Acta Sci. Pol.
Formatio Circumiectus 18 (3) 2018, 39–54
ENVIRONMENTAL PROCESSES

www.formatiocircumiectus.actapol.net/pl/ ISSN 1644-0765 DOI: http://dx.doi.org/10.15576/ASP.FC/2018.17.3.39

ORIGINAL PAPER Accepted:

ANALYSIS OF THE SPATIAL STRUCTURE OF URBAN ANTROPOGENIC AREAS

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ABSTRACT

The dynamic urbanization process, which results from widespread anthropogenic transformation, affects landscape changes. These changes, measured using various factors and indices, are the subject of research around the world. The purpose of the present work was to analyse the spatial structure of anthropogenic elements of land cover. On the basis of the landscape metric – the MSI index (Mean Shape Index), the geometry configuration of individual land cover elements was checked. A Kernel Density tool was used to create a map of the elements of density distribution. The information thus obtained about the surface of anthropogenic elements of land cover expressed in [m^2], per 1 km^2 of space, made it possible to indicate the location of areas most transformed by human activity. The area of research encompassed urban municipalities – of Tarnów and Nowy Sącz. As the source material, the vector layer of land cover was used (BDOT10k –Topographic Objects Database), which was reclassified into 11 new categories. The GIS (Geographical Information System) tools available in the QGIS and ArcGIS software were used for the purpose of the analysis.

Based on the conducted studies, it was found that despite a similar percentage of anthropogenic elements of land cover, the studied areas show a different character in terms of their spatial distribution and complexity of their geometry. In the case of Nowy Sącz, small point enclaves of areas showing high density of anthropogenically transformed surfaces were observed. These surfaces are characterized by a considerable degree of dispersion but a small degree of geometrical complexity. In the city of Tarnów, the research we conducted showed a different tendency due to the much larger size of the aforementioned enclaves. Tarnów is characterized by a higher share of developed areas in the city centre, whereas Nowy Sącz is more uniform in the growth of such areas in particular density zones. Moreover, in Tarnów, along with the increase in the density of the anthropogenic land cover, the complexity of the geometry of land cover elements decreases, whereas in the case of Nowy Sącz, the value of the MSI landscape metric is proportionally inversed.

Keywords: spatial structure, density analysis, MSI index, anthropogenic areas, Topographic Data Base

INTRODUCTION

As Seto and Fragkias point out (2005), twentieth century saw a manifest increase in the concentration of societies in urban areas. More than half of the world's population currently lives in cities (Angel et al. 2012, Stott et al. 2015). In Poland, as of 1 January 2017, there were 923 cities (Domagalski 2016). The area of all cities in Poland was 21,920 km2, which is only 7% of the country's area. However, these cities

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are inhabited by over 60% of all Poland's population (CSO 2017).

The process of dynamic densification of people dwelling in urban areas is associated with the phenomenon of urbanization (Zhao and Murayama 2011, Ramachandra et al. 2012). This state of affairs contributes to the intensification of the so-called of anthropogenic pressure, often leading to negative landscape transformations (Degórski 2009, Solon 2009, Tokarczyk-Dorociak et al. 2018). Both of these phenomena affect the structure and functioning of the city (Weng 2007), causing diversity in land use and land cover (Sudhira et al. 2004, Jat et al. 2008, Deng et al. 2009, Ramachadra et al. 2012, Edmondson and others 2014, Iraj et al. 2016, Noszczyk 2017). These changes have a huge impact on the quality of people's lives (Weber et al. 2014) and the state of the natural environment (Cartson and Arthur 2000, Luck, Wu 2002, Dietzel et al. 2005b, Foley et al. 2005, Yang, Liu 2005, and Kienast et al. 2009, Solon 2009, Triantakonstantis and Stathakis 2015, Noszczyk et al. 2017). This is because, through their development, they contribute to the loss of biologically active areas (Haack et al. 2006, Falcucci et al. 2007). Increasing the size of impermeable surfaces leads to an increase in the surface temperature of the land (Ibrahim and Rasul 2017) and the formation of the so-called heat island effect (Chen et al. 2006), as well as increasing the risk of flooding (Angel et al. 2011). For this reason, as Degórski (2009) notes, the study of anthropogenic pressure and assessment of its impact on the condition of the natural environment becomes an important direction for research. In the literature on the subject, many concepts can be found to study the degree of anthropogenic transformation (Janecki 1983, Kostrowicki et al. 1988, Patili et al. 2001, Chmielewski 2012, Pukowiec-Kurda and Sobala 2016).

The increase in the size of areas with anthropogenic character is a phenomenon observed all over the world (Sudhira et al. 2004, Correa Ayrama et al. 2017). Controlling the changes that occur in land cover throughout the Earth's surface, especially in areas where these changes proceed quickly and often in an unplanned manner, is without doubt a necessity (López et al. 2001). Information on the land cover and land use of the area, as emphasized by Prastacos et al. (2011), since the 1960s, has been used in analysing the structure of cities, their development and functions, and forecasting phenomena occurring in urban areas. The data potential in this type of research has been used repeatedly (Dietzel et al. 2005a, Herold et al. 2002, Deng et al. 2009, Triantakonstantis and Stathakis 2015). The size, shape, location, and relations between particular categories of land cover may be subject to research (Kistowski 2003, Cao et al. 2017). Such analyses make it possible, among other things, to determine the correlation between different areas, to understand the prevailing trends, and to measure the pace of changes, which are taking place. Due to its exhaustible nature, space is one of the most important environmental resources (Ligtenberg et al. 2004, Lorens 2005, Fanhua et al. 2012). Monitoring urban development (Jat et al. 2008) and proper urban planning (Ramachandra et al. 2012) are therefore absolutely necessary, as they constitute useful elements in the proper management of a region, and guarantee correct implementation of sustainable development principles (Fanhua et al. 2012, Megahed et al. 2015). However, according to Bochenek (2006), proper land management of urban areas requires a set of detailed information on land coverage and land use.

One of the valuable data sources on land cover in Poland is the Topographic Objects' Database (BDOT10k) managed by the governors ("marshals") of individual regions. It is a set of consistent and up-to-date information on topographic objects, technical infrastructure and natural phenomena, along with their attributes. As indicated by Chałka et al. (2011), since 2013 Poland possesses one of the most up-to-date, modern databases of topographic objects throughout Europe. It is created on the basis of data retrieved from such registers as: BDOT500 (Topographic objects database with the level of detail ensuring the creation of standard cartographic analyses on the scale of between 1:500 and 1:5000), EGiB (Land and buildings records), GESUT (Geodetic records of utility networks), PRG (State register of boundaries and areas of the country's territorial division units), PRNG (State register of geographical names), TERYT (National Official Register of Territorial Division of the Country), all on the basis of orthophotomaps, existing cartographic materials, and direct field measurements (Regulation 2011, Halik and al. 2015). However, we should bear in mind that these databases are sometimes not updated on a regular basis, due to the time duration of administrative procedures.

Along with the dynamic development of computer technologies, obtaining geospatial data is now much easier and much faster (Halik et al. 2015). Detailed analyses of changes in land use and land cover are enabled and significantly accelerated by the remote sensing techniques (Fan and Myint 2014) and GIS – Geographic Information Systems (Pawlak 1999, López et al. 2001, Foody 2007). Integration of GIS with correctly maintained databases on land cover makes it possible to characterize space in terms of structures that occur in it (Sudhira 2004) and, what is important, it enables quantitative determination of the intensity of phenomena as well as monitoring of spatial-temporal dynamics of the changes (Cao et al. 2017), and modelling of future transformations (Jat et al. 2008). Due to the ability to facilitate performing such versatile and comprehensive spatial analyses (Johanson 1990, Longley et al. 2008, Gajos and Sierka 2011, Urbański 2012), there is a dynamic growth in the use of GIS tools also in urban transformation research (Cheng and Masser 2003, Jat et al. 2008), including studies of areas at risk of anthropofenic pressure (Salata et al. 2016, Cegielska et al. 2017a, Cegielska et al. 2017b).

In addition, an appropriate methodology is necessary, which will facilitate translating the information on land cover into relevant indicators describing the structure of the city (Prastacos and Lagarias 2016). One way of analysing the management may be to calculate the density of the analysed elements (Peña 2012, Song et al. 2013). To this end, landscape documents defining its specific features, both structural and functional, are used increasingly often (Malinowska and Szumacher 2013). Taking into account the usefulness of spatial metrics in characterizing the landscape structure, it should be noted that these indicators may constitute valuable instruments for identifying urban growth patterns based on certain spatial features (Aguilera et al. 2011).

The article aims to present, in a quantitative way, the spatial structure of anthropogenic elements of land cover. The composition and share of the tested elements, their density as well as the configuration reflecting their physical shape were verified using landscape metrics, namely the MSI index (Mean Shape Index). On the basis thereof, an attempt was made to:

- identify and characterise the areas that were most transformed by man within the analysed area,
- link the degree of land transformation by man with the density of anthropogenic land cover forms and their configuration.

In the present study, we have assumed that the increase in anthropogenic land transformation is related to the increase in the density of anthropogenic land cover elements. In addition, it was assumed that with the decline in the degree of anthropogenic terrain transformation, the shape of the patches of land becomes increasingly complex. A fall in the value of the MSI index could, therefore, indicate an increase in human interference with the changes in land cover.

MATERIAL AND METHODS

The present study encompassed the cities of Tarnów (72 km^2) and Nowy Sącz (58 km^2) (see: Figure 1).

The procedure for preparing the materials for testing is shown in the diagram (see: Figure 2). The input material for these analyses included vector data on land cover, derived from the BDOT10k topographic database. A detailed procedure for designating the surface of individual objects of land cover classes is set out in the Annex to the Regulation by the Minister of Interior and Administration of 17 November 2011 on the database of topographic objects and the database of general geographic objects, as well as standard cartographic studies. The next stage of the work was reclassification of the land cover categories from the form of BDOT10k database codes, taking into account the second and third level of detail, into the text form. The objects were grouped in 11 new categories (see: Table 1, figure 3A), in respect to the classification used in the Corine Land Cover database.

Statistical and cartographic studies were performed using the QGIS and ArcGIS software. The reclassification procedure was carried out in the QGIS software using the field calculator tool. To this end, an individual formula has been developed which classifies objects based on a logic conditional.

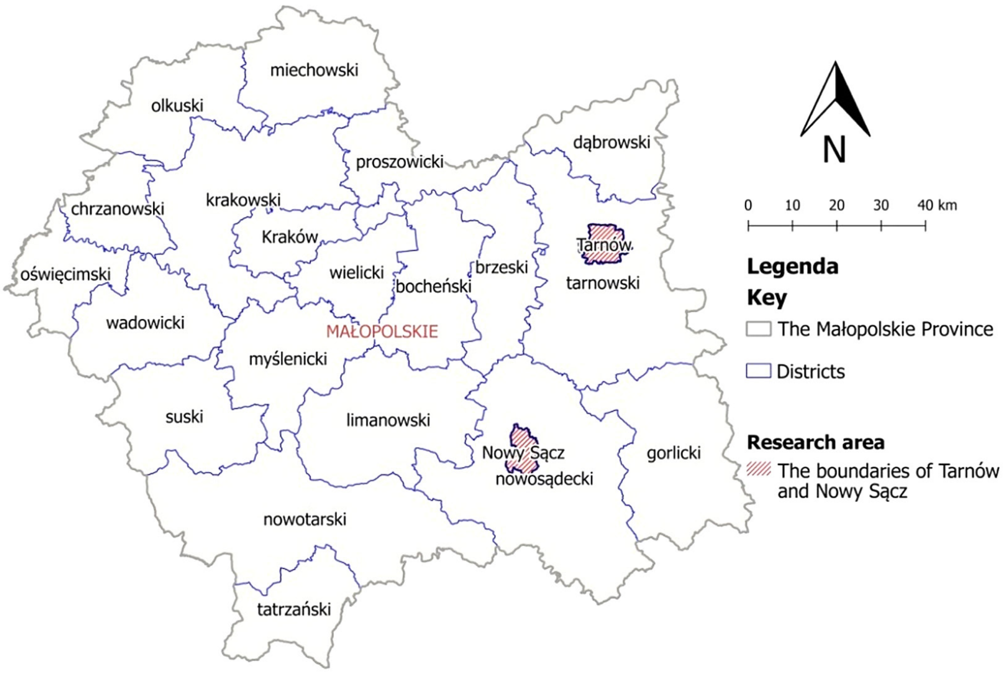

Fig. 1. Location of the studied research area

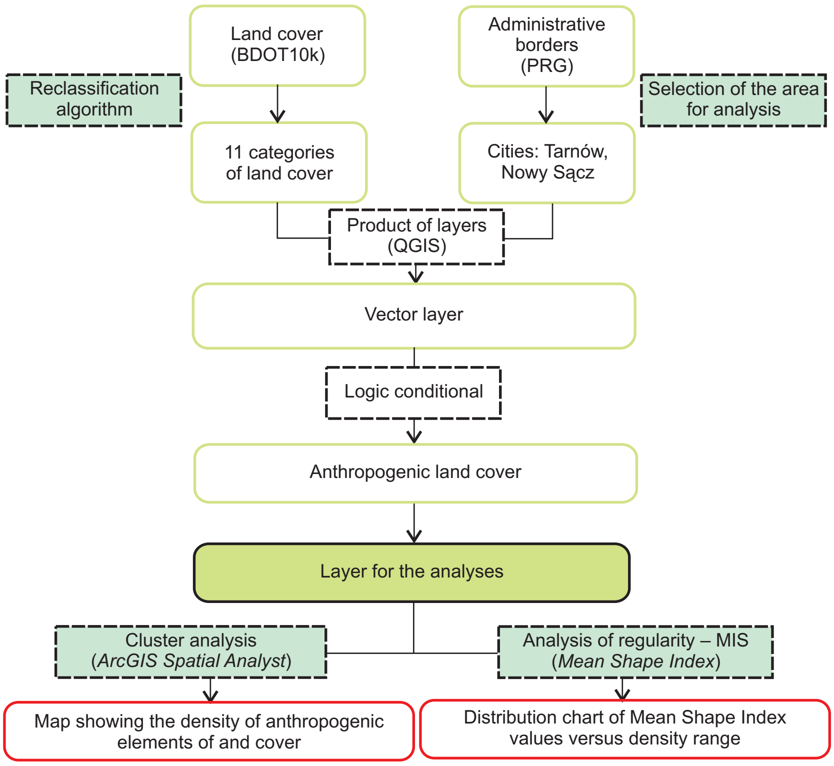

Fig. 2. Procedure for preparing the material for research, and performing the analysis

Table 1. Reclassification of land cover categories based on the divisions according to BDOT10k

Reclassified categories of land cover	Topographic Objects Database (BDOT10k)		
	Code		Object name
Arable land	PTTR	02	Cultivation on agricultural land
Built-up areas	PTZB	01	Multi-family housing
		02	Single-family housing
		03	Industrial and storage facilities
		04	Retail and service facilities
		05	Other buildings
Roads	PTKM	01	Areas under car routes
		02	Areas under railways/tramway tracks
		03	Areas under car routes and railways/tramway tracks
		04	Areas under airport routes
Industrial and commercial areas	PTNZ	01	Areas under technical infrastructure or buildings
		02	Industrial and storage area
	PTPL	01	Square/yard
Permanent cultivation areas	PTUT	01	Allotment garden
		02	Plantation
		03	Orchard
		04	Forest nursery
		05	Horticultural nursery
Tree and shrub areas	PTLZ	03	Trees
	PTRK	02	Shrubs
Wasteland	PTGN	01	Colluvium or rubble
		02	Rocky area
		03	Sandy or gravel-covered area
		04	Other types of wasteland
	PTWZ	01	Excavation pit
		02	Dumping ground
Landfill sites	PTSO	01	Municipal waste landfill site
		02	Industrial landfill sites
Meadows, pastures	PTTR	01	Grassland
Forests	PTLZ	01	Forest
		02	Copse
	PTRK	01	Mountain pine
Land under surface water	PTWP	01	Sea water
		02	Flowing water
		03	Stagnant water

In further analyses, only land of an anthropogenic character was considered. According to the assumption, the following eleven land cover categories were selected: built-up areas, roads, industrial areas, commercial areas, and landfills. As a result, a thematic layer composed of the selected objects (polygons) has been developed (see: Figure 3B). The choice of anthropogenic areas was made semi-automatically using the *Select by expression* logic conditional tool.

In order to quantify the anthropogenic elements of land cover in spatial terms, a density analysis was carried out (see: Figure 4). This stage has been implemented in the ArcGIS software. ArcGIS *Spatial Analyst* allows you to estimate the cluster density of point and line objects, but it supports only one kernel function (described by the square kernel) (De Smith 2007). The square root kernel is an approximation to the Gaussian kernel, which is used due to computational simplicity and speed of execution indicated in the literature (Hawthorne 2012). The density analysis takes into account specific amounts of the phenomenon spreading across the entire landscape based on the amount that is measured at each location. The value of the surface area is the highest at the point location, and it decreases as the distance increases. It is possible to weight observations based on the population field included in the attributes table (ESRI 2014). In GIS systems, the result of cluster density analysis is usually a raster where each cell is assigned a density value (Longley et al. 2005, Gibin et al. 2007).

The above analysis was carried out within the administrative boundaries of the cities of Tarnów and Nowy Sącz. The vector layer originating from the BDOT10k database containing only anthropogenic elements of land cover was converted into a grid with the mesh size of 1 m. Next, using the Raster to Point tool, each raster cell was assigned one point representing a surface area of 1 m^2. In the case of density analysis, each point had the same weight.

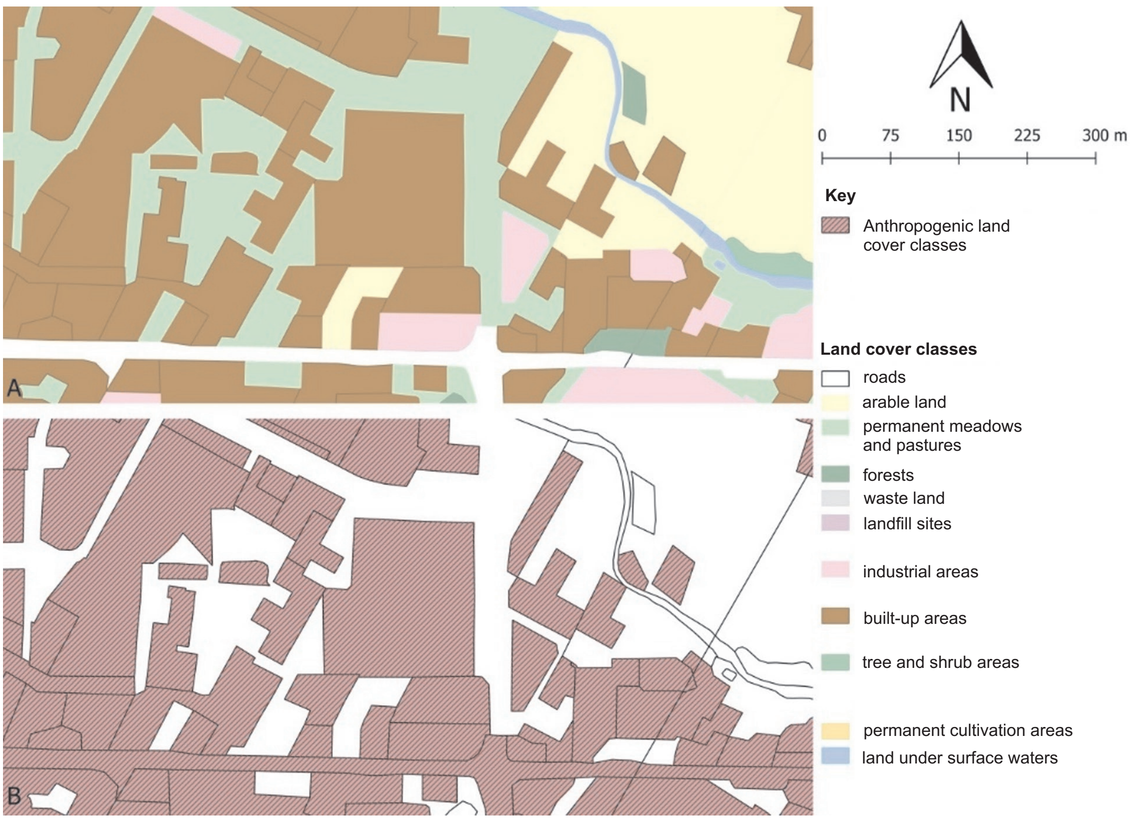

Fig. 3 . a) Categories of land cover, b) Selected elements of land cover with anthropogenic character

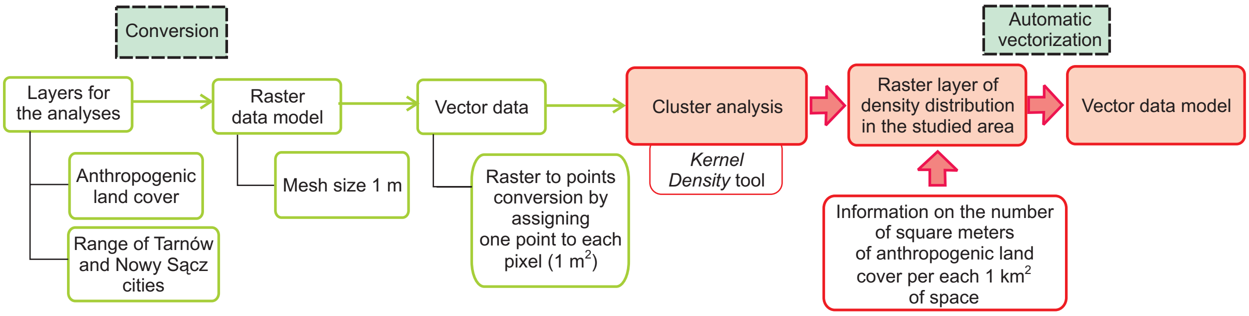

Fig. 4. Flow-chart of the analysis

Using the *Kernel Density* tool, density analysis was carried out, and its end result was obtaining a raster layer of density distribution in the studied area. The resulting layer contained information on the size of anthropogenic elements of land cover expressed in [m^2), per 1 km^2 of space. The last step of the analysis was to convert the raster to a vector form using the automatic vectorization tool. The range of values obtained as a result of calculations concerning the density of anthropogenic land cover elements was divided into 5 classes based on Jenks natural breaks classification model (Jenks 1967). As a result, the following ranges were obtained:

For the city of Tarnów:

- 0.00 – 0.12 (1) lowest density
- 0.12 – 0.35 (2) low density
- 0.35 – 0.59 (3) average density
- 0.59 – 0.84 (4) high density
- 0.84 – 1.00 (5) highest density

For the city of Nowy Sącz:

- 0.00 – 0.12 (1) lowest density
- 0.12 – 0.34 (2) low density
- 0.34 – 0.57 (3) average density
- 0.57 – 0.81 (4) high density

0.81 – 1.00 (5) highest density

In the present study, we have assumed that the increase in anthropogenic land transformation is related to the increase in the density of anthropogenic land cover elements.

In addition, an analysis was carried out to examine the configuration of anthropogenic land cover elements. To this end, a landscape metric was used, namely, the MSI (Mean Shape Index). It is given as the ratio of the perimeter of the element to the element of its surface, corrected by the constant for the standard of the square. MSI is equal to the mean shape index of patches in the landscape (Howard 2015). Its square value (maximally dense shape) is 1, and it increases with the increasing complexity of the geometry of these patches (McGarigal and Marks 1995). Thanks to these calculations conducted for each of the density zones, the configuration of anthropogenic elements of land cover was also examined. In the study, we have assumed that with the decline in the degree of anthropogenic terrain transformation, the shape of the patches becomes increasingly complex. Thus, a drop in the value of the MSI index could indicate an increase in human interference with the changes in land cover.

RESULTS

The results of the analyses we have conducted made it possible to understand the spatial structure of anthropogenic elements of land cover in the cities of Tarnów and Nowy Sącz. Considering the share of anthropogenic land cover categories in the areas of both cities, as well as the surface areas of particular density classes of anthropogenic elements, a significant similarity was found between the surveyed units. At the same time, a somewhat different character of development was observed: in Nowy Sącz, the areas densely covered with anthropogenic forms are more concentrated, while in Tarnów these areas, in the form of large enclaves, occur in various parts of the city. The share of built-up areas has the most impact on the increase in the density of anthropogenic areas. Studying the complexity of the geometry of individual patches of land cover reveals a degree of diversity between the surveyed units. In general, the increase in the density of anthropogenic forms of land cover in Tarnów corresponds to the increase in the concentration of land cover patches, while in Nowy Sącz the situation is reversed. However, no correlation was found between the increase in the density of anthropogenic land cover elements and the decrease in the geometry of their patches.

Area distribution of anthropogenic elements of land cover in the city of Tarnów and Nowy Sącz is presented in Table 2.

second class. However, for the fifth class, describing areas with the highest degree of anthropogenic density of terrain cover, a slight increase in the area size can be observed.

Figure 6 presents the spatial distribution of anthropogenic land cover elements based on density values in Tarnów and Nowy Sącz. This visualization allows identification of areas, which have been heavily transformed by human activity. The noticeable lack of density map content in the easternmost part of Tarnów was caused by the lack of anthropogenic cover, which made calculations impossible.

Table 2. Areas of individual anthropogenic land cover categories

City	Total size of anthropogenic areas		Built-up areas		Commercial and industrial areas		Roads		Landfill sites	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Tarnów	24.55	33.95	20.02	27.68	1.91	2.64	2.35	3.25	0.27	0.37
Nowy Sącz	18.88	32.81	16.01	27.82	1.57	2.73	1.23	2.14	0.07	0.13

The percentages in the table above refer to the content of a given land cover category relative to the area of the entire administrative unit. In both cities, the share of the total area of anthropogenic elements of land cover in the total area of the city is at a very similar level. The cities adopted for the analysis thus have a similar degree of anthropogenic transformation (looking only from the perspective of land cover). Similar values in both cities were also observed in the case of built-up areas, as well as commercial and industrial areas. In Tarnów, however, larger areas were occupied by landfills and a slightly larger share of the road network was noted, which indicates a more extensive communication network of the city, and is undoubtedly associated with its more industrial character.

When calculating the surface area of individual density classes of anthropogenic elements, similar percentages of these classes were observed within the boundaries of both studied cities (see: Figure 5). Thus, it can be concluded that the distribution of anthropogenic coverage in both cities is similar. The majority of the studied area consists of areas with low density of anthropogenic land cover categories. As the density of anthropogenic elements increases, the percentage share of subsequent density classes decreases. The largest step was observed between the first and the

As shown in Figure 6, the areas qualified in the classes with the densest distribution of anthropogenic land cover elements are cumulating mainly in city centres, as well as within housing estates and industrial areas, and they also coincide with the existing road network (A4 motorway, national roads: Nos. 28, 73, 75, 87, 94, and provincial road No. 973) and the railway. Slightly different characters of the development of the two analysed cities are apparent. Nowy Sącz is characterized by a large concentration of areas densely covered with anthropogenic forms. In the case of Tarnów, these areas, apart from the city centre location, are also scattered over the whole area in the form of large enclaves, mainly covering industrial areas, including: Zakłady Azotowe GRUPA AZOTY SA, KRYSZTAŁOWY Green Industrial Park, or MECHANICZNE Business Zone, as well as housing estates located in the south-western part of the city, for instance: Koszyce, Kolorowe, Zbylitowska Górka, Dąbrówka Infułacka, Dąbrówka, and Błonie. In the case of the city of Nowy Sącz, a characteristic feature is the high fragmentation of areas with high density of anthropogenic areas, in the form of small point en-

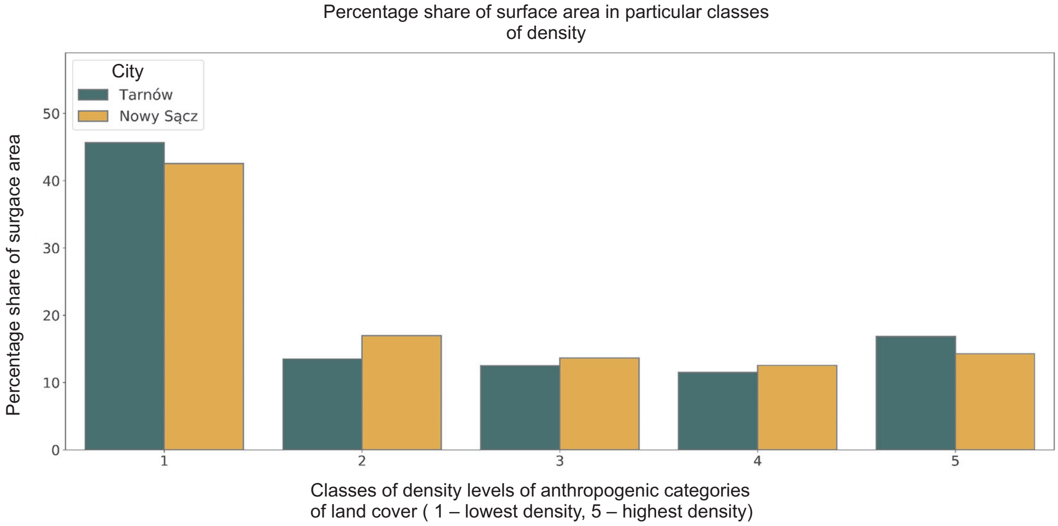

Fig. 5. Percentage of area sizes for anthropogenically modified areas in particular density classes

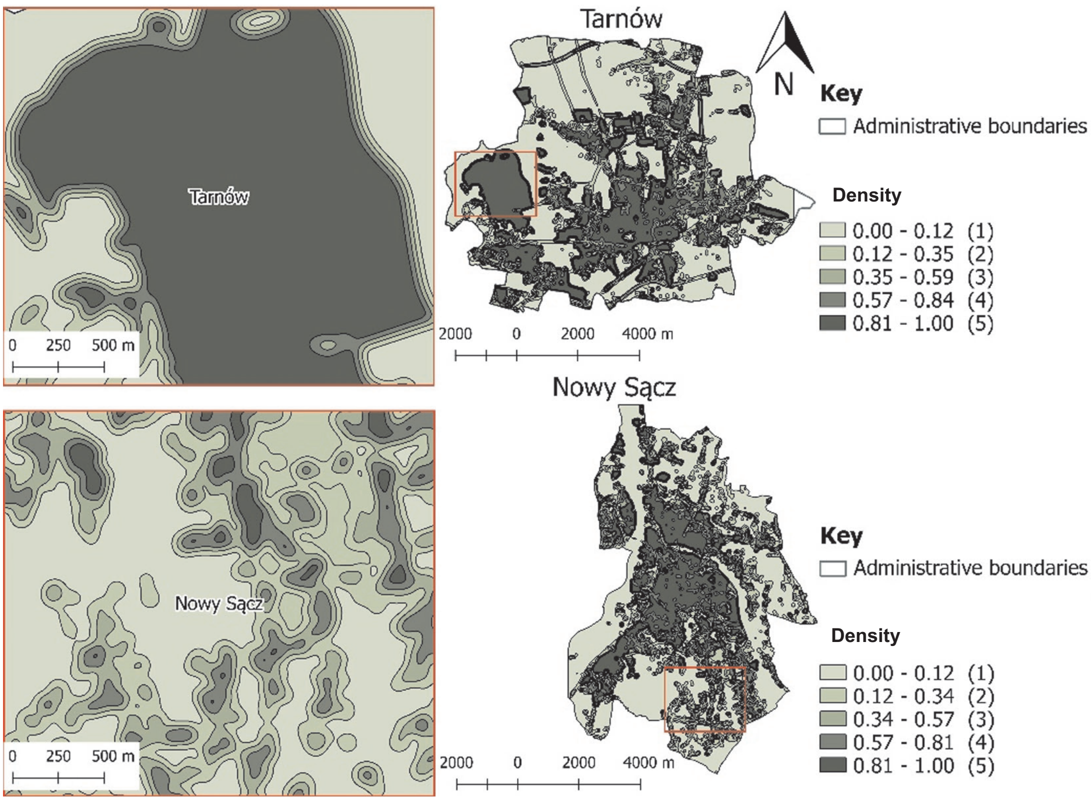

Fig. 6. Density of anthropogenic land cover elements for Tarnów and Nowy Sącz (the numbering of the ranges given in brackets corresponds to the numbering of classes in Figure 5)

claves (see: Figure 6). This testifies to the local occurrence of the building structure typical of rural areas.

Continuing the analysis of the spatial structure of urban anthropogenic areas, it was broadened by studying the distribution of individual anthropogenic categories of land cover within the adopted density classes (see: Figure 7). It was observed that the share of built-up areas affects the increase in density of anthropogenic forms to the greatest extent. With the increase in density, the percentage share of the size of these areas increases. The other land cover categories are of lesser importance. The largest percentage of the road network in Tarnów was recorded in the third density class, whereas in Nowy Sącz in the fifth class, one the strongest degree of anthropogenic pressure. Both cities have a similar distribution of industrial and com-

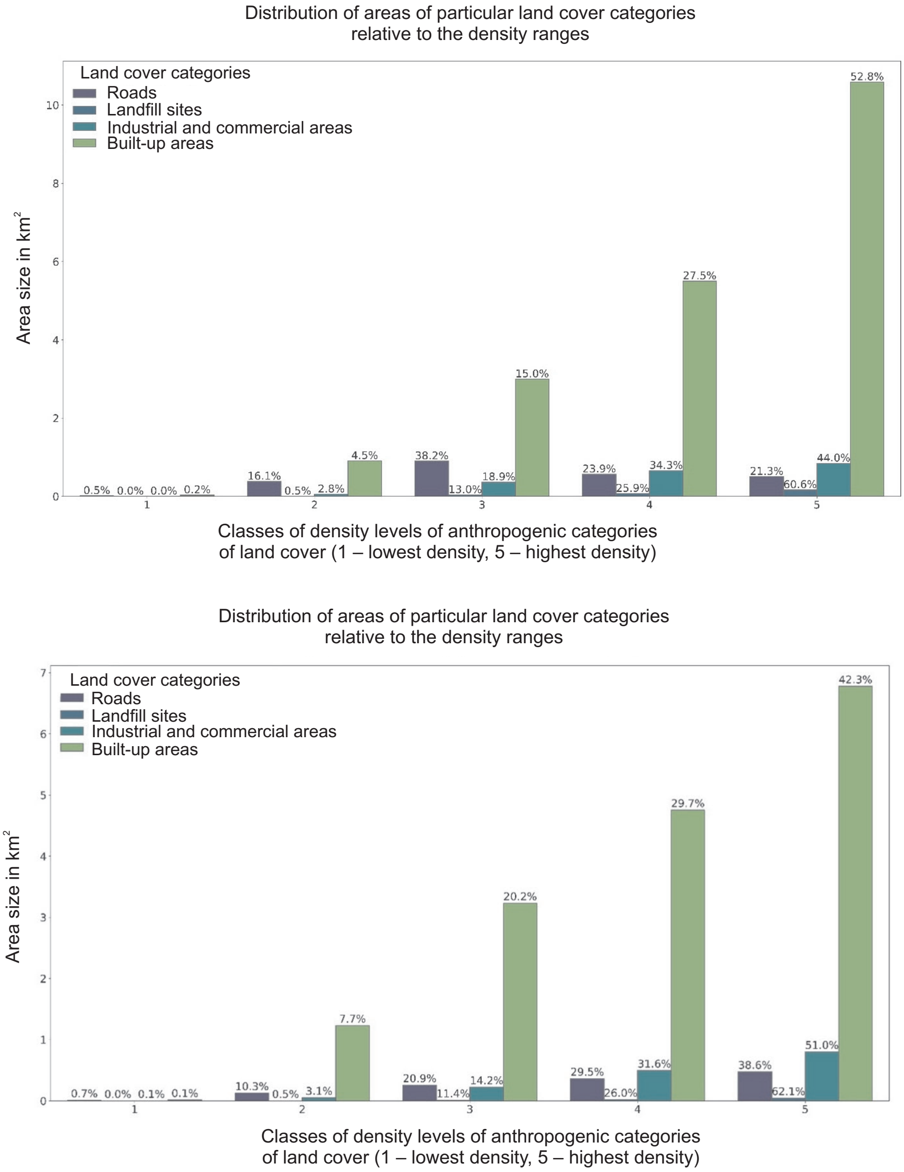

Fig. 7. Distribution of areas of individual land cover categories relative to the density ranges for the cities Tarnów and Nowy Sącz

mercial areas. An important fact is that nearly 53% of built-up areas in Tarnów are located in the zone characterized by the highest density of anthropogenic land cover. This means a greater concentration of buildings in the city centre compared to Nowy Sącz. Nowy Sącz is characterized by a more uniform increase of built-up areas in the density zones, which indicates their greater fragmentation.

In addition to the density of anthropogenic areas and their structures within the particular density zones, the geometry of individual patches of land cover was also examined. In Tarnów, along with the increase in the density of anthropogenic forms of land cover, the concentration of the land cover patches' shapes increases, whereas in the case of Nowy Sącz, the proportion of that index is inversed (see: Figure 8). The sole exception to this rule, in both cities, is the second density class.

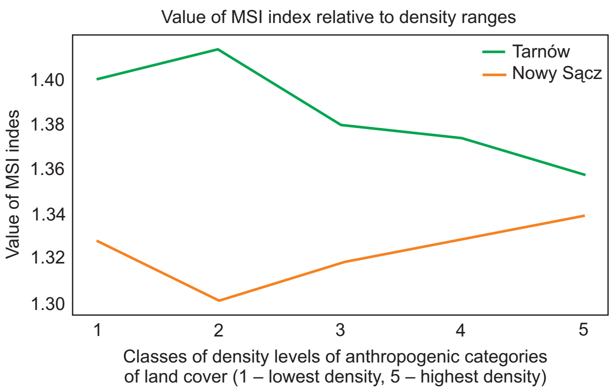

Fig. 8. The distribution of the MSI index value relative to the density ranges

On the basis of the above chart, it can also be stated that Nowy Sącz, despite the high fragmentation of the patches with the highest density of anthropogenic elements of land cover therein, is characterized by a lower complexity of their geometry. In the case of this city, the second class is characterized by the smallest value of the MSI index, indicating the most regular form of land cover patches. It is quite the opposite in the case of Tarnów, where the same class is characterized by the greatest complexity of geometry.

It is impossible to link the increase in the density of land cover elements of an anthropogenic nature with a decrease in the complexity of the geometry of their patches. Therefore, no correlation has been confirmed that increased human intervention in the transformation of land cover affects the increase of concentration or regularity of land cover forms of anthropogenic nature. The lack of such dependence was also noticed in the study by Pudowiec-Kurdy and Sobala (2016).

CONCLUSIONS

The present study was an attempt to quantify the spatial structure of anthropogenic land cover elements and to link the degree of land transformation by human activity to the density of anthropogenic land cover forms and their configuration. We have demonstrated that the increase in anthropogenic terrain transformation is related to the increase in the density of anthropogenic land cover elements. With increasing their density, the share of land cover forms of anthropogenic nature increases, particularly built-up areas. However, no correlation was found between the density of these elements and the complexity of their geometry. Therefore, no effect of anthropogenic activity on the decrease in the value of the MSI index was observed.

We have shown that both in the case of the city of Tarnów and of Nowy Sącz, areas revealing their anthropogenic character occupy almost the same percentage in relation to the total area of respective city, which proves a similar level of urbanization of both. The distribution of anthropogenic land cover in both cities is similar. The regions with the densest distribution of anthropogenic land cover elements accumulate mainly in city centres, as well as within housing estates and industrial areas, and they also coincide with the existing road network. We have also observed that the research areas show a slightly different character considering the concentration of anthropogenic areas. In the case of the city of Nowy Sącz, a characteristic element is the occurrence of large dispersion of small point enclaves of areas with high density of anthropogenic land cover elements, which proves the local occurrence of the structure typical of rural areas. In Tarnów, on the other hand, there are enclaves of much larger area sizes, which overlap with the industrial areas.

The conducted research has also demonstrated the usefulness of data derived from the Topographic Objects Database (BDOT10k) and GIS systems for the analysis of density and complexity of anthropogenic land cover elements and identification of the areas most transformed by human activity. BDOT10k land coverage classifications and analyses performed on their basis constitute a valuable source of information applicable in determining quantitative and spatial changes in both urban and suburban areas. However, we should remember about the sensitivity of the indicators used to the quality of cartographic studies (Kupfer 2012, Kozak et al. 2014). The results are strongly dependent on the degree of generalization of land cover categories (Huang et al 2006) and simplification of their shape (Dungan et al. 2002, Wu et al. 2002, Wu 2004). The application of land cover data from various sources would allow us to examine the reliability of the results obtained and make it possible to compensate for the impact of the quality of map foundations.

Estimating the density of land cover of urban areas with anthropogenic forms makes it possible to locate the areas most affected by anthropogenic pressure. This information, in turn, is an important element in the proper administration of the region and spatial management. Additionally, taking into account the spatial and temporal dynamics in this type of analysis may also enable visualization of the spatial development directions of the studied area, monitoring the phenomenon of suburbanisation and urbanization, and constitute a valuable tool in the interpretation of spatial changes taking place. Furthermore, the use of GIS tools for the analysis facilitates conducting the studies in a comprehensive and semi-automatic manner. The methodical framework for performing digital data analysis makes parameterization of the method possible, which in turn affects the possibility of modifying it and extending the scope of its application.

The research was financed from the subsidy of the Polish Minister of Science and Higher Education (DS 3371/KGPiAK/2017, FD – Fun Dydakt/W301/KGPiAK/2017).

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ANALIZA STRUKTURY PRZESTRZENNEJ MIEJSKICH OBSZARÓW ANTROPOGENICZNYCH

STRESZCZENIE

Dynamiczny proces urbanizacji zachodzący na skutek powszechnej antropogenizacji wpływa na zmiany krajobrazu. Zmiany te, mierzone za pomocą różnorodnych współczynników i indeksów, są globalnym obiektem badań.

Celem pracy była analiza struktury przestrzennej antropogenicznych elementów pokrycia terenu. Na podstawie metryki krajobrazowej – indeksu MSI (Mean Shape Index) sprawdzono konfigurację geometrii poszczególnych elementów pokrycia terenu. Do sporządzenia mapy rozkładu gęstości elementów użyto narzędzia Kernel Density. Uzyskanie informacji o powierzchni antropogenicznych elementów pokrycia terenu wyrażonej w m^2, przypadającej na 1 km^2 przestrzeni, umożliwiło wskazanie lokalizacji obszarów najbardziej przekształconych przez człowieka. Obszar badań stanowiły powiaty grodzkie – Tarnów i Nowy Sącz. Jako materiał źródłowy wykorzystano wektorową warstwę pokrycia terenu (Baza Danych Obiektów Topograficznych BDOT10k), którą reklasyfikowano na 11 nowych kategorii. Do przeprowadzenia analiz zastosowano narzędzia GIS (ang. Geographical Information System) dostępne w programach QGIS i ArcGIS.

Na podstawie przeprowadzonego badania stwierdzono, że pomimo podobnego procentowego udziału antropogenicznych elementów pokrycia terenu, obszary badawcze wykazują odmienny charakter pod względem przestrzennego rozkładu ich rozmieszczenia oraz złożoności ich geometrii. W przypadku Nowego Sącza zauważono występowanie niewielkich punktowych enklaw terenów wykazujących wysoką gęstość powierzchni antropogenicznych, które ponadto charakteryzują się znacznym stopniem rozproszenia, ale małym stopniem złożoności geometrycznej. W mieście Tarnów przeprowadzone badania wykazały tendencję odmienną ze względu na znaczne większe powierzchnie wspomnianych enklaw. Tarnów charakteryzuje się wyższym udziałem terenów zabudowanych w centrum miasta, a Nowy Sącz bardziej jednostajnym ich przyrostem w poszczególnych strefach gęstości. Ponadto w Tarnowie wraz ze wzrostem zagęszczenia terenu spada złożoność geometrii elementów pokrycia terenu, natomiast w przypadku Nowego Sącza wartość metryki krajobrazowej MSI jest proporcjonalnie odwrotna.

Słowa kluczowe: struktura przestrzenna, analiza gęstości, indeks MSI, tereny antropogeniczne, Baza Danych Obiektów Topograficznych