

THE ANALYSIS OF LAND COVER MACROSTRUCTURE IN THE SUBURBAN AREA OF KRAKOW

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Summary

The suburban areas are lands under strong anthropogenic pressure which results in their significant transformation. Identifying the direction of changes and their intensity is the basis of research based on the analysis of land use and land cover.

The study involved the analysis of land cover in the area of suburban zone of the city of Krakow based on the vector geodata available in the European Environment Agency database (Urban Atlas download service). Geographic data were classified according to various categories of coverage. The area was divided into evaluation clusters that included covering buffer zones with the given parameters according to the distance from the city: zones 0–5 km, 5–10 km, 10–15 km and 15–20 km. All analyzes were performed by means of the QGIS software using geoprocessing tools and additional ones of spatial statistics (among other things Group Stats). The percentage of each category of coverage in relation to the total area was made for each of the separate buffer zones' statements. The theory of changing the structure of coverage categories along with diverging from the city according to the diagram of reducing participation of heavily anthropogenic areas to those less exposed to it was confirmed on the basis of this analysis.

Keywords

GIS • QGIS • Urban Atlas • land cover • buffer zones

1. Introduction

Suburban areas are considered to be the grounds where various processes of great importance for all branches of development both social, economic and spatial take place. Intensification of investments undertaken at these areas is observed which is particularly important in regard to limited land resources (especially in cities or big agglomerations) [Cegielska, Kudas and Salata 2015]. Observing a suburban area as the potential place of locating investments both residential and the other can be analysed from two points of view. Somewhat, such approach helps to level the investment pressure that occurs in the cities and it powers the economy responding to customers' requests. However, on the other hand, it is a significant problem from the point of view of preserving spatial order [Cegielska, Kudas and Szylar 2015]. Dynamic development of new housing influences acceleration of metropolisation processes.

Commonly occurring processes of suburbanization are phenomena of “spilling” cities onto the suburban areas where all kinds of activities are also transferred [Nocko and Żelechowski 2011]. However, perceiving the subject so narrowly is wrong due to complexity and different aspects of this phenomenon [Lisowski and Grochowski 2007]. Traditional consideration of the process consists only in transferring spatial forms of the city from the central grounds to the adjacent areas creating spatial combination of some kind. Spatial character of urbanization of settlements that belong to suburban zone is mainly expressed by the level of concentration, housing kind and character which influence changing landscape and also space development form and arrangement [Staszewska 2012]. The impact of city agglomerations on adjacent areas drives the process which, unfortunately, occurs somewhat spontaneously and uncontrollably without respect for space, intensifying building chaos and disrupting spatial order [Jaroszewicz et al. 2012] which leads to significant dispersion of build-up areas and sometimes to maximization of building intensity [Bajwoluk 2008, Poniży 2008].

Areas located near cities as well as the ones from the zone of their influence are undoubtedly being transformed a great deal and in most cases these transformations are of negative character (landscape degradation) [Folley et al. 2005, Kienast et al. 2009]. It is a difficult task to recognize change directions and indicate their dynamics taking complexity of the problem into consideration [Drzewiecki 2008]. Information that concern land usage and covering considered in the range of landscape microstructure (small areas, single lines and objects) and macrostructure (categories of land cover, e.g. arable land, forests), their size, shape, spatial arrangement or mutual interactions seem to be necessary for this purpose. It is also significant to indicate the difference between land usage and cover. Land cover is understood as the biophysical elements that really occur at the land’s surface. Land usage is defined as actual space usage that reflects human activity in the landscape [Kistowski 2003, Lambin et al. 2006, Rozporządzenie 2011, Bičik et al. 2015].

According to Degórski [2009], the reason of landscape transformations is in many cases strong anthropogenic pressure. When researching the processes of its intensity at suburban areas, the maps of land usage and cover that reach the global scale are the valuable source of information. Their availability is possible thanks to dynamic development of satellite technologies and geographic systems of spatial information (GIS). They allow to limit some problems of substantial nature as for example low precision and resulting from it wrong qualification of covering category [Moody and Woodcock 1996, Kozak 2003, Adamczyk 2006, Salata et al. 2016]. GIS technologies and offered tools allow to perform spatial analyses of complex and multifactorial character [Gajos and Sierka 2011], showing at the same time wide possibilities of using them, among other things, in the range of areas’ valorization [Kuraś 2007, Kunz 2008], planning and spatial development [Hessel et al. 2009], planning the way of land usage due to protection of its components [Zeilhofer et al. 2011] or land susceptibility to anthropopression’s risk [Tomczyk 2011, Salata et al. 2016, Cegielska et al. 2017].

The aim of the paper was to conduct the analysis of macrostructure of land cover at the suburban area of Krakow city on the basis of spatial data gained from the Urban

Atlas portal. QGIS software was used for the tests. Additionally, relations of spatial distribution of particular coverage categories depending on the distance from the city were surveyed.

2. The research area

The surveys included with their range the suburban zone of Krakow city: districts of Krakow, Proszowice, Wieliczka, Myślenice and partly Wadowice and Bochnia districts. Selection of administrative units as the suburban area of Kraków was performed on the basis of classification of the European Environment Agency database (Urban Atlas service) which determined the above-mentioned areas as the suburban area on the basis of occurring urbanization phenomenon. The selected area is included in Krakow Metropolitan Area (in Polish short: KOM) separated with selected demographic, social, economical and infrastructural standards containing a significant part of its surface area. It comprises some kind of functional structure around the central city connected with it by interactive relations [Urząd Statystyczny... 2013]. As Bajwoluk says [2008], the borders of the KOM zone are difficult to determine because of their elasticity, continuous spatial changes and increase of housing intensity in the range of former settlement systems. Changing preferences of investors and increasing competitiveness of regions affects the “fluent zone border”.

According to its definition, the suburban zone is some kind of transitional band [Gonda-Soroczyńska 2009]. Taking functional division of territorial units into account, such kind of zones take place at the analysed area being mostly urbanized grounds [Urząd statystyczny... 2013]. According to the records of the Development Strategy of Małopolska Province for the years 2011-2020, Małopolska is characterised by high density of population (almost 222 persons · km⁻² considering increasing density in cities and decrease at rural areas). After demographic projects, the population number will be continuously increasing in the 2020 term. Taking investment attraction of the region into account, it should be noticed that the province is indicated as a favourable place to locate investments. It is also confirmed by the analyses of the Institute of Surveys on Market Economy. According to its opinion, the position of Małopolska as the region which is attractive for investments increased in 2010. The Strategic Programme of Environment Protection [2014] points out that having regard to the mentioned conditions of development, regional residential attractiveness as well as social trends to settlement near the city, the suburban zone of Krakow is exposed to considerable anthropopression on natural environment. In the course of time, it can result in irreversible changes in ecological ecosystems. It determines a significant impulse to survey anthropopression intensity and most of all to establish areas exposed to it.

3. Material and methods

In realization of research purposes, the vector data that come from the European Environment Agency (Urban Atlas downloading service) were the source materials.

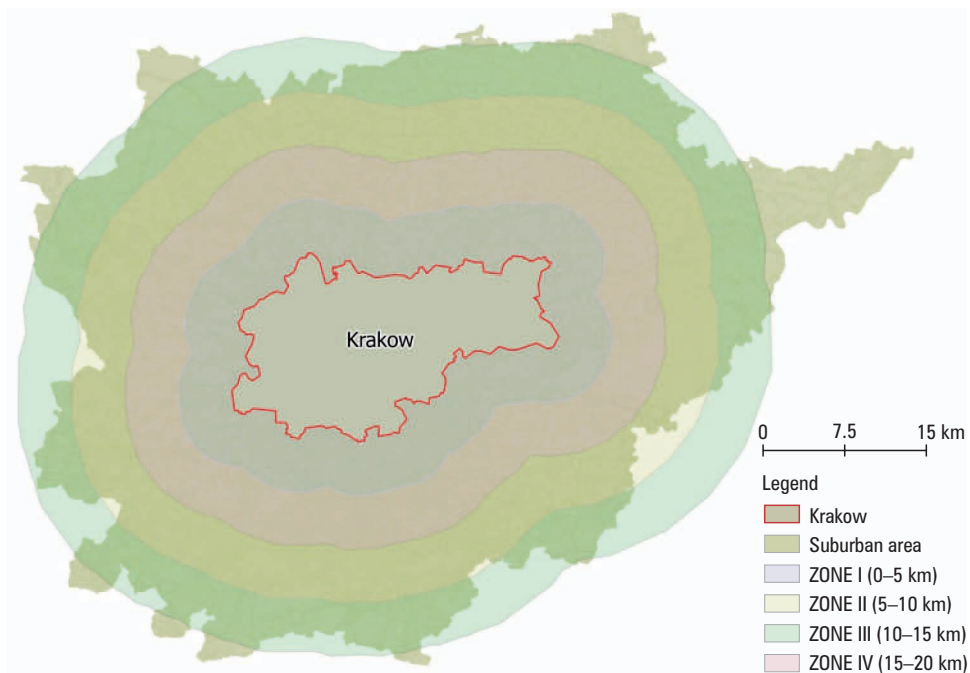
This portal provides high quality spatial data that concern land usage and cover for most big European cities inhabited by minimum 100,000 persons (metadata, mosaics of satellite images) and areas described as suburban ones.

The automatic procedures of classification were used to separate clusters of individual cover categories. Prepared materials were interpreted according to recommendations of the European Commission [2006] using specified magnifications in order to provide high accuracy and polygons' continuity. Taking rules of identification of smaller objects than recommended into account, they were included in the adjacent unit according to two rules – to the unit with the longest common border (except for the class of roads and railways – in this case the object completely surrounded by one of mentioned classes should be aggregated individually) or to the unit with the biggest area.

Data collected in vector form were subjected to classification process according to the unique value (individual coverage categories). By used categories of land cover, shall be understood [European Commission 2006]:

- agricultural + semi-natural areas + wetlands – agricultural areas, half-natural wetlands, arable lands (also set aside ones), permanent crops such as orchards, pastures, grassland, meadows, scrublands (including transitive forests), bare rocks, beaches, dunes, wetlands, flooded areas or exposed to be flooded, cane plants of lakes, rivers and streams;
- airports – the area of an airport with every equipment and installation (runways, related buildings);
- construction sites – single artificial buildings;
- continuous urban fabric – (housing with regular structure, characteristic for cities) – areas with average grade of soil sealing where over 80% of the area is built up (mainly residential housing) together with lands connected with housing; buildings and roads as well as bands of non-linear vegetation take the biggest part of the area; non-built-up areas take its small percentage;
- discontinuous dense urban fabric – built-up areas (mainly residential housing) with average grade of soil sealing (50–80%) together with related lands (e.g. parks, areas planted with vegetation, non-built-up public places);
- discontinuous medium density urban fabric – built-up areas with moderate grade of soil sealing (30–50%) with slight dominance of areas covered with vegetation (except for forests and agricultural lands);
- discontinuous low density urban fabric – areas slightly built-up, with low grade of soil sealing (10–30%), with dominance of vegetated areas (except for forests and agricultural lands);
- fast transit roads and associated land – express roads with accompanying facilities;
- forests – forest areas with trees higher than 5 metres, together with wooded lands and scrublands on the edge of woodlands; it does not consider forests located at urban areas that are subject to strong anthropopression;

- green urban areas – public green areas mainly used for recreation purposes (gardens, parks, zoo);
- industrial, commercial, public, military and private units – built-up areas where at least 30% of land is covered with artificial surface (e.g. concrete, asphalt, gravel) and over 50% of them is occupied by buildings with predominant functions different from residential ones (industrial, commercial, transport);
- isolated structures – individual structures of „artificial” character that contain housing areas, individual farms and buildings connected with them;
- land without current use – areas in temporary state, waiting to be used again, wastelands;
- mineral extraction and dumpsites – areas of mines, open-cast mines and dumpsites;
- other roads and associated land – roads, crossroads, parking places;
- railways and associated land;
- sports and leisure facilities;
- water bodies – seas, lakes, fish ponds (natural and artificial), rivers.



Source: authors'study

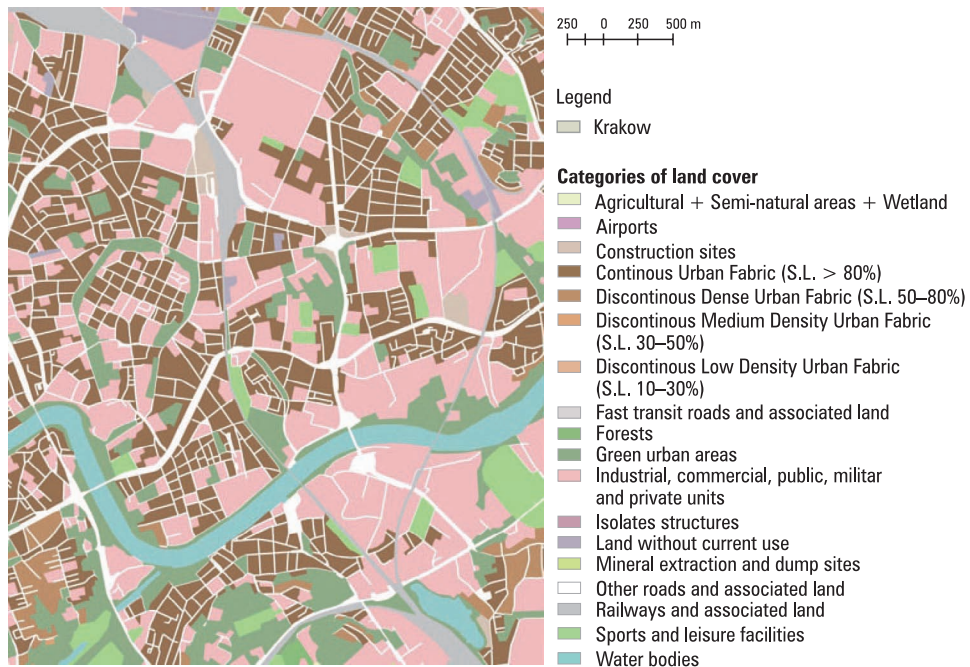
Fig. 1. The research area – buffer zones around Krakow city

The analysis of land cover in the suburban zone of Krakow was performed in division into 4 buffer zones with constant width of 5 km (in the distance of 0–5 km, 5–10 km, 10–15 km and 15–20 km) (Figure 1) using QGIS software. Geoprocessing tools and additional tools of spatial statistics (among other things Group Stats) were used for the analyses. Similar delimitation of the city region of Krakow was elaborated by Zborowski [2004] dividing analysed area into rings (I ring: communes directly adjacent to the city, II ring – communes neighbouring with I ring of units).

In case of every separated buffer zone, statistical statements concerning percent share of individual cover categories were conducted.

4. Results and discussion

Analysing land cover in the suburban zone of Krakow, occurring groups of particular cover categories (e.g. big fields of forests or anthropogenized areas) as well as regions where the areas where significantly distracted cover class were notices. Exemplary spatial distribution is presented in Figure 2.



Source: authors' study on the basis of vector data gained from the European Environment Agency

Fig. 2. Classified categories of land covering of the suburban zone of the city of Krakow

According to Bajwoluk's opinion [2008], the suburban zone of Krakow exposed to investment pressure undergoes numerous transformations in regard to former settle-

ment systems. In many cases, in connection with new building concentration, distracted structures come into being mostly along main communication tracts as the supplement of present buildings. It is a characteristic element for the areas adjacent to urban centres [Cegielska, Kudas and Salata 2015]. Some areas are also marked by creating completely new urban fabric which is not the city, nevertheless. There is lack of built-up public spaces or urban greenery there. The other characteristic features as e.g. service building which is concentrated along main communication tracts and routes from the city or industry diversified in terms of surface which occurs in the form of single objects or big separated areas are also assigned within functional-spatial structure.

Conducting the quantitative analysis in individual ring zones (Table 1, Figure 6), it is worth to notice that in case of every zone the agricultural areas (agricultural + semi-natural areas + wetlands) cover 65–69 % of their area which can be described as the average result. The lands with the slight human impact and characterised by occurring of small anthropogenic pressure increase their area along with diverging from the city – the amount of forest areas rises from about 9 % to 22 %.

Table 1. Categories of land cover in individual buffer zones

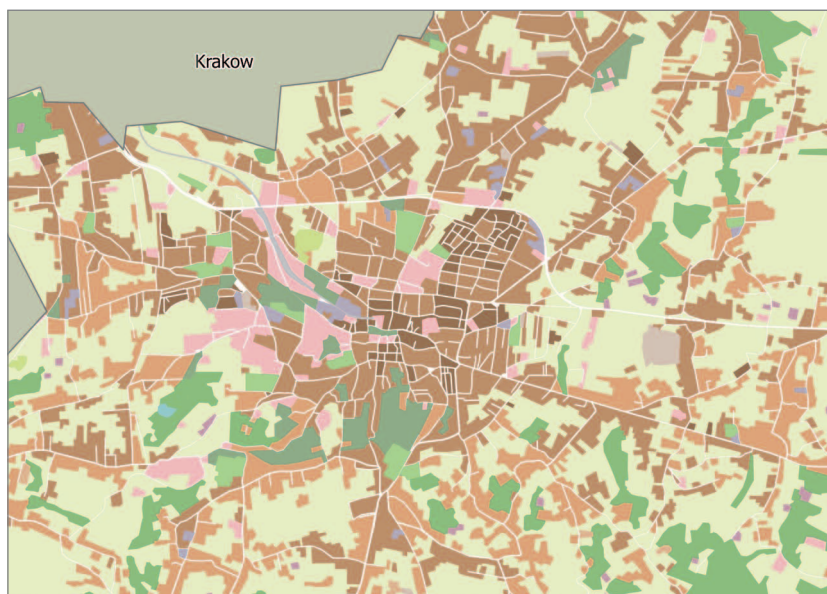
No.	Categories of land cover	Share in the area of the Zone I	Share in the area of the Zone II	Share in the area of the Zone III	Share in the area of the Zone IV
		[%]	[%]	[%]	[%]
1	Agricultural + Semi-natural areas + Wetlands	65.65	69.45	60.63	65.98
2	Airports	0.37	0.00	0.00	0.00
3	Construction sites	0.43	0.20	0.05	0.06
4	Continuous Urban Fabric (S.L. > 80%)	1.55	0.59	0.82	0.62
5	Discontinuous Dense Urban Fabric (S.L.: 50–80%)	11.01	6.96	5.44	4.78
6	Discontinuous Low Density Urban Fabric (S.L.: 10–30%)	0.12	0.15	0.12	0.09
7	Discontinuous Medium Density Urban Fabric (S.L.: 30–50%)	3.55	2.48	1.85	1.57
8	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)	0.00	0.00	0.00	0.00
9	Fast transit roads and associated land	0.14	0.03	0.02	0.01
10	Forests	9.26	15.65	24.74	22.09
11	Green urban areas	0.50	0.07	0.26	0.20
12	Industrial, commercial, public, military and private units	2.19	0.75	1.03	0.56
13	Isolated Structures	0.95	1.31	1.19	1.36

Table 1. cont.

No.	Categories of land cover	Share in the area of the Zone I	Share in the area of the Zone II	Share in the area of the Zone III	Share in the area of the Zone IV
		[%]	[%]	[%]	[%]
15	Mineral extraction and dump sites	0.11	0.03	0.24	0.15
16	Other roads and associated land	2.13	1.74	1.67	1.63
17	Railways and associated land	0.20	0.07	0.09	0.07
18	Sports and leisure facilities	0.73	0.18	0.14	0.28
19	Water bodies	0.95	0.31	1.67	0.53
TOTAL		100.00	100.00	100.00	100.00

Source: authors' study

Significant difference between occurring anthropogenic areas in individual zones is worth noticing. In case of lands located near the city (the zone to 5 km), built-up areas definitely dominate occupying almost all available space between the dense network of roads. The areas situated in the zone which is most away from the city (15–20 km from the city) only contain anthropogenic areas next to main roads which occur much less often (Figures 4, 5).



Source: authors' study

Fig. 4. The fragment of land cover in the buffer zone of 0–5 km



Source: authors' study

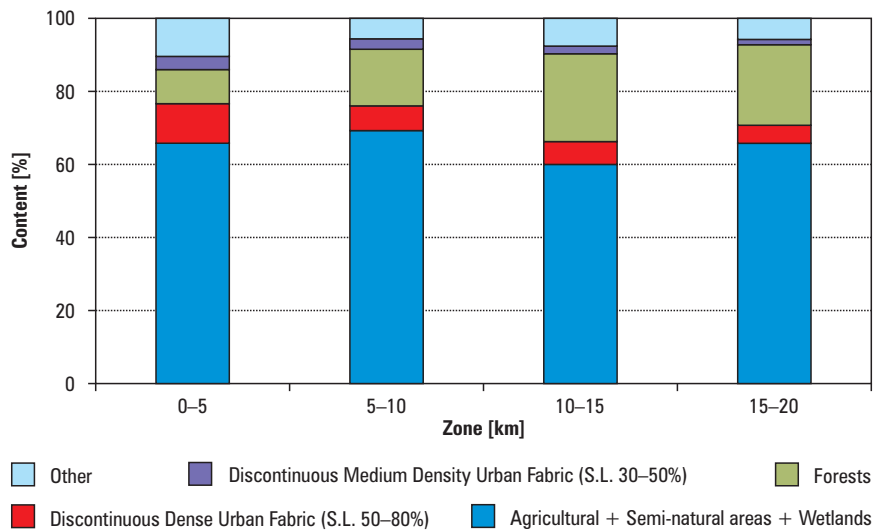
Fig. 5. The fragment of land cover in the buffer zone of 15–20 km

Taking areas with significant human impact into consideration, gradual decrease of its share in every zone together with going away from Krakow occurs. For the sustained urban fabric, it is the change of value from 1.5% for the zone I to 0.6% in the zone IV. Similar trend can be observed in case of the other areas where anthropogenic pressure occurs to a lesser or bigger extent: the areas of roads, railways, commercial ones, of general interest, sports grounds or urban greenery.

Categories of land cover were grouped considering increase of intensity of anthropogenisation phenomenon occurrence according to the scheme:

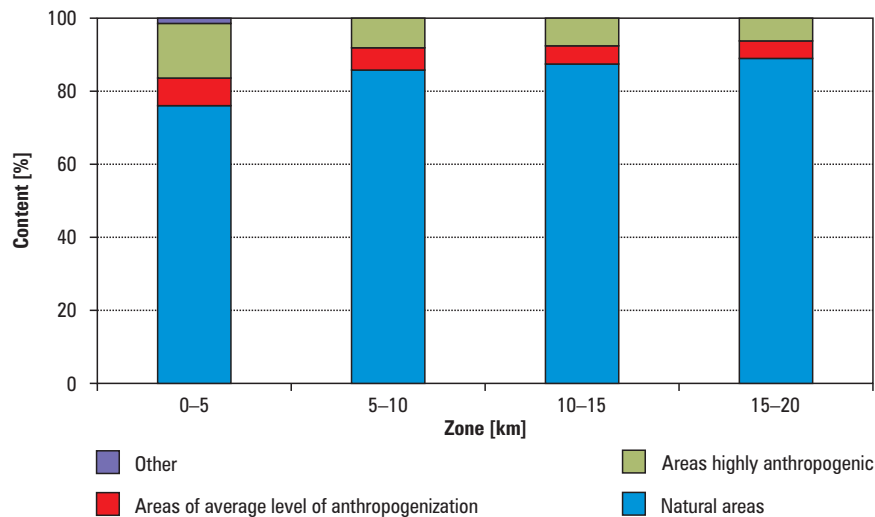
- natural areas: agricultural + semi-natural areas + wetlands, forests, water bodies;
- areas with average grade of anthropogenisation: construction sites, discontinuous low density urban fabric (S.L.: 10–30%), discontinuous medium density urban fabric (S.L.: 30–50%), discontinuous very low density urban fabric (S.L. < 10%), isolated structures, other roads and associated land, railways and associated land;
- highly anthropogenized areas: airports, continuous urban fabric (S.L. > 80%), discontinuous dense urban fabric (S.L.: 50–80%), fast transit roads and associated land, industrial, commercial, public, military and private units;
- other: green urban areas, land without current use, mineral extraction and dumpsites, sports and leisure facilities.

Grouped classification also confirms earlier results. As the distance from the city increases, the content of areas with slight anthropogenisation (natural ones) increases by almost 13% and the share of strongly anthropogenic areas declines by almost 40% (Table 2, Figure 7).



Source: authors' study

Fig. 6. Content of individual categories of land cover in ring zones



Source: authors' study

Fig. 7. Percent share of grouped categories of land cover in ring zones

Table 2. Grouped categories of land categories in individual zones

Grouped categories of land covering	Zone I	Zone II	Zone III	Zone IV
Natural areas	75.85	85.41	87.04	88.60
Areas of average level of anthropogenization	7.38	5.95	4.98	4.78
Areas highly anthropogenic	15.26	8.34	7.31	5.97
Other	1.50	0.29	0.68	0.65

Source: authors' study

5. Summation and conclusions

Suburban zones are the areas where dynamic changes due to anthropogenic pressure can be observed causing the constant growth of built-up areas. That influences the necessity of constant monitoring required for taking planning actions that reduce negative results of this phenomenon (elaborating local plans of spatial development, study of spatial development conditions and directions). Due to their close connection to the city, these areas and adjacent cities should be treated as „spatial and functional wholeness”. To a certain extent, occurring changes influence cities' development, their spreading and functioning. The opinion of Falkowski [2009] who assumes that prevailing trends will progress becomes correct as the attempt to estimate further changes.

The example of Krakow metropolitan area is not isolated. As the Statistical Office in Krakow says [2013], there are several metropolises in Poland (e.g. the Gdansk-Gdynia-Sopot metropolitan area, Warsaw metropolitan area or Poznań agglomeration). However, each of them having some characters in common possesses diverse organizational, functional and spatial structures.

The analysis of spatial structure of the surveyed area on the basis of data that concern area using in the suburban zone of Krakow city presents in a clear way variation of covering elements. Pursuant to the performed analysis, the theory of Gonda-Soroczyńska [2009] according to which both diversity and intensity of social and economic phenomena decrease along with diverging from city borders was confirmed.

Materials used for research can be used complementarily and they can be helpful in observations and evaluations that occur between various forms of land covering as well as landscape connections and variations [Kunz 2008].

The applied method of land cover analysis by means of buffer zones around big city centres is a universal method. Referring to the subject of the analysis, in conjunction with intensive transformations in suburban areas as a result of anthropogenic pressure, it helps in an easy way to modify the measure of the analysis.

Performed surveys and prevailing urban trends suggest the necessity of conducting more detailed analyses that will allow to check the kind of occurring pressure (e.g. settlement of investment ones). Suburban areas should be developed comprehensively not only serving as so called cities' bedrooms.

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