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APPLICATION OF GIS IN SPATIAL ANALYSIS OF INDUSTRY CONCENTRATION: THE CASE STUDY OF TEŠANJ MUNICIPALITY (BOSNIA AND HERZEGOVINA)

Abstract: The focus of this study is a spatial analysis of the industry distribution and concentration, on the example of municipality of Tešanj (Bosnia and Herzegovina), based on the application of GIS methods. Municipality of Tešanj is one of the most developed municipalities in Bosnia and Herzegovina, while Tešanj's industry significantly contributes to the economic development of this country. GIS analysis of industry was based on the field work, locating and georeferencing industrial companies, acquisition, adaptation, adjustment and validation of digital surface models and google satellite imagery, mapping of relief, hydrography and transport network. With the aim of geovisualization of spatial distribution of industry, spatial descriptive statistics and non-parametric density estimation analysis (Kernel Density Estimation) were performed. In order to determine the distribution of industry in relation to relief (elevation, slope, and aspect), hydrography and transport network, GIS techniques of reclassification, vectorization, count point in polygons, buffer and clip geoprocessing tools were used. Conducted research provided a new insight into the data mining and visualization based on principles of QGIS, the effects of geographic factors on industry distribution, and confirmed the importance of relief, hydrographic and transport network on the concentration of industry in municipality Tešanj.

Key words: GIS, spatial analysis, industry concentration, geographic factors, Tešanj

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Introduction

A significant feature of the economic or industrial landscape is the intense concentration of economic activities. This concentration is found in a large number of countries, in different time periods, and numerous studies around the world analysed the issue of geographical concentration of industry (Hanson, 2001; Dumais et al., 2002; Aiginger & Davies, 2004; Cabral et al., 2012; Ayadi & Wided, 2014; Luque, 2015, Amirapu et al., 2018; Chain et al., 2018). Understanding the geographical concentration of industry is important from the perspective of spatial and regional planning of industry, because it is a vital activity for employment, economic growth and regional development, while adequate and quality analysis of geographical concentration of industry is a prerequisite for potential economic and other local and national benefits (Behrens & Bougna, 2013; Lehocky & Rusnák, 2016).

Previous research on the economy, especially the industry of the municipality of Tešanj, is deficient. The Development Strategy of the Municipality of Tešanj 2018-2027 should be highlighted in which the basic economic indicators were analysed and the basic guidelines of economic development of Tešanj municipality were given, then the research of Alagić & Petković (2016) who analysed the economic development of small communities based on their own resources versus the existence/non-existence of capital support: case study for Tešanj municipality, and the Alagić (2013) study on assessing the local economic development capacity of the Tešanj municipality. Unfortunately, so far, no more complex research has been conducted on the spatial distribution and concentration of economic activities in the municipality of Tešanj, but at the entity and state level there are certain studies on the spatial distribution of the economy. For example, Nurković (2007) analysed the spatial distribution of industry in Bosnia and Herzegovina, Fetahagić & Kašmo (2010) researched the spatial distribution of economic activities relevant to the Federation of Bosnia and Herzegovina, while Gekić & Bidžan (2015) performed a geographical analysis of industry on the example of Bugojno municipality.

On the other hand, numerous studies have emerged in the world in the last few decades that theoretically explain the factors of industrial location, geographical dispersion and concentration of industry at the regional and national level. For example, Stiperski (1994) researched industrialized areas in Croatia, Traistaru et al. (2002) the effects of economic integration on patterns of regional specialization and geographical concentration of productive activities in Bulgaria, Estonia, Hungary, Romania and Slovenia, Dauth et al. (2016) long-term processes of concentration and dispersion of manufacturing activities in Germany, while Rastvortseva and Chentsova (2015) researched the geographical concentration of industry in Russia.

The degree of concentration is a significant structural feature of industrial activity because concentration is an important factor in explaining the greater or lesser efficiency of different industries. The primary concentration indicator is the absolute number of industrial companies, and the secondary is their spatial distribution. Therefore, when researching the distribution and concentration of industry, it is necessary to take into account both of these factors (Tipurić et al., 2003).

When researching spatial distribution of industry, or geovisualizing any other data, the importance of digital technology and geographic information systems should especially be highlighted (Milojković & Jovanović, 2018; Rikalovic et al., 2014). Spatial

analysis, with the application of geographic information systems, provides a geovisualization of spatial concentration processes and phenomena, including industry (Jansenberger & Staufer-Steinnocher, 2004; Murray, 2010; Rikalovic et al., 2014). Geoprocessing techniques and tools in GIS, such as transformation, rasterization, and reclassification methods, etc., enable the collection, storage, analysis, and geovisualization of geospatial data (Cambell & Shin, 2011; Chang, 2019). In addition, the methods Spatial Point Pattern Analysis (SPPA) and Kernel Density Estimation (KDE) should also be mentioned, which enable the measurement of the degree of concentration, and can also be used to measure the industry concentration through the analysis of spatial distribution of industrial plants in a particular area (Fischer, 2006; Kosfeld et al., 2010).

There are numerous studies that analyse the issue of spatial concentration and distribution of economic activities and industry, but also research on industrial concentration based on non-parametric interpolation method (KDE), as an effective tool for determining the spatial distribution of the phenomenon (Kosfeld et al., 2010). Thus, Jansenberger and Staufer-Steinnocher (2004) applied the Dual KDE method in the study of spatio-temporal changes in the food trade market in Austria, while Dominicis et al. (2007) used spatial analysis to determine the spatial distribution of economic activities in Italy.

The aim of this study is to research the efficiency of GIS methods and techniques in spatial analysis of industry, and on the example of Tešanj's industry quantify the impact of relief, hydrography, transport and planned industrial zones on the development and distribution of this economic activity. Moreover, using various GIS methods and techniques, on a case study of Tešanj's municipality, a procedure for determining areas suitable for industry development will be elaborated.

Data and methods

The area of municipality Tešanj is one of the most economically developed areas in Bosnia and Herzegovina. It is located in northern Bosnia, between Pannonian Bosnia and the central Bosnian mountains, in the valleys of the rivers Usora and Bosna, between 44°34'15" and 44°49'56" N and 17°50'25" and 18°06'15" E, covers an area of 160.76 km², and is characterized by Cfb climate. Administratively it belongs to the Zenica-Doboj Canton, i.e. the entity of the Federation of Bosnia and Herzegovina (Fig. 1).

In 2018, there were 43,675 inhabitants in the municipality, of which 71.4% were working-age population, 13,697 employed and 5,803 unemployed. In the same year, 2,495 business entities were registered in the municipality, of which 16.6% of business entities were engaged in the activities of mining and quarrying, processing industry, and production and supply of electricity, gas, steam and air conditioning (FZS, 2019). The development of Tešanj's industry began in the second half of the 20th century and was especially intensified at the beginning of 21st century. According to the 2013 census, the Tešanj's industry employed 4,668 workers or 36.78% of the total number of employees, i.e. 2.51% of employees in the manufacturing industry of Bosnia and Herzegovina, 4.01% of the FB&H, and 16.86% of employees in the industry of Zenica-Doboj Canton (BHAS, 2013). However, Tešanj's industry today employs a significantly larger number of workers, because 6,464 employees were registered in 121 surveyed industrial companies. This is a consequence of the lack of official statistics which in the total number of

employees do not register workers from the neighbouring municipalities of Bosnia and Herzegovina. Industry in municipality Tešanj is characterized by heterogeneity, and the most developed industries are metal processing, food and textile industry, leather and footwear industry, wood, chemical, graphic industry and printing. Most Tešanj's companies are export-oriented, and therefore the municipality of Tešanj records good business results and significantly contributes to the economic development of Bosnia and Herzegovina.

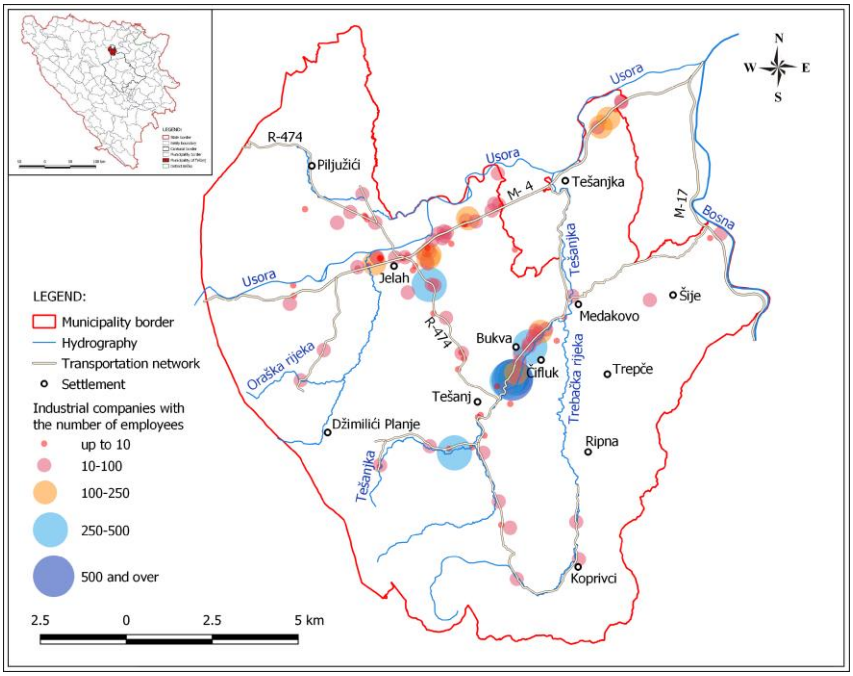

Fig. 1. Spatial distribution of industry in the municipality of Tešanj, 2020

The analysis of the spatial distribution and concentration of the Tešanj's industry was carried out in several phases, based on the analysis of Google satellite imagery and DEM of terrain, using GPS and QGIS tools:

- locating and georeferencing industrial companies,
- relief analysis (hypsometry, slope and aspect) and hydrography analysis with the use of QGIS tools
- mapping of the transport network,
- analysis of descriptive statistics and KDE analysis based on georeferenced locations for 121 industrial companies, where the number of employees (5 or more workers) was taken as the weight of the company, while
- in the final phase of the research, the degree of influence of physical and socio-geographical factors on the concentration of industry was determined, i.e. by applying reclassification and vectorization methods, count points in polygon, buffer and clip geoprocessing tools in QGIS, the distribution of industrial enterprises in relation to altitude, slope and aspect, hydrographic and transport network was analysed.

During 2020, industrial companies, with the number of employees, in municipality Tešanj were located. Based on the data of Tešanj's Development Agency (2018), the Foreign Trade Chamber of Bosnia and Herzegovina (2020), google satellite imagery, GPS and interview method, a database was created for 121 industrial company, with the number of employees and their main industrial activity. Based on the created database in QGIS, the sample was mapped by the geocoding method, i.e. by converting the postal addresses of industrial enterprises into geographical coordinates.

Based on the data of Federal Administration for Geodetic and Property Affairs (2020) and JAXA Digital Surface Model (2018), a 10-meter Digital Elevation Model of the Tešanj's area in the appropriate projection was created in order to perform terrain analysis, i.e. the relief (hypsometry, slope and aspect), while on the basis of Google satellite imagery, digitalization of hydrography, transport network and their analysis was also performed.

Spatial descriptive statistics were used in the analysis of the distribution of industry in the Tešanj's area. A vector file with 121 points was created where each point represents the location of an industrial company with the number of employees. Spatial descriptive statistics were determined for unweighted data (companies' location) and weighted data (companies with the number of employees). Two QGIS plugins were used to determine the measures of spatial descriptive statistics or centrographic measures: the standard deviational ellipse and the standard distance plugin, while the geostatistical tool SPPA was used to determine the mean centre or central average point.

In order to determine the degree of concentration and geovisualize the location of the Tešanj's industry, a non-parametric density estimation technique (KDE method) and SPPA interpolation technique were applied, which provide density or concentration estimation at any location within a defined research area (Jansenberger & Staufer-Steinnocher, 2004; Kalinic & Jukka, 2018).

A vector file with 121 industrial location was used in the KDE analysis. The aim of this analysis was to transform point vector data into a continuous surface or surface map showing industry concentration. The KDE tool within the SAGA toolbox was used in the analysis, and two analyses were performed. In the first case, the variable of the location of industrial companies was taken, and in the second case, the weight (number of employees in companies) was added.

Evaluation of kernel density estimator requires the determination of two parameters: the kernel function (k), which determines the weighting of the points, and the radius or bandwidth of the kernel (h), which defines the distance from the each georeferenced point when calculating KDE (Chen, 2015; Yu & Ai, 2014). Kernel functions are used to estimate the density of a process, and one of the most commonly used is quartic kernel functions, whose expressions are (Eq. (1), (2)): (Yu & Ai, 2014)

$$f_{(s)} = \sum_{i=1}^{n} \frac{1}{h^2} k\left(\frac{d(s,c_i)}{h}\right) \quad (1)$$

$$k\left(\frac{d(s,c)}{h}\right) = \frac{3}{4}\left(1 - \frac{d(s,c))^2}{h^2}\right) \quad (2)$$

where f(s) is the density of the location s, h is the radius or kernel bandwidth (only events or locations within the radius are used to estimate the density f(s)), c_i is the location of the observed events, k() is the weight of the location or event at a distance d(s,ci) to the location s.

Therefore, the quartic kernel function was used in the study of industry density estimation in the municipality of Tešanj, while the hopt method was used to determine the radius or the kernel bandwidth. This method integrates two basic pieces of information: sample size and a measure of dispersion or the standard distance, which in this case represents the dispersion of industrial companies around the mean centre. The radius or width of the kernel (bandwidth) is calculated using following expression (Eq. (3)) (Yu & Ai, 2014):

$$h_{opt} = \left(\frac{2}{3n}\right)^{\frac{1}{4}} * \sigma \quad (3)$$

where n represents the sample size and σ the standard distance.

The administrative boundary of the municipality of Tešanj was used to limit the area of KDE analysis. Also, it was necessary to determine the cell size, i.e. the raster size used to convert industrial sites from discrete data to a continuous area. In this case, density is defined as the number of industrial companies per unit area, and a cell size of 10 m was also determined. The results of this analysis are two surface maps that show the spatial distribution and intensity of industry concentration in the municipality of Tešanj.

In the final phase of the research, the degree of influence of the most significant physical-geographical and socio-geographical factors on the concentration and distribution of the Tešanj's industry was determined, and their geovisualization was also performed. Based on the generated DEM, the hypsometry, slope and aspect analysis of the terrain was performed, and then using methods of reclassification and vectorization (Weih & Mattson, 2004; Chang, 2019;) the appropriate bands, classes or categories of the mentioned terrain characteristics in vector format were singled out. After that, with buffer and clip GIS spatial techniques, the location of industrial companies in relation to altitude, slope and aspect, hydrographic and transport network was analysed. Using the buffer technique or zoning method, which represents the separation of spatial zones at a given distance from the object (Chang, 2019), new polygonal entities are formed, i.e. buffers at a certain distance from rivers and roads in the municipality of Tešanj. Then, using the count points in polygon and clip techniques, which overlap the two layers (Cambell & Shin, 2011), the newly formed vector layers were overlapped with the industry locations vector layer.

The results of the research are geovisualized in the form of 8 thematic maps that illustrate the spatial distribution, degree and concentration of industry, and the distribution of the Tešanj's industry in relation to basic physical-geographic and socio-geographic factors.

Results

Using the KDE method, the contemporary spatial distribution and the degree of industry concentration in the municipality of Tešanj were determined (Fig. 2 and 3). Based on 121

locations of industrial companies (unweighted data) in municipality Tešanj, a standard distance of 5,216.9 m and a radius (bandwidth) of 2,390.4 m was determined, while based on 121 locations of industrial enterprises with the number of employees (weighted data) a standard distance of 4,627.3 m and a radius of 2,120.2 m was also determined. The results of the conducted KDE analysis are two surface maps that show the spatial concentration of Tešanj's industry. The distribution of industrial companies without the number of employees (Fig. 2) shows that the highest degree of concentration of industry is in the valley of the river Usora, in the settlements of Jelah and Ljetinić along the magistral road M4. However, when taking into account the number of employees (Fig. 3), the highest concentration of industry is in the valley of the river Tešanjka, in the settlement Bukva located along the local road connecting Tešanj and Tešanjka, i.e. the magistral road M4 with the regional road R474.

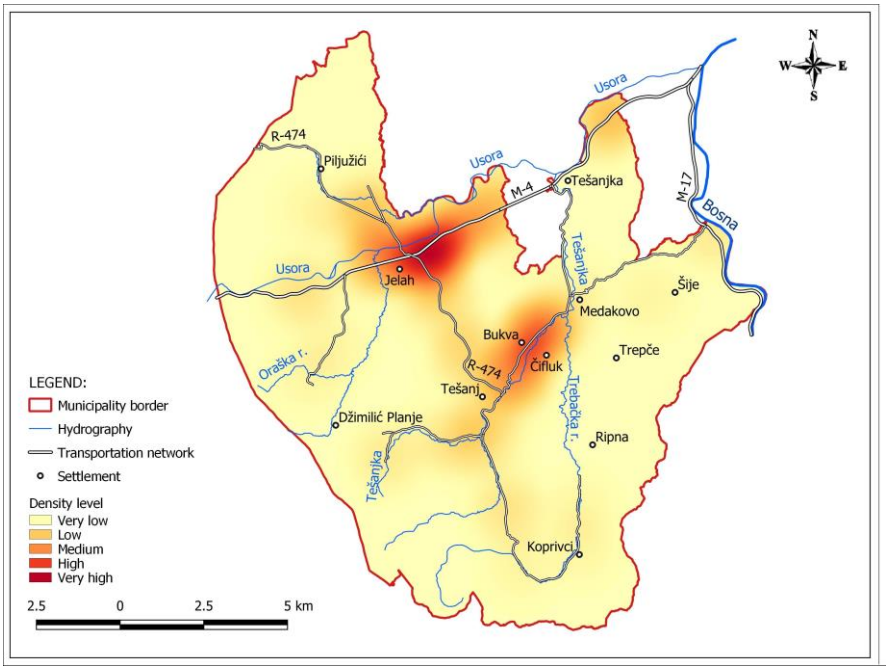

Fig. 2. Spatial distribution and industry concentration in the municipality of Tešanj (unweighted data)

The results of the analysis showed that there are two significant areas of concentration of the Tešanj's industry, and that the spatial concentration of industry is conditioned by the physical-geographical factors (relief: hypsometry, slope and aspect of the terrain, and hydrographic network, etc.) and socio-geographical factors (transport-geographical position, distribution and quality of transport network, and the planned development of industry determined by urban planning and construction of planned industrial zones). The analysis of the generated DEM of terrain showed that the municipality Tešanj is mostly flat, slightly undulating and hilly area with heights up to 500 m (94.33%), of which the lowland belt covers 19.66% of the territory, and the foothills 80.34%. The highest territory within the foothills has height of 200-350 m (75.34%). Mountain ranges cover 5.67% of the territory, while the most common levels are 500-600 m (77.49%) (Fig. 4).

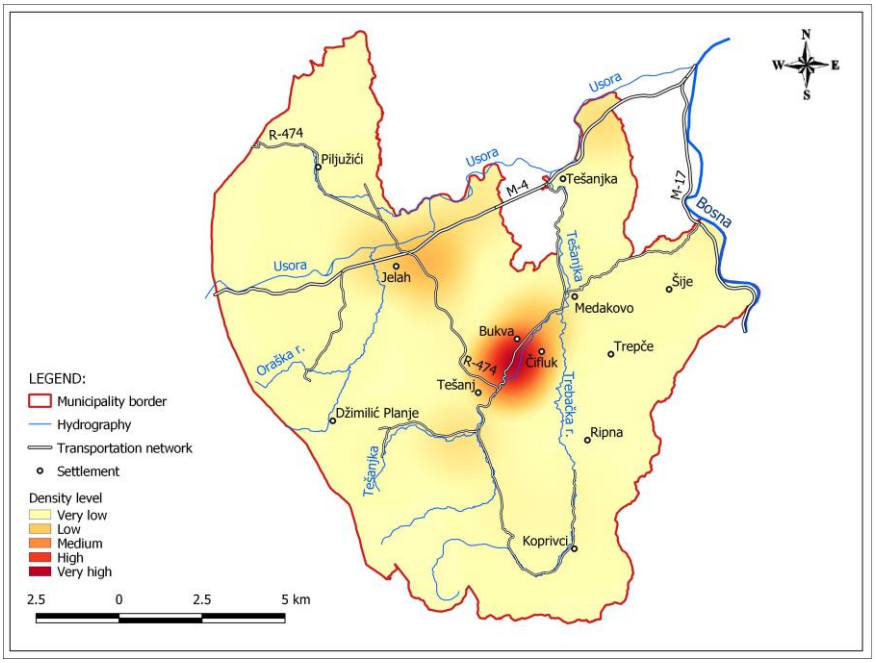

Fig. 3. Spatial distribution and industry concentration in the municipality of Tešanj (weighted data)

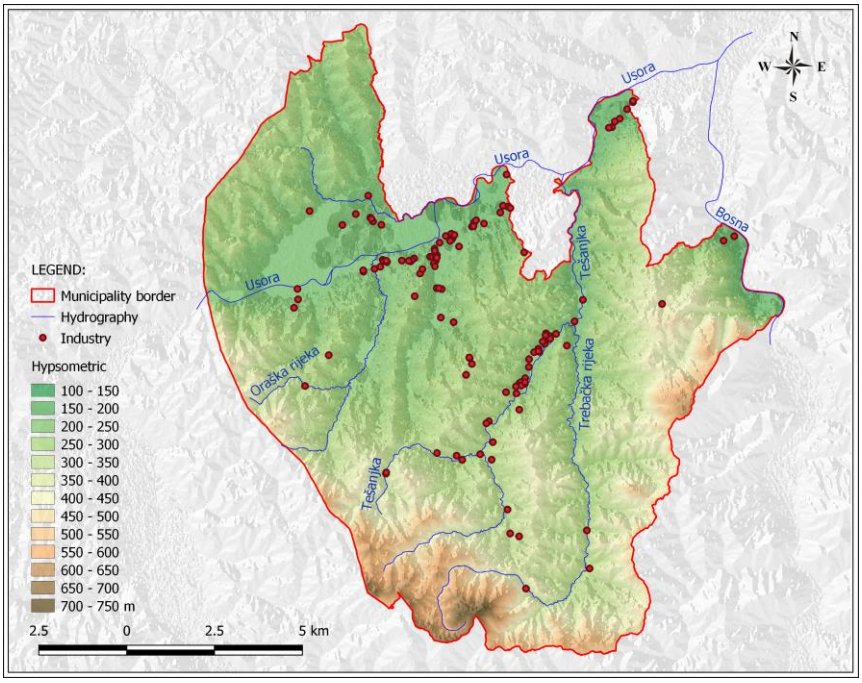

Fig. 4. Distribution of industry in the municipality of Tešanj in relation to terrain hypsometry and hydrography

The data of the conducted analysis on the relief as a factor of distribution of the Tešanj's industry are presented in Tab 1, 2 and 3. The largest number of industrial capacities in the municipality of Tešanj is located up to 200 m (65.29% of industrial companies and 52.44% of employees), on 200-300 m 32.23% of industrial companies and 47.02% of employees, while over 300 m only 2.48% of industrial companies and 0.54% of employees (Tab. 1).

Tab. 1. Industry distribution in the municipality of Tešanj by hypsometry

Hypsometry	Elevation (m)	Area (km²)	Number of companies	Share of companies (%)	Number of employees	Share of employees (%)
Lowland belt	100-150	0.13	0	0.00	0	0.00
	150-200	29.68	79	65.29	3,390	52.44
Foothill belt	200-250	40.14	23	19.01	2,430	37.60
	250-300	30.90	16	13.22	609	9.42
	300-350	20.77	2	1.65	15	0.23
	350-400	15.68	1	0.83	20	0.31
	400-450	9.22	0	0.00	0	0.00
	450-500	5.13				
Mountain belt	500-550	4.30				
	550-600	2.76				
	600-650	1.36				
	650-700	0.60				
	700-750	0.09				
Total		160.76	121	100.00	6,464	100.00

The results of the analysis of the slope model of the terrain in municipality of Tešanj show that slopes up to 1° cover 14.12% of the territory, 1-5° (36.75%), 5-12° (29.89%), 12-20° (17.38%) and over 20° (15.98%) (Fig. 5, Tab. 2).

Tab. 2. Distribution of industry in relation to the slope of a terrain

Slope (°)	Area (km²)	Number of companies	Share of companies (%)	Number of employees	Share of employees (%)
0-1	22.69	49	40.50	3,902	60.37
1-3	18.70	28	23.14	1,133	17.53
3-5	17.68	13	10.74	497	7.69
5-8	23.87	18	14.88	691	10.69
8-12	24.18	7	5.78	123	1.90
12-16	16.48	3	2.48	20	0.31
16-20	11.47	1	0.83	0	0.00
20-30	17.58	2	1.65	98	1.51
30-40	6.48	0	0.00	0	0.00
>40	1.63	0	0.00	0	0.00
Total	160.76	121	100.00	6,464	100.00

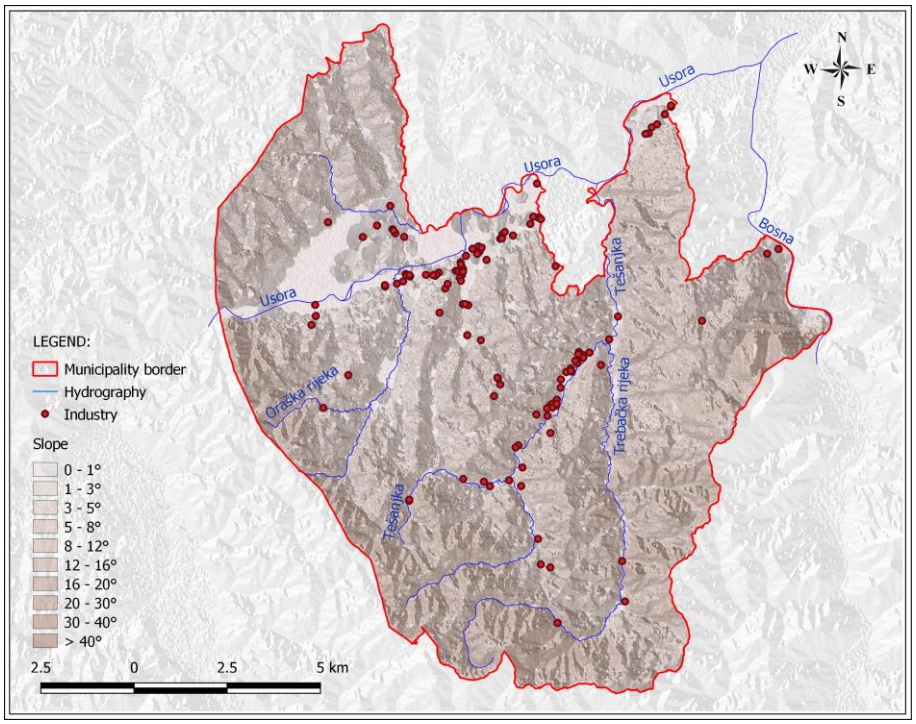

Fig. 5. Distribution of industry in relation to the slope of a terrain in the municipality of Tešanj

In the zone of slope up to 3°, 63.64% of industrial companies and 77.90% of employees are distributed, and up to 5° 74.38% of companies and 85.59% of employees. Moreover, 20.66% of companies and 12.59% of employees are located on a slope of 5-12°, and over 12° 4.96% of companies and 1.82% of employees (Fig. 5, Tab. 2).

Analogous to the determined slopes, their aspect was also determined. As a basic factor of spatial orientation of slope, the dominant direction of hilly and mountain relief forms and river valleys in the direction of north was taken, which is why the contact valley or slope area is characterized by north western, north eastern, western and eastern orientation. The analysis of the aspect model of the Tešanj's area showed that north-facing slopes or shady exposures (48.66%) are more represented than south-facing slopes or sunny exposures (26.69%), while eastern (12.33%) and western aspect (12.32%) are equally represented. Therefore, 56.20% of industrial companies with 62.95% of employees are located on north-facing slopes, and 26.45% of companies and 22.12% of employees are located on south-facing slopes. Moreover, 9.09% of companies and 7.90% of employees are located on the eastern aspect, and 8.26% of companies and 5.09% of employees are located on the western aspect (Fig. 6, Tab. 3).

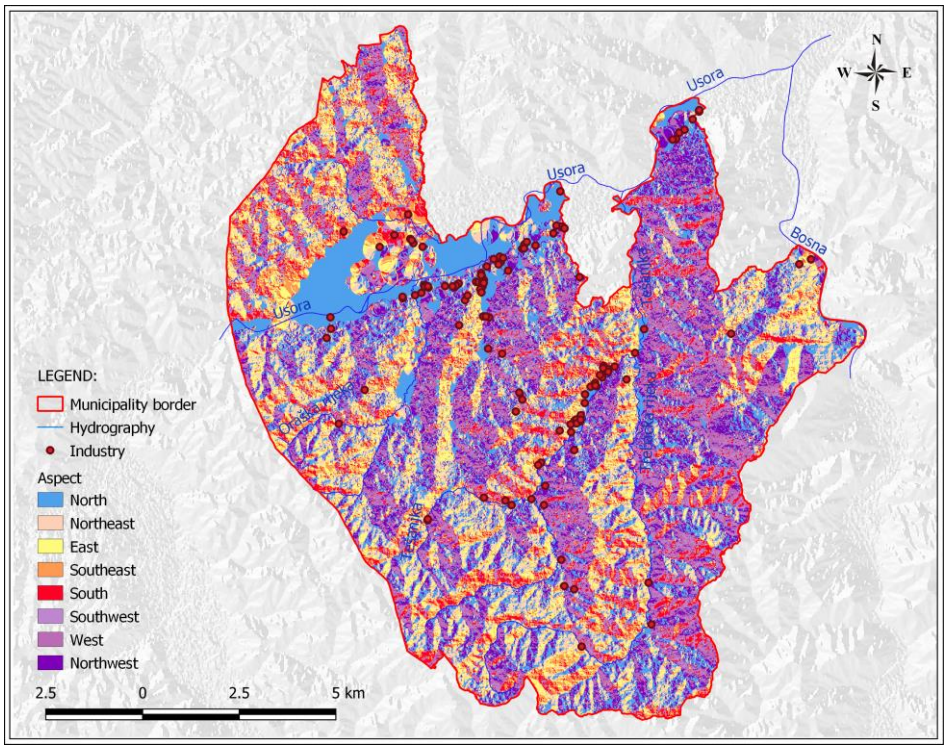

Fig. 6. Distribution of industry in relation to the aspect of a terrain in the municipality of Tešanj

Tab. 3. Distribution of industry in relation to the aspect of a terrain

Aspect	Area (km²)	Number of companies	Share of companies (%)	Number of employees	Share of employees (%)
N	35.23	37	30.58	2,762	42.73
NE	20.97	17	14.05	1,089	16.85
E	19.82	11	9.09	636	9.84
SE	15.22	11	9.09	511	7.90
S	13.66	14	11.57	705	10.91
SW	14.02	7	5.79	214	3.31
W	19.81	10	8.26	329	5.09
NW	22.03	14	11.57	218	3.37
Total	160.76	121	100.00	6,464	100.00

Hydrographic objects are also a significant economic resource, and one of the basic factors of industrial production, and therefore industrial companies are concentrated in their immediate vicinity. In this regard, the analysis of the distance of industrial companies from the river flows in the Tešanj area was performed (Fig. 7, Tab. 4).

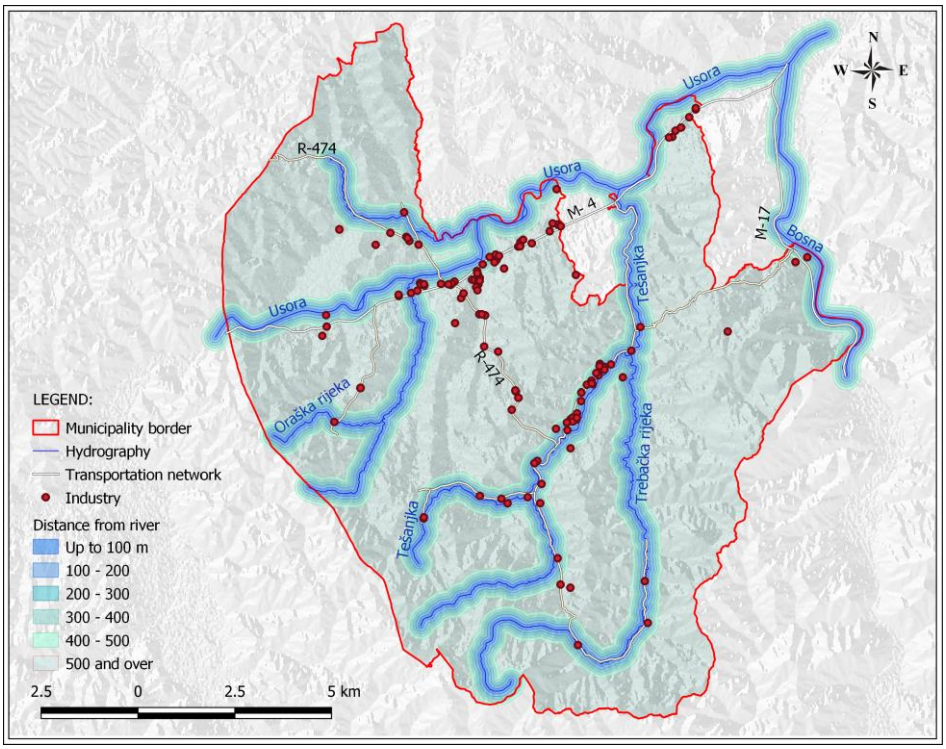

Fig. 7. Buffer distances of industrial companies from the river flow

Tab. 4. Distribution of industry in relation to the distance from the river flow in the municipality of Tešanj

Distance from river (m)	Number of companies	Share of companies (%)	Number of employees	Share of employees (%)
up to 100 m	21	17.36	1,095	16.94
100-200	28	23.14	1,985	30.71
200-300	15	12.40	1,467	22.69
300-400	20	16.53	1,036	16.03
400-500	8	6.61	67	1.04
500 and over	29	23.96	814	12.59
Total	121	100.00	6,464	100.00

GIS analysis of the hydrographic network and georeferenced locations of industrial companies in the municipality of Tešanj shows that 17.36% of companies with 16.94% of employees are located up to 100 m from the river flows, 40.5% of companies with 47.65% of employees up to 200 m, 52.9% of companies with 70.34% of employees up to 300 m, 69.43% of companies with 86.37% of employees up to 400 m, and 76.04% of companies with 87.41% of employees up to 500 m (Tab. 4).

The industry distribution and concentration in municipality Tešanj is also conditioned by socio-geographical factors. Fig. 8 and Tab. 5 presents data on the distribution of industrial companies depending on the transport infrastructure in the municipality of Tešanj. Along with the significant development of transport network in the municipality of Tešanj, in the second half of the 20th century, there was a development

of the economy and industry. Based on the data of the Development Strategy of the Municipality of Tešanj (2018) the transport network of the municipality consists of the magistral roads M-4 and M-17 with a total length of 23.4 km of asphalt road, regional road R-474 Prnjavor-Novi Šeher in the length of 21.3 km, and about 110 km of local and 317 km of unclassified roads. The mentioned roads connect the municipality with larger centres of Bosnia and Herzegovina, but also the surrounding countries.

The results of GIS analysis showed that at a distance of up to 100 m, from the main roads, 57.02% of companies are located, up to 300 m (85.12%), while at a distance of over 500 m, 6.62%. Near the magistral roads M-17 and M-4, 51 industrial companies are located (42.14%), on the Jelah-Tešanj road (the regional road R-474) 24 facilities (19.83%), and on the local road Tešanj-Tešanjka 34 objects (28.09%) (Fig. 8, Tab. 5).

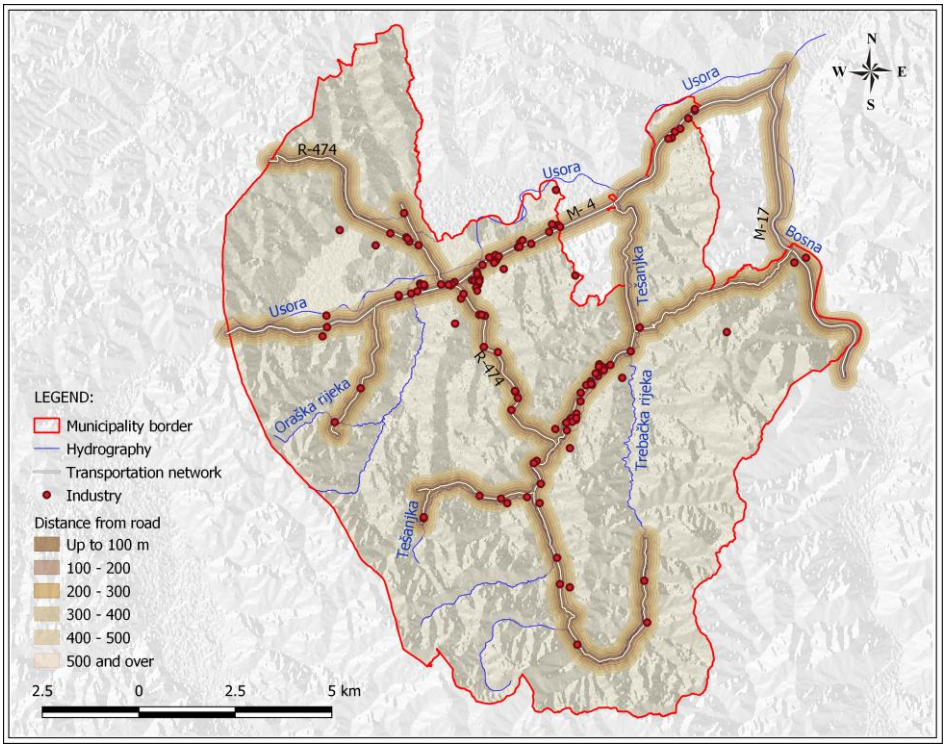

Fig. 8. Buffer distances of industrial companies from the main roads

Tab. 5. Distribution of industry in relation to the distance from the main roads in the municipality of Tešanj

Distance from road (m)	Number of companies	Share of companies (%)	Number of employees	Share of employees (%)
up to 100 m	69	57.02	3,130	48.42
100-200	20	16.53	1,744	26.98
200-300	14	11.57	909	14.06
300-400	5	4.13	171	2.65
400-500	5	4.13	323	5.00
500 and over	8	6.62	187	2.89
Total	121	100.00	6,464	100.00

In the area of the municipality of Tešanj, three business zones have been developed and defined, representing larger areas with a concentrated significant number of industrial and business entities, while in the future the construction of a fourth industrial zone is planned in Ljetinić, in the Usora river valley and along the main road M-4. Tešanj's business zones are regulated by the spatial planning documentation of the municipality. Based on the data of the Development Strategy of the Municipality of Tešanj (2018) business zone Bukva-Vila (area 59.50 ha; 34 companies with 3024 employees) is located in the valley of the river Tešanjka in the settlement Bukva, while business zones Ciglana-Glinište (area 91 ha; 37 companies with 1238 employees) and Ekonomija (13.2 ha; 7 companies with 899 employees) are located in the valley of the river Usora in the Jelah settlement. The establishment of these business zones has conditioned a stronger concentration of industry in these three areas in the municipality of Tešanj.

Discussion

Numerous factors affect industry distribution and concentration, while geographical factors are especially important because they are a prerequisite for development of any economic activity (Nordhaus, 2006). The research findings of this study confirmed that geographic factors play a significant role in the spatial distribution of industry, and that GIS is a very effective tool in determining degree of geographic concentration of industry and provide a new insight into the relationship between different geographic factors and industry distribution and concentration. The results of the GIS analysis of spatial distribution of industry in municipality Tešanj confirmed the interdependence between industry and geographical factors (Buurman & Rietveld, 1999; Mejia-Dorantes et al., 2012), and supported the theory that different factors affect the spatial distribution and location of industry, usually physical and socio-geographical (Šiljković, 2011), while a factor analysis of industry distribution and concentration is a very significant for planned industry development (Behrens & Bougna, 2013; Lehocky & Rusnák, 2016).

Data obtained by GIS analysis contribute to a clearer understanding of the effect of physical-geographical factors (hypsometry, slope, aspect, hydrography, etc.) (Weih & Mattson, 2004; Li et al., 2005; Bathrellos et al., 2012; Smajić et al., 2018; Smajić et al., 2021), and socio-geographical factors (transport infrastructure, planned industrial zones, etc.) (Leitham et al., 2000; Holl, 2004; Lončar, 2008; Pelajić & Tepšić, 2010; Howland, 2010; Rikalovic et al., 2014) on spatial distribution of industry.

One of the most significant physical-geographical conditions that affect the distribution of urban infrastructure and industry is relief (Bathrellos et al., 2012), and in the geomorphological interpretation of the terrain and its influence on the distribution of urban infrastructure, the analysis of the slope, from the perspective of inclination and spatial orientation of the slopes, is especially important (Weih & Mattson, 2004; Li et al., 2005; Smajić et al., 2018). Hydrographic objects are also a significant economic resource, and one of the basic factors of industrial production, and therefore industrial companies are concentrated in their immediate vicinity. The GIS analysis of industry distribution in municipality Tešanj confirmed the highest location of industry companies in the river valleys of the municipality, up to 300 m and on gentle and north-facing slopes.

Moreover, numerous social factors affect the location of industry such as market, labour, capital, economic restructuring (Šiljković, 2011), and in addition to the above, in

the municipality of Tešanj, the impact of transport infrastructure and planned development of industry and their impact on spatial industrial distribution should be highlighted. There is a high degree of correlation between transport network and spatial distribution of industry (Leitham et al., 2000; Holl, 2004; Rikalovic et al., 2014), and there are numerous studies that have used spatial statistics techniques in GIS to determine the degree of their interdependence (Buurman & Rietveld, 1999; Mejia-Dorantes et al., 2012).

An important location factor of industrial activity is also represented by planned industrial zones, as the most significant morphological form of industry concentration, and numerous factors are taken into consideration during their selection (Lončar, 2008). The choice of location of industrial zones is determined by numerous factors, the most significant of which are physical-geographic conditions, resources, transport and communal infrastructure, market, labour etc., while their origin and development are regulated by urban and implementation plans (Lončar, 2008; Pelajić & Tepšić, 2010; Howland, 2010). Three planned industrial zones in the municipality Tešanj highly affected the distribution of industry.

GIS analysis of industry distribution has certain advantages and limitations. In this study QGIS was used, an open source software which is easy to access and therefore provides a cost-efficient analysis. On the other hand, data mining for this kind of analysis is time consuming because it encompasses field work, acquisition, adaptation, adjustment and validation of digital surface models and google satellite imagery, and application of several different GIS techniques to get the final results. Moreover, one of the limitations of this research is sample size which is limited by relatively small administrative unit with limited number of companies.

However, data obtained by QGIS analysis of DEM and Google Satellite Imagery of researched area are of a satisfactory quality, and adequate and quality analysis of geographic concentration of industry is a prerequisite for future economic development (Tipurić et al., 2003; Lehocky & Rusnák, 2016). This study confirmed that GIS tools are effective in quantifying the influence of geographical factors, and determining areas potentially suitable for industry development. Therefore, on a practical level, this research is significant for future spatial planning and sustainable development of economy and industry. Moreover, this study can also be used as an example for analysing industry development in similar areas in developing countries, while taking into account their specific geographical features and factors.

Conclusions

The municipality of Tešanj is one of the most economically developed areas in Bosnia and Herzegovina, which was affected by the process of industrialization in the second half of the 20th century. The location of the first Tešanj's industrial facilities along the main roads in the valleys of the Usora and Tešanjka rivers, which conditioned the further concentration of the industry, was also conditioned by geographic factors. In this regard, the degree of concentration of the Tešanj industry was determined using and the quartic kernel function and hopt method. Based on generated 10-meter Digital Elevation Model, its reclassification and vectorization, a digitalization of relief, hydrography, transport network and their analysis was performed, while count points in polygon, buffer and clip

QGIS techniques were used to determine the distribution of industry in relation to geographic factors.

The results of the GIS analysis showed that the highest degree of concentration of industry is in the valley of the river Usora, i.e. in the settlements of Jelah and Ljetinić along the magistral road M-4. However, when the number of employees is taken into account, the highest concentration of industry is in the valley of the river Tešanjka, i.e. the settlement Bukva located along the local road Tešanj-Tešanjka. One planned industrial zone is located in the settlement of Bukva, and two in the settlement of Jelah, which are also an important micro-location factor of the industry. Therefore, the spatial distribution and concentration of the Tešanj's industry was conditioned by physical-geographic factors, of which favourable climatic, geological, relief and hydrological conditions should be singled out, and social-geographical factors, among which the most important are transport infrastructure and planned industrial zones.

The conducted GIS analysis determined that the largest part of the Tešanj's industry is located at an elevation of up to 300 m (97.52% of companies with 99.46% of employees). The analysis of the slope model and aspect of terrain showed that 74.38% of industrial enterprises with 85.59% of employees are located on the slope up to 5°, while industrial companies are more located on north-facing slopes (56.20% of industrial companies and 62.95% of employees) than on south-facing slopes (26.45% of industrial companies and 22.12% of employees). Most of the industrial capacities are located up to 500 m from the rivers (76.04% of companies with 87.41% of employees).

Transport network should be highlighted when it comes to the socio-geographical factors that affect the location of the Tešanj's industry because 85.12% of Tešanj's industrial companies are located up to 300 m from the main roads. Along the main roads, three planned industrial zones have been located, and the construction of the fourth planned industrial zone in the Usora valley along the main road M-4 is also planned. The business zone Bukva-Vila is located in the valley of Tešanjka on the local road Tešanj-Tešanjka (34 industrial companies with 3024 employees), the business zone Ciglana-Glinište (37 industrial companies with 1,238 employees) and the business zone Ekonomija (7 industrial companies with 899 employees) are located in the Usora valley on the main road M-4. Municipal business zones are well connected with transport infrastructure, both within the zone and with regional and main roads to which communal and other infrastructure is accessible. The production of spatial-planning documentation created preconditions for spatial-economic development, and the creation of planned industrial zones created preconditions for the continuation of activities on planned construction and management of planned economic and industrial development in the municipality.

Results of conducted research have a great significance in future planning of industrial development in researched area. GIS proved to be efficient tool in quantifying degree of industry concentration, and industry factor analysis. Moreover, this study could also serve as research model for other industrial areas in Bosnia and Herzegovina and other developing countries.

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ПРИМЈЕНА ГИС-А У ПРОСТОРНОЈ АНАЛИЗИ КОНЦЕНТРАЦИЈЕ ИНДУСТРИЈЕ: СТУДИЈА СЛУЧАЈА ОПШТИНА ТЕШАЊ (БОСНА И ХЕРЦЕГОВИНА)

Резиме: Значајно обиљежје економског или индустријског пејзажа је интензивно концентрисање привредних активности. Разумијевање географске концентрације индустрије битно је из перспективе просторног и регионалног планирања индустрије, јер се ради о виталној дјелатности за запошљавање, економски раст и регионални развој, док је адекватна и квалитетна анализа географске концентрације индустрије предувјет потенцијалних економских и других локалних и националних добити. Приликом истраживања просторне дистрибуције и концентрације индустрије, те геовизуализације података, посебно треба истаћи значај географског информационог система. Просторна анализа, уз примјену ГИС-а, омогућава геовизуализацију просторних концентрацијских процеса и феномена, укључујући и индустрију. Стога је фокус ове студије на просторној анализи дистрибуције и размјештаја индустрије примјеном ГИС метода, а на примјеру општине Тешањ (Босна и Херцеговина).

Општина Тешањ је једно од привредно најразвијенијих подручја Босне и Херцеговине, а тешањска индустрија значајно доприноси њеном економском развоју. ГИС анализа концентрације индустрије базирана је на теренском раду, лоцирању и георефернцирању индустријских компанија, одабиру, прилагођавању, усклађивању и прецизности дигиталних површинских модела и google сателитских снимака, те анализи рељефа, хидрографије и саобраћајне мреже. С циљем геовизуализације просторног размјештаја индустрије кориштена је просторна дескриптивна статистика и непараметарска статистичка техника процјене густоће (Kernel Density Estimation метод). У циљу утврђивања просторног размјештаја индустрије у односу на рељеф терена (надморска висина, нагиб и експозиција), хидрографску и саобраћајну мрежу, кориштене су ГИС технике рекласификације и векторизације, те count point in polygon, buffer и clip геопроцесуирајући алати. Проведено истраживање даје нови увид у процес прикупљања и геовизуализације података на принципима ГИС-а, значај географских фактора у размјештају индустрије, те потврђује утицај рељефа, хидрографске и саобраћајне мреже на концентрацију тешањске индустрије. Студија је потврдила да је ГИС веома ефективан алат у факторској анализи индустрије и квантификацији утицаја географских фактора на индустријски развој. Стога је проведено истраживање битно за будуће просторно планирање и одрживи развој економије и индустрије, те може послужити као модел за анализу индустријског развоја сличних подручја земаља у развоју, а узимајући у обзир њихове специфичне географске карактеристике и факторе развоја.