surfaces is faster than the growth in the number of population. The growth dynamism of residential areas is less, anyway, than the triple value defined in the preface (Marshall's equation). Looking at the newly built real estates the authors believe that the reason for this is the shortage of capital, as most of the homes were built for families with more modest incomes. Investors wanted to build the largest possible number of homes on relatively small areas, leaving little space for both green areas and auxiliary roads. Knowing the examples from Western Europe (Haase & Nuissl, 2007) it is thought to be an important feature of suburbanisation in the Central European macro-region. The proportions of residential areas of higher prestige are compatible with the building up proportions of an average suburban zone in Germany. This results in the higher proportion of non-permeable surfaces within residential zones, with all of its environmental consequences (unfavourable changes in the proportions of runoff, infiltration and evaporation). According to Kopecká and Rosin (2015), urbanisation can be perceived from an economic point of view as streamlining the use of space. Intensive urban growth associated with an increase in impermeable surfaces is one of the most significant threats to biodiversity and soils. This is exacerbated by the lack of gardens in the new land plots, and the very low proportion of green surfaces, and even those are typically mowed lawn with a few ornamental plants and bushes, the majority of which are non-indigenous species. No fruit trees and other tress with larger foliage can be seen in the newly built-up areas – partly because they typically were plough lands before and partly due to the density of building up.

Urban sprawl is even more characterised by the enlargement of artificial surfaces outside residential areas: territories used for industrial, commercial and transportation purposes, or for recreation and sport. The increase of these areas is much more dynamic, as they only partly depend on the growth in the number of population. It can be connected to economic growth, transformation of the lifestyle of the population, the penetration of extra-urban shopping centres and the new ways of passing leisure time. It is also related, on the other hand, to the inconsiderate planning of the growth of residential areas, as the appearance of new residential zones does not always take place in areas most suitable from transportation aspects, and so the number and capacity of the network elements is continuously growing too. All this leads to the ever more serious fragmentation of the landscape and the habitats, the appearance of an increasing number of degraded surfaces and vegetations, the disappearance of alleys and groups of trees beside the roads, which makes the landscape more homogenous and boring, and thereby less valuable. We agree with Haladová and Petrovič (2015) who monitored the land use changes in the model area of Nitra.

Agriculture in this region has been gradually declining and disappearing in the past years. On the other side, urbanisation, technicisation and industrialisation are highly supported.

It is visible that the volume of urban sprawl and suburbanisation in our rural towns is not really significant on the whole. It concerns a relatively small number of population and area even in our case where economic growth induces a considerable in-migration and there is a relatively high solvent demand. The impacts on the environment and the landscape, on the other hand, are more considerable, and in the middle run even real estate problems are expected, as the residential zones are built relatively homogeneously and at the same time are more susceptible to market impacts than areas with diverse real estate structures.

Conclusions

The paper presents the spatial processes of a Slovakian urban area during the last period of almost two decades. This period resulted in significant changes in the lives of cities and their peri-urban areas. Migrating out from the cities, the changes in building up and lifestyle to such extent had been untypical formerly. The large number of out-migrants and the transforming economy together impact the landscape and surface of peri-urban areas and the proportions and styles of building up, which may result in obvious environmental problems in the coming decades. In the authors' opinion the transformation taking place in Central Europe is similar to the urbanisation processes of Western Europe, but traditionally belated compared to those and with more limited assets of capital; also, the transformation is smaller in volume because of the lower density of population. It is definitely worth surveying these processes and exploring their characteristic features, as these are the most significant settlement development processes of our time and the decades to come, and their environmental impacts may be important not only in themselves but are also given a special emphasis by the expected climate change.

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Rescaling Smart Destinations – The Growing Importance of Smart Geospatial Services during and after COVID-19 Pandemic

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Abstract

The COVID-19 pandemic has imposed numerous, lasting adverse effects on the global tourism industry. At the same time, it exposed the competitive advantages that existing smart tourism infrastructure could provide for addressing urgent health issues and providing meaningful smart services. This paper initially provides examples of smart geospatial services based on COVID-19 pandemic-related data, such as algorithms for measuring social distancing through CCTV and proximity contract tracing protocols and applications. Indeed, smart destinations, as an evolutionary step of smart cities, very quickly became a practical and research framework in various other disciplines, from leisure and service-oriented to technical and geospatial domains. However, various technologies employed and interests of different stockholders create a constant need for rescaling of smart data to facilitate their usability in providing optimized smart tourism services. One of the pressing concerns is the functional alignment of geospatial data with tourism-related data. Thus, we aim to pinpoint the growing importance of smart geospatial services, by pointing to the main downturn of the current smart destination issue with geospatial data resolutions, and, by building upon the relations of the geospatial layer of data with the tourism-specific layer. To this end, we pinpoint two further research directions – reinvestigating spatial and temporal resolution as a core of data smartness and the need for contextual (tourism-oriented) scaling of smart technology. This could be of keen interest in post-pandemic tourism, where smart geospatial services will be of pressing concern, but also it still an issue to be resolved in further smart destination development.

Keywords: smart tourism destination; smart tourism; service optimization; spatial optimization; COVID-19

Introduction

With a quick spread of COVID-19, the globalized world has suddenly faced an immediate threat of infection and high death rates. The horrifying images of people suffering from the disease and an unprecedented reaction and measures undertaken by the Chinese state shocked the world (Gössling et al., 2020). The sense of urgency in western societies, however, occurred a bit later, with media reports from northern Italy. These reports showed another layer of a threat – the inability of one of the most advanced health systems in the world to cope with a problem of this scale when no vaccine or conventional treatment is available. The global audience was warned that social (physical) distancing and limited interactions with other

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people would be the best way to deal with the current situation. This triggered an active collaboration of all citizens, trying to protect themselves and others, transforming this disease into a common problem (Stankov et al., 2020). The travel and tourism industry, as one of the backbones of a globalized society, was the first to be hit by the COVID-19 pandemic, showing its well-known fragility to sudden changes in tourism flows (Dwyer et al., 2020).

In a time of a crisis created by COVID-19 pandemic, people, organizations, and states turned towards technology asking for support (Gretzel et al., 2020; Stankov & Gretzel, 2020). There have been many voices stating the increased willingness of people and organizations to engage more with technology or to change the attitudes towards it and even to temporarily forget about its potential downturns, such as privacy concerns or health issues due to its prolonged use (Geist, 2020). During the recent epidemic, a huge amount of mobile data on calls and behavior on social networks, collected from millions of users, concerning on the grounds of privacy and data protection. Access to data from personal devices may be justified, but it must comply with the privacy policy and citizens must be aware of its importance (Tešić et al., 2020).

Most notably, technology has been used to connect isolated people and workers and to replace physical interactions. In tourism, as well as, in other domains, there have been numerous innovative examples of robots replacing medical workers, smartphone mobile applications used to track people and their contacts, or Big Data-driven models predicting the spread of the virus (Zeng et al., 2020). Tourism marketing has switched to some already existing and new virtual solutions to satisfy people's desire for travel, such as virtual museum tours and even a virtual reality concert in Helsinki that attracted over one million spectators (Chandler, 2020).

Despite the crisis, tourism can not occur just in virtual spaces, and many solutions have appeared to help in resolving the spatial issue of the current pandemic – a physical distancing. Indeed, tourist information services and travel planning assistants appear to be heavily influenced by the post-pandemic environment. As more and more people avoid crowded places, the popularity of outdoor activities is increasing, but also soon, we can expect the acceleration of digital transformation and even greater application of digital solutions (OECD, 2020; Stankov & Filimonau, 2019). As a consequence, even a new term of "non-contact tourism" emerged in South Korea, refereeing to novel travel trend that avoids crowded spaces and/or indoor activities, but prefers outdoor attractions and activities with plenty of space available (El-Assasy, 2020). The following table summarizes the most novel examples of using smart services within smart destinations. Interestingly, all services are heavily impacted by the geospatial perspective for mitigating the issue of physical distancing.

Many of those examples came from states and cities that have extensively developed and optimized their smart infrastructure, such as South Korea, Singapore, or interestingly, Helsinki, that, together with Lyon, was rewarded for the first edition of the European Capital of Smart Tourism competition in 2019. Thus, smart city infrastructure seems to be a competitive advantage in combating COVID-19. Indeed, an advanced smart city and smart destination, in particular, rely heavily on the spatial component, as most of the services offered are location-oriented, both from the perspective of users and service providers. Since smart tourism destinations are grounded in situation-based optimization between technol-

Table 1. Examples of new smart geospatial services that have emerged in response to the COVID-19 pandemic.

Example	Description	Geospatial perspective	Sources
Newcastle Urban Observatory, UK	Algorithms for measuring social distancing through CCTV and machine learning	• CCTV enabled for face recognition • Geospatial machine learning algorithms • Issues with privacy	(Das & James, 2020)
Government Technology Agency, Singapore	*TraceTogether* proximity contract tracing application deployed to the general public	• Geospatial data with timestamps • Issues with privacy	(Ahmed et al., 2020)
Ministry of Land, Infrastructure, and Transport (MOLIT), South Korea	COVID-19 Smart Management System (SMS)	• Integrated geospatial information framework • Thematic geospatial analysis • Spatial statistics • Geospatial dashboards	(Lee & Lee, 2020; Franch-Pardo, et al., 2020)
European Commission	Re-open EU, web platform to support a safe relaunch of traveling and tourism across Europe	• Real-time web platform • Geospatial data tourist information service	(European Union, 2020)
INRIA, France and Fraunhofer, Germany	ROBERT proximity contact tracing app protocol for StopCovid app	• Geospatial data with timestamps • Issues with privacy	(Ahmed et al., 2020)

ogy and physical environment (Liberato et al., 2018a), they should have the ability to provide related real-time information, improve real-time information access (Gajdošik, 2019), generate context-awareness and real-time monitoring (Buhalis & Amaranggana, 2015). This complex ecosystem of technologies and different actors generate transparency in the governance of real-time information, enhancing the competitiveness of a smart tourism destination (Koo et al., 2016; Hernandez-Martin et al., 2017; Lin, 2017).

However, despite the existence of smart technology infrastructure, its factual transferability to optimized geospatial services is the hard-to-reach goal for many smart cities. Most of the outputs of smart systems build on sensors feeds can be presented on a map, since the data is a sequence of records ordered by time, and the location of the sensor is known. Typically, a geospatially enabled software is equipped with the possibilities to handle that data, transform, analyze even in a real-time if needed. To make a functional GIS for a smart tourism destination, it is crucial to input quality data that are as much as seamless to cover the tourism process of interest for service optimization. Sensors embedded in tourist destinations should monitor the overall environment, as well as the behavior of tourists (Gajdošik, 2019). However, smart systems provide a plethora of discreet and continues data, that cover particular destination but a change of scale and more in-depth inspection will show that they are not as usable at a certain point of interest for tourism process (tourism context scaling), either data can not be measured at that location or time (spatial and temporal scaling). Although smart sensors play an increasing role in the acquisition of data to enable smart service optimization, the understanding of its spatial capabilities to facilitate the tourism process as they interfere and influence the tourism system has received only minimal attention. In essence, smart tourism destinations face a challenge of the lack of geospatial understanding, which is primarily related to the different spatial coverage of smart technologies. This implies the need to upgrade existing and developing new urban innovations where smart systems help strengthen social and physical infrastructure to improve the provision of tourism, public, and social services (González-Reverté, 2019).

This "geospatial flaw" could potentially limit the capacities of smart destinations to tailor their services in post-pandemic tourism, where more emphasis will be put on locations, both for the issues of health safety or for its traditional importance for the optimization of smart services for tourists. Indeed, with the advent of Tourism 4.0, there is a growing need for spatial optimization of smart tourism destinations. Combining smart tourism capabilities with spatial thinking, both within realms of conceptual modeling and practical endeavors, can lead to the potential quality of life improvement in the city (Sagl et al., 2015) and service optimization for smart tourism destination. To address this issue we pinpoint two further research directions, emphasizing the scaling problem of smart system coverage for further research and service optimization in smart tourism destinations.

Further research directions

Reinvestigating spatial and temporal resolution as a core of data smartness

Geospatial information is crucial to analyzing and quantifying the performance of smart cities and smart destinations, which is related to mobility, energy consumption, environmental pollution, or public health. Given that the smart environment is based on the merging of the physical world and the digital sphere through the Internet of Things and ambient intelligence (Femenia-Serra et al., 2019a), we can single out intelligence, connectivity, and interaction (Liberato et al. , 2018b) as an essential function of geospatial data in the context of smart tourism development.

Spatial and temporal data and the demand for it are at the center of understanding of planning, management, and environmental protection on a smart tourism destination, necessary to ensure a balance between residents, tourists, and destination management (Supak et al., 2015). In the immediate past, cities and tourism destinations have been able to improve their governance using geospatial technologies. Nevertheless, there is a long way to go to take full advantage of these technologies (Tao, 2013). The integration of smart geospatial technologies with information-communication technologies (ICT) and sensors refers to the location cloud. The ultimate goal of a spatiotemporal data collecting is to provide location-based services for various applications using location cloud and transforming all available geographic location information (Li et al., 2013). Spatial and temporal modeling is critical to risk and vulnerability prevention for smart cities (Roche, 2017) and smart tourism destinations. One of the more important challenges for the adoption of spatial autocorrelation in the analysis of tourism data is the specifics of spatial units for data aggregation (Stankov al., 2017).

The spatial and temporal resolution of smart technologies allows for finding acceptable solutions to optimize services for a tourism destination and to improve the experience of tourists until the time when sensors will become ubiquitous creating a full realistic destination model. In this case, tourism experience can be enhanced by implementing technology platforms that interconnect stakeholders, integrate inputs from different sources, and enable real-time dynamic information sharing (Femenia-Serra et al., 2019b). Such systems can enhance and facilitate decision-making and what is also important, increase business efficiency. However, the complexity of networked society requires accurate, reliable, and real data to help decision-makers in social and economic decision-making processes. If we look closely, we can certainly see that most of that data are spatially related (Gruen, 2013). The theory of spatial sciences and geography speaks of the concept of "places" used in digital spatiality and has a significant position in the concept of smart cities and smart tourism destinations. A smart tourism destination needs to be spatially enabled, in the way that spatial enablement refers to the "places" as a system to maintain space-time processes (Roche, 2014). Spatial-temporal optimization can lead to a change in service or quality of service in the short or long term. The smart city infrastructure is equipped with the ability to collect large amounts of data and most of that data has a spatial and temporal dimension (Roche, 2017), while all of this data can also be used for smart tourism destination services optimization and higher competitiveness (Cimbaljević et al., 2018). Geo-referencing and spatiotemporal quantifying are required by almost every element of a smart city (Li et al., 2013) and smart tourism destination. For the tourism destination, it is essential to provide integrated service, but also to be proactive to prevent the problems of providing real-time information, and to anticipate the needs of tourists. Therefore, service optimization should be based on a functionally-pragmatic principle. More specifically, it should be striving for urban-technological planning (Sigalat-Signes et al., 2019), so that smart systems can capture, analyze and interpret information in real-time (Lopez de Avila, 2015), but in the way that technological improvements and urbanism are given equal attention, as well as to focus on tourist offer. In the case of smart destinations, service optimization is of particular importance to collect tourism data and those left by tourists while visiting a place to provide services in real-time (Hjalager, 2015). On the other side, it is also vital for optimized strategic management that will help stakeholders to improve the tourist experience at the destination (Polese et al., 2018).

The need for contextual (tourism-oriented) scaling of smart technology

Smart technologies are becoming ubiquitous. Increasing number of consumers live in smart cities and travel to smart tourism destinations. The spatially enabled society provides spatial information to citizens, tourists, businesses, and governments to maximize the quality of their activities (Williamson et al., 2010; Stankov et al., 2018). Stakeholder interconnection at a smart tourism destination creates a smart tourism ecosystem (Boes et al., 2016) in which everyone is connected from the citizens to the government. With the use of sensor-based technology, destinations collect and process large amounts of data. In this way, suppliers (organizations, businesses) can create value for individuals by providing optimized information that is processed based on the data collected (Kim & Kim, 2017). Thus, tourism ecosystems become more open, emphasizing the importance of public-private cooperation, which enables coordination between entities. Further, if we consider the external and internal contexts, we can see that external or physical contexts are strongly related to the physical environment and are typically measured by physical sensors (Sagl et al., 2015). There are rare experimental cases of using body-mounted devices to directly measure tourists' emotions or to use big data analytics to derive tourists' emotional affection or sense of a place. However, typical smart city physical sensors cannot measure tourists' experience, so it is mostly ignored and neglected. For example, when receiving data collected from sensors related to air pollution, tourists may be misled to think that air is completely polluted in the broader area of the city, although that it is not a case in reality. Air pollution is usually monitored in areas that are often at risk, while sensors are rarely installed at non-hazardous locations. Data collected from sensors are very easily accessible publicly through mobile applications, but tourists are often not trained to interpret the available data, and thus all this can mislead tourists and

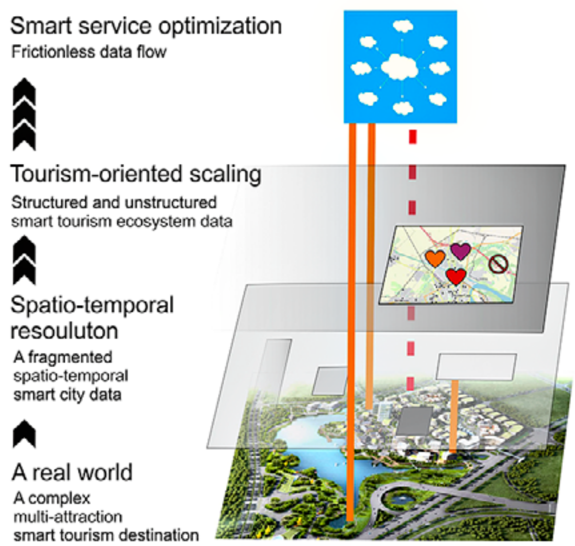

Figure 1. Essential layers of smart destinations for smart geospatial services

direct them to make erroneous conclusions that can lead to tourists behavior change in the direction of giving up consumption, which eventually leads to a decrease in revenue at the destination. The need to scale and better integrate different spatial data with tourism data to enable location technologies that provide the basis for optimized smart geospatial services accelerates in the COVID-19 pandemic environment.

Taking all of the above into account, data collected from remote sensors through the smart infrastructure must be precisely processed using spatial scaling, time scaling, and contextually tourism-oriented scaling before presentation to tourists. Travelers need to judge the impact of the information used and learn to react with the whole situation in mind (Batty et al., 2012). To cope with the contemporary challenges of smart technologies, citizens and tourists need to become spatially literate (Roche et al., 2014).

The number of sensor technologies and sensor applications is rapidly increasing, but the distribution between sensors and applications is not uniform and proportional, so the broad capabilities of sensor technologies application remain limited (Sagl et al., 2015). Although the types of data collected through sensors and their smart applications remain the same, challenges in the future could be the development of self-maintainable sensors and location and spatial information as a common good (Roche et al., 2014). Vast amounts of spatiotemporal referenced data collected through smart sensor infrastructure can be analyzed and transformed in real-time through cloud computing (Li et al., 2013), which will eventually support the managing of smart city and smart tourism destination. In this regard, data exchange is vital in tourism destinations through the technological platform that is supporting open data initiatives (Gajdošik, 2019).

Concluding remarks

A smart environment brought democratization in spatial data provision and sharing, allowing a variety of data types and sources, from administration and business to residents and travelers (Williamson et al., 2010). Almost all new technologies for smart cities and smart tourism destinations are geospatially enabled. A smart infrastructure collects a considerable amount of data that, by its quality and orientation, is not primarily tourism-oriented. Data collected from sensors in smart tourism destination can be used for smart services optimization and higher competitiveness. Analysis reveals that if the data collected by the sensors must first be subjected to contextual (tourism-oriented) scaling before presenting to tourists. If the data collected by the sensor is presented to tourists without fine-tuning it can mislead tourists. There is a lack of data as for now because smart infrastructure cannot measure the experience of tourists.

Spatial and temporal modeling is crucial for smart tourism destinations management. Utilizing the spatial and temporal resolution of smart technologies enables us to find acceptable solutions to optimize the services of a smart tourism destination and to enhance the tourists' experience, in the direction of the connected experience. Therefore, successful spatial-temporal modeling requires ICT, geospatial, and sensors technology interconnectivity, cooperation, as well as knowledge sharing.

Finally, we can ask ourselves: can more sensors, more sensor applications, more sophisticated methods of data transformation, and the inclusion of contextual and spatiotemporal approaches lead for sure to improvement in services and competitiveness in the smart tourism destination in post-pandemic period? We can only hope that in the future, the full integration of various sensing technologies along with strategies for gathering and transforming data and contextual rescaling will help us to discover all the critical relationships and good and bad causalities that exist between tourists and fully sensor-equipped smart tourism destination.

The direction of further research could be the goal of building a conceptual model that would alleviate the problem of capturing and scaling all types of data collected through the smart city infrastructure in smart tourism destinations, which could be used to optimize services and increase competitiveness. Finally, if we know the scale of data collected through sensors infrastructure in smart tourism destination, future research in this area also could relate to the serious privacy concerns for residents and tourists within the smart tourism destination.

The COVID-19 pandemic accelerates the need to scale and better integrate different spatial data with tourism data to enable location technologies that provide the basis for optimized smart geospatial services in the post-pandemic era. Future research could focus on geospatially distributed tourism preferences in the environment after COVID-19. Spatial data science and location-based data may be more important than ever during this pandemic, and the question arises as to which COVID-19 spatial data are most important for tourism in destinations around the planet. Smart and spatial technologists have massive data collecting possibilities, and they must be used carefully, especially taking into account the challenge of privacy issues in which direction future research may also go.

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The Perceived Value in Ecotourism Related to Satisfaction and Loyalty: a Study from Costa Rica

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Abstract

Ecotourism allows activities in contact with nature in protected natural areas to contribute to environmental care. This study seeks to establish the dimensions of perceived value in ecotourism and analyze its relationship with satisfaction and loyalty. It was an in situ research carried out in two protected areas of Costa Rica: Arenal National Park and Caño Negro National Wildlife Refuge. The sample consisted of 310 surveys for domestic and foreign tourists. The data were interpreted through a factorial analysis to identify the dimensions that make up the perceived value. Also, Spearman's correlation technique and the stepwise multiple regression method were used to find the relationships among the variables. The findings show that there are three dimensions of perceived value: economic-functional, emotional, and social. Overall satisfaction and loyalty had a high average score, and the dimensions found are significantly and positively related to overall satisfaction. The "economic-functional value" dimension has a greater influence on overall satisfaction, and the "emotional value" dimension is the most significant predictor of the intentions to return, recommend, and say positive things about the ecotourism destination.

Keywords: ecotourism; perceived value; satisfaction; loyalty; Costa Rica

Introduction

Natural resources are one of the main attractions exploited by tourist activity; however, the incessant increase in the currents of national and international tourists who visit different destinations each year can lead to great changes in ecosystems (Si-Shyun, 2018). Ecotourism grows three times faster than tourism in general (Hultman et al., 2015). In the ecotourism modality, tourists have diverse reasons to visit different attractions and destinations related to nature (Chikuta et al., 2017). Their ecotourism preferences can be varied, including nature, culture, farm, wildlife, and adventure (Björk, 2007; Honey, 2008). Specifically, community ecotourism has focused not only on the conservation of the environment but also on the preservation of the culture to improve the well-being of the local population (Jones, 2005; Liu et al., 2014; Reimer & Walter, 2013). For rural communities, ecotourism could become a gateway for economic development (Ketema, 2015). In these circumstances, to sustain the tourist activity, preventive or remedial measures must be taken

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to avoid the negative impact it may bring (Briassoulis & Van Der, 2013; Tanti & Raya, 2016).

In this regard, the destinations that base their tourism offer mainly on their natural resources have to face great challenges to maintain their sustainability. In this sense, there is an increase in the demand of tourists who are attracted to nature, giving greater value to the spaces perceived as responsible in ecological terms, and producing a permanent pressure on the environment of the place (Thapa & Lee, 2017). That is why protected areas have to optimize the experience assuming the double role, that of providing enjoyment through recreational activities and maintaining the sustainability of their natural areas that are part of the tourist heritage of the place (Wolf et al., 2017; Thapa & Lee, 2017). Ecotourism, green tourism or nature-oriented tourism is a segment that is reaching a growing popularity throughout the world. Therefore, each tourist destination receives more and more tourists who like contact with nature and are willing to comply with the protection rules of the natural area chosen to carry out leisure activities (Cheng & Wu, 2015). Also, the studies on the perceived value of tourists who like contact with nature emphasize the importance of knowing how and to which destination attributes the tourist gives a greater value during their travel experience. This market segment has a collective appreciation, understanding and assessment of the existence of environmental problems in the world (Chiu et al., 2014; Mostafa, 2007).

In this context, Costa Rica is a country that receives tourist flows to carry out activities in nature. This ecotourism destination of international importance has a large number of protected natural areas, including the Arenal National Park and the Caño Negro National Wildlife Refuge. The Arenal National Park is home to the Arenal Volcano, an icon of the nature of this country. The Caño Negro National Wildlife Refuge hosts a large number of endangered species.

Although this important ecotourism destination has a large number of protected areas considered main attractions within ecotourism, so far, no empirical studies have been carried out on the perceived value related to this type of tourism in Costa Rica. This study adds to the scientific literature as it is one of the few inquiries that analyzes the perceived value in protected areas. In fact, to the best of our knowledge, there are no studies in the literature that analyze the dimensions of perceived value that influencesatisfaction and predict ecotourism loyalty.

Therefore, this research focuses on establishing the dimensions that make up the perceived value and analyzing its relationship with the satisfaction and loyalty in ecotourism. The research was carried out in two protected natural areas of Costa Rica: Arenal National Park and Caño Negro National Wildlife Refuge. The theoretical and empirical findings of this research may have implications in the management of protected areas, being demand studies a crucial factor in the development of sustainable management plans.

Literature Review

Tourism comprises a set of economically important activities in the world to generate businesses that stimulate local economic movement and thereby find benefits that contribute to the place's development and its inhabitants' quality of life (Aliman et al., 2014; Hartwell et al., 2016). However, people involved in tourism and the society must be aware of this responsibility to assure good practices towards the environment and the preservation of the tourist heritage (Buckley, 2018; Hernández et al., 2017; Thapa & Lee, 2017). Several authors consider that although environmental knowledge is one-dimensional, it must be segmented into two constructs based on the amount of objective (real) and subjective (perceived) knowledge concerning the environmental conditions of protected areas (Bamberg & Möser, 2007). Thus, environmental responsibility in tourism refers to responsible travel, which is especially carried out towards some natural protected conservation areas (Wolf et al., 2017). Recent studies have researched the ecotourism potential and zoning, nature protection and sustainable tourism interaction as well as residents' perceptions towards protected areas and ecotourism (Balist et al., 2019; Carvache-Franco et al., 2018; Carvache-Franco et al., 2020; Jojić et al., 2018; Šiljeg et al., 2019; Stojanović et al., 2018).

In recent decades, the demand and popularity of nature-related tourism has led to various forms of tourism, including ecotourism, green tourism or nature tourism. They stand out for being associated with recreational activities that contribute to a healthier life, challenging several sites to maintain the sustainability of resources, as well as to optimize the experience, grant value and satisfy their visitors (Thapa & Lee, 2017). Thus, all the elements that participate in the configuration of positive experiences for tourists influence cognition and affection, contributing to the increase in value. It means that if the factors that allow the tourist and environment interaction satisfaction are combined, the value in the experience increases (Fiore & Kim, 2007).

In the marketing literature, the concept of perceived value has been widely used to analyze and understand the future behavior of tourists concerning purchasing decisions (Jamal & Sharifuddin, 2015). In tourism literature, perceived value is commonly conceptualized as the personal evaluation of travel products such as quality service, price, emotions, and social factors (Chiu et al., 2014). The concept of perceived value is closely related to consumer behavior and is a predictor of behavioral intentions (Cronin et al., 2000; Oh, 2000). In this way, the measurement of perceived value can have far-reaching implications for the field of tourism (Petrick, 2002).

The perceived value can be understood as a construct made by the differences between the benefits received (economic, social and relationships) and sacrifices made (price, time, effort, risk, and convenience) by the consumer (Cronin et al., 2000; Grewal et al., 1998). From this perspective, perceived value is recognized as a multidimensional concept, which involves individual evaluations of the benefits obtained in the travel experience, compared with the sacrifices made, and conditioned by aspects of a rational, affective, and social nature (Chiu et al., 2014). Due to this, the perceived value is subordinated to the judgments of the tourist, whose evaluation is grounded on the pre-purchase information, the quality of the services, the tourist resources, the surrounding nature, the time, money and effort invested, among other aspects (Jamal & Sharifuddin, 2015). These conceptions of value are based mainly on a utilitarian perspective that involves economic (cognitive) and affective (emotional) assessments, that is, it is between the costs and benefits received and that can be measured after the experience (Oliver, 1997, p. 394; Sánchez-Fernández & Iniesta-Bonillo, 2009).

Williams and Soutar (2009), in a study in Australia, found five dimensions of perceived value (functional value, value for money, emotional value, social value, and novelty value) in their adventure tourism study, concluding that all dimensions significantly influenced tourist satisfaction. In another research conducted in Malaysia, Jamal et al. (2011) established five dimensions of perceived value: functional value (establishment), functional value (price), experimental value (host-guest interaction), experiential value (activity, culture, and knowledge), and emotional value. Other studies involve the functional, affective, and social dimensions, which affect the general evaluation of the tourists' experience, and, in turn, result in a comparison between the benefits obtained and the costs assumed (Bajs, 2015; Solís-Radilla et al., 2016). In this perspective, some authors recognize social interaction as an important dimension of the quality of the experience and a determining factor of the perceived value, since it can significantly affect the dimensions of value during the intercultural exchange between local people and tourists, participating in the development of knowledge of tourists who learn something different from those exposed in their usual environment (Chiu et al., 2014; Rasoolimanesh et al., 2016; Zhang et al., 2017).

In this way, Lee et al. (2007) divided the perceived value into functional value, general value, and emotional value, and tested its effects on tourist satisfaction with the tour of the demilitarized zone in South Korea. They found that the three values positively influenced tourist satisfaction. Ha and Jang (2010), in another study, considered the hedonic and utilitarian value in gastronomic experiences in Korean restaurants in the United States. They found that both values were positively related to satisfaction. Lee et al. (2010) established the functional and emotional value when investigating the behaviors of visitors to a festival. Their findings showed that both types of perceived value are positively related to tourist satisfaction.

Similarly, Kim and Park (2017), based on twelve variables, found four dimensions of perceived value: economic, functional, emotional, and social. Through the study, they showed that these values had positive effects on overall satisfaction; also, that general satisfaction and tourist satisfaction were a significant antecedent of destination loyalty. In another research, Kim and Thapa (2018) on Jeju Island in South Korea examined how tourists perceived values (quality, emotional, price, and social), perceived quality, emotional, and social values significantly affected the the satisfaction and flow experience. The flow experience was significantly and positively related to satisfaction, environmentally responsible behaviors, and loyalty to the destination. More current in Ecuador, Carvache-Franco et al. (2019) identified four values: economic, functional and social. They also found that the values that are related to satisfaction and loyalty were functional and emotional.

In the same perspective, Peña et al. (2012) examined the relationships between perceived value, satisfaction, and loyalty in rural tourism in Spain. Those results revealed that the perceived value has a positive effect on tourist satisfaction and loyalty, coinciding with several studies that have established the significant influence of perceived value on the satisfaction of the experience (Chen & Tsai, 2007; Sun et al., 2013). Likewise, for Castellanos-Verdugo et al. (2016), satisfaction can promote the intentions to return and the willingness of ecotourists to recommend the site to family and friends. Therefore, a greater degree of knowledge about ecotourism in the hands of the visitor will favor a positive perception of the value of the ecotourism site, as well as will bring greater positive attitudes towards ecotourism. It should be noted that, in the field of tourism, satisfaction is commonly known as a pre-trip evaluation and post-trip expectations and experiences (Chen & Chen, 2010). Along these lines, Adam et al. (2019) studied the satisfaction and motivation of ecotourists in Kakum National Park, using the following factors: "educational satisfaction," "social satisfaction," "satisfaction with sanitation" and "satisfaction with relaxation."

In another study in Bali, Jaya (2018) identified that the destination image and the perceived value have a positive and significant effect on customer satisfaction. The perceived value has a higher correlation coefficient value when compared to the target image in customer satisfaction. The perceived values that should be the material of the evaluation are the functional and the emotional value. Within this perspective, the perceived value has been considered as a predictor of travelers' intentions (Eid & El-Gohary, 2015), which represents good planning strategy for destinations to attract tourists who share common needs and values, offering practical implications for the commercialization of ecotourism experiences (Kim & Park, 2014). In such circumstances, tourist destinations should increase their capacity to attract new tourists, without neglecting the promotion and conservation of lasting relationships with tourists who have already visited them (Bala et al., 2014). Thus, the future behavior assumed by the consumer is a product of the perceived value of each tourist experience (Chiu et al., 2014). Therefore, the perceived value directly influences tourist fidelity (Oliver, 1997; Chen & Chen, 2010). From this perspective, tourists can have a favorable attitude towards a destination and express their intention to revisit and recommend it. Several researchers have incorporated the concept of consumer loyalty to tourism (Baloglu, 2001; Iwasaki & Havitz, 1998; Yoon & Uysal, 2005). In loyalty, there can be several criteria. For example, in their study about Galapagos (Ecuador), Rivera and Croes (2010) suggested that ecotourists probably would not return, but they would recommend the destination. Previous studies have shown that perceived value leads to favorable results such as satisfaction and behavioral intentions (Chua et al., 2015; Kim et al., 2015). That is why our study tries to find the relationship between perceived value and other variables as satisfaction and loyalty.

Study area

Costa Rica is a world-renowned country for its ecological wealth. In 2018, Costa Rica had a total of 2,314, 888 tourist arrivals. (Costa Rican Institute of Tourism ICT, 2020). Ecoutourism experiences stand out since more than 90% of tourists visit national parks and protected reserves, which cover 20% of the national territory (Conservation System of Protected Areas of Costa Rica SINAC, 2019). In Costa Rica, approximately 75% of tourist visits are for vacation. Among the main reasons for visiting the country, the second reason is ecotourism with approximately 64% of visits (Costa Rican Institute of Tourism ICT, 2020). Hence, ecoutorism is

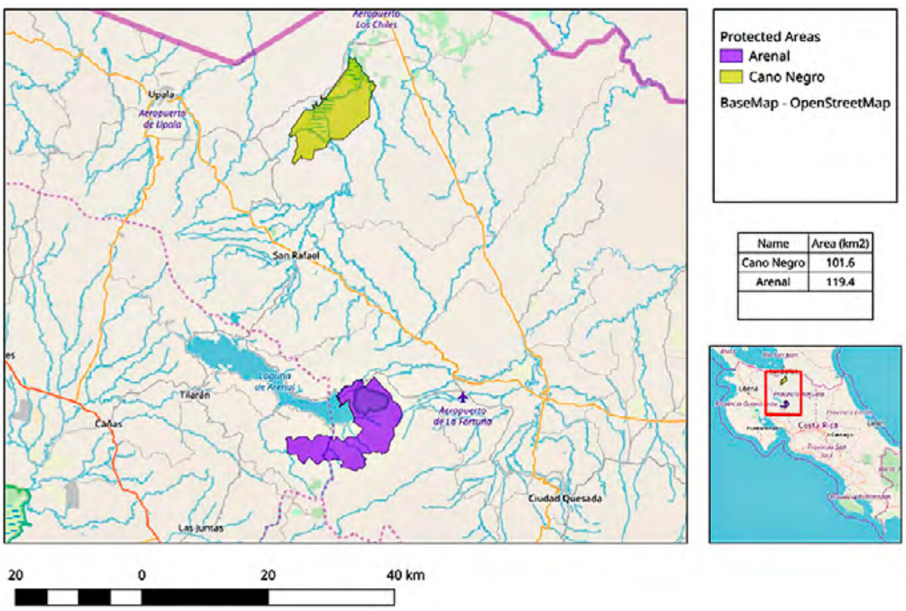

Figure 1. The geographic location of protected areas: Arenal Volcano National Park and Caño Negro Mixed National Wildlife Refuge (Costa Rica).

Source: www.idehn.tec.ac.cr

Figure 2. Arenal National Park
Source: Jonathan Serrano Hernández

relevant in Costa Rica. Costa Rica has two protected areas widely visited by domestic and foreign tourists, ideal for ecotourism: The "Arenal National Park" and the "Caño Negro National Wildlife Refuge." (Figure 1).

The "Arenal National Park" with its natural icon the "Arenal Volcano," a colossus that began its activity in 1968, is one of the most visited parks nationally. It has a territorial extension of 12,010 hectares and houses a unique natural wealth. It has been considered a living laboratory in which geomorphological richness and the complexity of development in biological processes are highlighted. This Costa Rican National Park received 111,286 tourists in 2018 (Costa Rican Institute of Tourism ICT, 2018). The park was famous for the lava flows that made it shine for many years, despite its activity ceded in 1992. However, it remains one of the nationally protected areas with more geological and geomorphological wealth since it houses both pioneer vegetation and a primary forest. It is a protected area of great richness and attractive for the Performance of research studies and natural observation. (Figure 2, 3).

Costa Rican natural wealth also includes "Caño Negro National Wildlife Refuge," with an area of 9,969

Figure 3. Arenal National Park
Source: Jonathan Serrano Hernández

Figure 4. Caño Negro National Wildlife Refuge
Source: Moises Brenes Arias

Figure 5. Caño Negro National Wildlife Refuge
Source: Moises Brenes Arias

hectares. This refuge shelters migratory birds and endemic freshwater fish, many of these endangered species. Its main attraction is a lagoon and a wetland of more than 880 hectares, which can be crossed in canoes or boats. This protected area constitutes a habitat for many migratory birds and endangered fish, as well as plants, mammals, and reptiles such as the alligator. That is why it was cataloged as the third most important wetland worldwide by The Ramsar Wetlands Convention. The intergovernmental treaty that offers the framework for the conservation and rational use of wetlands and their resources worldwide. Also, it has been recognized as a sanctuary and named since 1991, "Wetland of International Importance". (Figure 4,5).

Methodology

The sample was obtained from national and foreign tourists who were visiting the Arenal National Park and the Caño Negro National Wildlife Refuge in Costa Rica. Tourists were over 18 years of age. The method of simple random sampling was used to provide all the visitors within the protected area with the same probability of being chosen.

A three-section questionnaire was developed to achieve the objective of the present study. The first section dealt with the sociodemographic information of the respondents. It consisted of questions related to origin, gender, age, marital status, education, professional activity and in the company of those who travel with tourists. The second measured the perceived value through 12 items, which were related to previous findings on economic, functional, social and emotional values. Thus, for perceived value, the items used by Kim and Park (2017) were adapted. The question of perceived value was measured using a 5-point liker scale where 1 meant "strongly disagreed" and 5 "strongly agreed." The Cronbach's Alpha reliability index reached a value of 0.94, which indicates a robust index for the scale of the perceived value of the present study.

The third part analyzed the satisfaction and loyalty of tourists. The general satisfaction question was measured through a 5-point likert scale, where 1 was "not at all satisfied" and 5 was "very satisfied." The loyalty questions were measured through a 5-point Likert scale, where 1 was "Strongly disagree" and 5 was "totally agree." Loyalty questions inquired about return, recommendation, and saying positive things about protected areas.The instrument was designed based on several previous studies of perceived value and its relation to satisfaction and loyalty.

The surveys were administered during March and April 2019 to visitors who were within the protected natural areas while resting or performing recreational activities. The sample was collected by a student from the Costa Rica Institute of Technology, who was attentive to clarify the doubts or concerns of the visitors while they were answering the questionnaire autonomously.

The population variability was estimated at 50% (p = q = 0.5). 310 valid surveys were obtained, this being the sample size, with a margin of error of +/- 5.56% and a confidence level of 95%. The data collected was organized, tabulated, and statistically analyzed using the SPSS 22.0 program for Windows. The data were analyzed in two stages: first, a factorial analysis was carried out to identify the constructs that underlie the variables, providing an overview of the most important perceived values using these constructs. Specifically, a Varimax rotation was used to facilitate the interpretation of the data. The Kaiser criterion was used to find the number of factors, where only factors with eigenvalues greater than 1 were used. The KMO index (Kaiser-Meyer-Olkin) and Bartlett's Sphericity Test were used to determine if it was appropriate perform the factor analysis. In the second stage, Spearman's correlation technique was used to know the dimensions correlated with general satisfaction. Besides, the stepwise multiple regression method was carried out to select the dimensions of the perceived value predicted by future behavior variables.

Table 1. Research file

Geographic area	Arenal National Park and the Caño Negro National Wildlife Refuge (Costa Rica)
Population	National and foreign visitors
Date of completion	January to May 2019
Process	Simple random sampling
Confidence level	95%
Error range	+/- 5.56%
Valid questionnaires	310

Results

The sample was taken from two protected areas of Costa Rica, where 79.4% were foreign tourists, and 20.6% were nationals. Regarding gender, 54.8% were men and 45.2% women. Its origin was mainly from Europe (36.8%) and North America (32.3%). The majority age group was between 21 and 30 years old, with 38.7%, followed by the group between 31 and 40 years old, with 21.3%. The majority were single (51.3%), followed by the married group (36.1%). About the level of education, the group of university students was the largest (46.2%). Regarding their professional activity, the group of private professionals had 27.4%. The majority traveled with the family (35.8%), followed by those traveling as a couple (29.7%). (Table 2).

Dimensions of perceived value (Factor analysis)

The factor analysis allowed extracting three dimensions of the perceived value. The principal component analysis was used as a technique for factor extraction. The Varimax rotation method was implemented to obtain a clearer interpretation of the factors so that each had very high or low factor loads. The factors taken into account in the Kaiser criteria had own values greater than 1.00. Three factors were part of the solution and represented 80.57% of the total variance. The KMO index (Kaiser-Meyer-Olkin) was 0.92, so it was excellent for factor analysis. Besides, Barlett's Sphericity Test was significant <0.05, so factor analysis was appropiate to apply. Table 3 shows these results.

According to the results of Table 3, the factors had a Cronbach's alpha coefficient between 0.892 and 0.918. Thus, each factor had high reliability, and this indicated that the variables of each factor measured the same construct and were highly correlated with each other. The primary factor was called "economic and functional" and is the factor with the greatest explanatory capacity (61.32%) of the total variance. This first dimension was related to the variables of perceived value: the service has good prices, the service has good value for money, the service is afford-

Table 2. Sociodemographic aspects and characteristics of the trip

Demographics	Categories	N=310	%
Origin	Domestic	64	20.6
	Foreign	246	79.4
Origin by continent	North America	100	32.3
	Europe	114	36.8
	South America	14	4.5
	Asia	12	3.9
	Rest of the world	70	22.6
Gender	Male	140	45.2
	Female	170	54.8
Age	Less than20 years old	40	12.9
	21 - 30 years old	120	38.7
	31 - 40 years old	66	21.3
	41 - 50 years old	41	13.2
	51 - 60 years old	35	11.3
	More than60 years old	8	2.6
Marital status	Single	159	51.3
	Married	112	36.1
	Other	39	12.6
Education	Elementary	12	3.9
	High School	67	21.6
	University	143	46.2
	Postgraduate/Master/ Ph.D.	88	28.4
Occupation	Student	60	19.4
	Researcher / scientist	10	3.2
	Businessman	50	16.1
	Private Employee	85	27.4
	Public Employee	57	18.4
	Retired	7	2.3
	Unemployed	10	3.2
	Other	31	10.0
With /without companion	Alone	10	3.2
	Relatives	111	35.8
	Friends	81	26.1
	Apartner	92	29.7
	Other	16	5.1

able, the service has an acceptable quality level, and the service is well organized. The second factor was "emotional" and met 10.63% of the total variance. This second dimension was related to the following variables: this visit makes me feel happy, I have positive feelings towards it, this visit is pleasant, and the service is convenient for me. The third factor is called "social" and comprised 8.62% of the total variance. This third dimension was related to the variables of perceived value: I feel like a special person, I make a

Table 3. Dimensions of perceived value (Factor Analysis)

Variables	Components			Factors
	1	2	3	
Good regarding price	0.851			Economic-functional
Value for money	0.844			
Service is affordable	0.794			
Acceptable quality standard	0.748			
Well organized	0.599			
Makes me feel happy		0.903		Emotional
Positive feeling		0.885		
Enjoyable		0.791		
Convenient for me		0.539		
I feel like a special person			0.852	Social
I make a good impression on other people			0.811	
I gain social approval from others			0.785	
Eigenvalues	7.36	1.28	1.03	
Variance explained (%)	61.32	10.63	8.62	
Cronbach's Alpha	0.918	0.907	0.892	
KMO	0.92			
Barlett's sphericity test	Chi squared = 3345. 69 sig=0.00			

Extraction method: Principal component analysis Rotation method: Varimax with Kaiser

good impression on other people, and I get the social approval of others.

Satisfaction and future behavior variables

The 5-point Likert scale (1 being little and 5 a lot) was used to analyze satisfaction and future behavior variables (Table 4).

Table 4. Variables of satisfaction and future behavior

Variables	Mean	Min.	Max.	Stand. Dev
Overall satisfaction	4.36	1	5	0.803
I have the intention to revisit this protected area	3.72	1	5	1.324
I have the intention to recommend this protected area	4.32	1	5	0.947
When I talk about this protected area, I will give positive comments	4.42	1	5	0.847

According to the results of Table 4, overall satisfaction reached a high level of 4.36 (higher than 4), so tourists were very satisfied in these protected areas. Concerning the variables of future behavior, the intentions of coming back to these protected areas reached a value of 3.72, so the perceived value of the services in these destinations should be improved. On the other hand, tourists had a high level of 4.32 concerning the intentions of recommending these protected areas. Also, tourists had a high level of 4.42 in intentions of saying positive things about these destinations.

Relationship between perceived value and satisfaction

Spearman's correlation coefficient has been used to analyze the relationship between perceived value and overall satisfaction. This coefficient was chosen because it was the most suitable for the analysis of ordinal or scale variables. Table 5 shows the results.

Table 5. Relationship between perceived value and overall satisfaction (Spearman correlation)

Factors	Correlation
Economic and functional	0.437**
Emotional	0.422**
Social	0.252**

***The correlation is significant at the 0.01 level*

As presented in Table 5, all dimensions of perceived value were significantly and positively related to overall satisfaction, so there is a significant relationship between perceived value and overall satisfaction, coinciding with several studies (Carvache-Franco et al., 2019; Jaya, 2018; Lee et al., 2007; Lee et al., 2010; Peña et al., 2012; Sun et al., 2013). The economic and functional dimension was the one most related to overall satisfaction, so prices and the quality of services should improve to increase the satisfaction of tourists in these destinations. The second dimension that was related to general satisfaction was the emotional dimension, which means that the emotion felt by tourists in these destinations needs to be improved to increase their overall satisfaction in these protected areas.

Relationship between perceived value and intentions to return to protected areas

For this case, the stepwise multiple regression method was used, which was appropriate to estimate or predict future behavior (return). A correlation coefficient was no longer used to find the relationship between perceived value and return intentions, because return is a future behavioral variable. Table 6 shows the results.

In Table 6, the R-square had a value of 0.28, so it was an adequate value, since the future behavior of tourists has been little predictable. However, the p value of the F test was significant ($p < 0.01$), which indicated a real relationship between the significant predictors (perceived value) and the response variable (return intentions). Therefore, the model was adequate.The "emotional" dimension was the most significant predictor of tourists' intentions to revisit these protected areas (Beta = 0.331, $p < 0.01$). The second most significant element was the "social" (Beta = 0.301, $p < 0.01$).

The perceived value and intentions of recommending protected areas

The stepwise multiple regression method was used to analyze the dimensions of perceived value that predict the intentions of recommending these protected areas. Table 7 shows the results.

According to Table 7, the R squared had a value of 0.48, so it was an adequate value for the analysis of future behavior. Furthermore, the p value of the F test was significant ($p < 0.01$), so there was a signif-

Table 6. Relationship between perceived value and intentions to return to protected areas (Regression)

Factors	Beta	t	Sig.	R^2	F	Sig.
Emotional	0.331	6.797	0.000	0.280	39,305	0.000
Social	0.301	6.181	0.000			
Economic and functional	0.287	5.897	0.000			
(Constant)		57.490	0.000			

Table 7. Relationship between perceived value and intentions to recommend protected areas (Regression)

Factors	Beta	t	Sig.	R^2	F	Sig.
Emotional	0.542	13.104	0.000	0.480	93,590	0.000
Economic and functional	0.371	8.977	0.000			
Social	0.221	5.337	0.000			
(Constant)		110.137	0.000			

icant relationship between the perceived value and the intention to return. Therefore, the model was adequate.The "emotional" dimension was the most significant predictor of tourists' intentions to recommend these protected areas (Beta = 0.542, p <0.01). The second most significant element was the "economic and functional" (Beta = 0.371, p <0.01). However, it is not a predictor as important as the emotional factor.

The perceived value and saying positive things about the ecotourism destination

The stepwise multiple regression method was used to analyze the dimensions of perceived value that predict the intentions of saying positive things about these protected areas. Table 8 presents the results.

In Table 8, the researchers found an R squared value of 0.50 that was appropriate for analyzing future behavios. Also, the model was adequate because the F test was significant (p(p <0.01) , and there was a significant relationship between the perceived value and the intention to return. Therefore, the model was adequate. The most significant predictor of tourists' intentions to provide positive feedback about the protected areas was the "Emotional" dimension (Beta = 0.569, p <0.01). The "economic and functional" (Beta = 0.370, p <0.01 was the most significant element. However, the latter is not a relevant predictor.

Table 8. Relationship between the dimensions of perceived value and saying positive things about the ecotourism destination (Regression)

Factors	Beta	t	Sig.	R^2	F	Sig.
Emotional	0.569	14.058	0.000	0.503	102,399	0.000
Economic and functional	0.370	9.140	0.000			
Social	0.206	5.102	0.000			
(Constant)		129.024	0.000			

Discussion

This study sought to establish the dimensions of perceived value and their relationship with ecotourists' satisfaction and loyalty. Thus, three dimensions of perceived value in ecotourism have been found: economic-functional value, emotional value, and social value. When comparing these results with other previous findings, we discovered similarities, as in the paper of Lee et al. (2007), who found general, functional, and emotional values, being the last two related to our economic-functional and emotional values. In another research, Williams and Soutar (2009) identified five dimensions of perceived value: functional value, value for money, emotional value, social value, and novelty value, which are comparable to our economic-functional, emotional, and social values, respectively. Moreover, Lee et al. (2010) discovered the functional and emotional values, similar to our economic-functional and emotional values, but they did not find the social value as in the current paper.

Another investigation is that of Jamal et al. (2011), who identified five dimensions of perceived value: first, functional value (establishment), and functional value (price) were both similar to our economic-functional value. He also found the experimental value (host-guest interaction) and the experiential value (activity, culture, and knowledge) comparable to our social value. Finally, his emotional value was also very similar to our emotional value. In the same perspective, Bags (2015) and Solís-Radilla et al. (2016) found functional, affective, and social values, which are similar to our economic-functional, emotional, and social values, respectively. Conversely, Kim and Thapa (2018) discovered quality, emotional, price, and social dimensions as perceived values, being closely related to the economic-functional, emotional, and social values, respectively, that emerged from this research. In more similar studies, Carvache Franco et al. (2019) and Kim and Park (2017) found four perceived values: economic, functional, emotional and social. In our investigation we found the same values (economic-functional, emotional and social) with the exception that the economic-functional value was found together, which contributes to the literature in this field, since it is possible in an ecotourism destination to find these four perceived values, but the economic and the functional values can also be seen as a single dimension, having its own characteristics, so it should not be studied separately.

Regarding the perceived value and its relation to general satisfaction, our results have found that all the dimensions of the perceived value were significantly and positively related to general satisfaction. Similar results were found in other studies (Carvache-Franco et al, 2019; Jaya, 2018; Lee et al., 2007; Lee et al., 2010; Peña et al., 2012; Sun et al., 2013), which indicates that all dimensions of perceived value are related to overall satisfaction.

Concerning the influence of the main dimensions of perceived value with general satisfaction, Kim and

Park (2017) found the functional, social, and emotional dimensions, related to those found by us. In another study, Kim and Thapa (2018) established the emotional and social dimensions in satisfaction, similar to our second motivation, "emotional value." Also, for Jaya (2018), the perceived values that should be the material of the evaluation were the functional and the emotional values, comparable to our economic-functional and emotional results. For Carvache-Franco et al. (2019), functional and emotional values were linked to satisfaction and loyalty, results that are closely related to ours (economic-functional and emotional values). The findings of this study contribute to the literature by establishing that the main perceived values related to general satisfaction are the "functional-economic value" and the "emotional value."

Regarding loyalty, several studies have found that perceived value influences the intention of returning to a destination (Chen & Chen, 2010; Oliver, 1997; Peña et al., 2012). However, it has not been found which dimension most influences the intentions of returning to an ecotourism destination. Our study contributes to the literature as it is the first to analyze the dimensions of perceived value that are the most important for satisfaction and loyalty in ecotourism. Few studies have been found that analyze whether there is a relationship between perceived value with satisfaction and loyalty. However, none of them has focused on analyzing the dimensions of perceived value that highly influence or affect satisfaction and loyalty in ecotourism.

As a contribution to the literature, the findings of this study showed that the dimension of "emotional value" was the most significant predictor of tourists' intentions to revisit, recommend and say positive things about these protected areas. Therefore, the "emotional" value is the main predictor of loyalty in ecotourism, this being the greatest contribution of this study to the literature in this field. This relevant contribution to the literature encourages the study of emotional value as the main predictor of loyalty. Thus, our research deepens the understanding of emotions and their relationship with the loyalty of tourists. In practice, by knowing the importance of emotional value for loyalty in ecotourism, tourism entreprises can improve the supply of activities related to emotional value, which bring new experiences or adventures to tourists. These type of activities would increase the loyalty of tourists in ecotourism.

Conclusions

Ecotourism is a type of tourism where visitors have the opportunity to carry out activities related to nature, culture, and community in a destination, respecting the environment. Protected areas are one of the main destinations visited for ecotourism because of their rich flora and fauna and where activities can be carried out in contact with nature. In this regard, it is important to conduct demand studies in these destinations to contribute with guidelines for the elaboration of public policies and the execution of sustainable programs within the protected areas.

Studying the perceived value in ecotourism is crucial to generalize results and contribute to the literature on this subject. In this way, three dimensions were found in the value perceived in ecotourism destinations. The most important being "economic and functional value," followed by "emotional value" and "social value." The "economic and functional" and "emotional" dimensions have the greatest influence on overall satisfaction. The "emotional" and "social" dimensions are the most significant predictors of tourists' intentions to return to these ecotourism destinations. En cambio, The "emotional" dimension was the most significant predictor of tourists' intentions to recommend and say positive things about this ecotourism destination.

Among the theoretical implications, previous literature has found four perceived values in ecotourism: economic, functional, emotional and social (Carvache Franco et al., 2019; Kim & Thapa, 2018; Kim and Park, 2017, Lee et al., 2007; Lee et al., 2010, Solís-Radilla et al., 2016; Williams & Soutar, 2009). But as seen in this research, the economic and functional value can be merged into a single dimension called "economic and functional" value. Regarding the relationship of perceived value with general satisfaction, the findings show that all dimensions of perceived value are related to general satisfaction, as previous studies have also shown (Carvache-Franco et al., 2019; Jaya, 2018; Lee et al., 2007; Lee et al., 2010; Peña et al., 2012; Sun et al., 2013). The main perceived values that are related to overall satisfaction are "functional-economic value" and "emotional value," closely related to the results reported in other studies (Kim and Park, 2017; Kim and Thapa, 2018; Jaya, 2018; Carvache- Franco et al., 2019). The emotional value is the main predictor of loyalty in ecotourism, representing the major contribution of this study to the literature.

Among the practical implications derived from this research, the perceived value helps tourism-related companies know the significance that tourists grant to services, according to its different dimensions. Therefore, protected area managers must improve emotional valueby offering innovative activities that really excite touristsand bring new experiences or adventures. Hence, tourists will feel memorable enjoyment. In addition, social interaction is an opportunity for meetingpeople with similar interests and sharing experiences. It is also vital to consider that the perceived value is a variable that helps companies to set prices and manage the quality of their services. That is why the economic and functional value that tourists perceive from the services provided must be analyzed. With the improvement of the supply considering the perceived value, the satisfaction and loyalty of tourists increases bringing benefits to the destination and the community. Besides, the perceived value also provides information to companies for preparing more efficient action plans, increasing the effectiveness of strategic actions and offering services considering the tourists expectations and values.

Finally, the main limitation of the present study was the temporality of the sample collection as the demand may vary in different seasons. In addition, as the study was carried out in two specific protected areas, soits results are limited to the perceived value of tourists visiting these sites. This research study opens a new line of research concerning the perceived value related to environmental care in an ecotourism destination.

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