

INTERFERENCES BETWEEN THE ECOLOGICAL NETWORK AND URBANIZED AREAS IN POLAND

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Abstract

This paper presents spatial relations between Polish urban areas and valuable habitats and links between them composing the country's ecological network. The quantitative analysis for 891 towns and cities was conducted using GIS techniques based on cartographic vector data and statistical data. Valuable habitats and links between them, such as national parks, landscape parks, CORINE biotopes sites, wildlife corridors linking NATURA 2000 sites and ECONET areas, can be found in 72% of Polish towns and cities. The proportion of artificial surfaces in those areas is different depending on the size of a town or city and its location. Urban areas with the highest index of presence of valuable habitats and links between them are concentrated in the south of Poland, where settlement network is most dense. However, in the case of those areas the proportion of artificial surfaces interfering with the ecological network is lower than Poland's average, being 16%. The pressure of anthropogenic land cover extending onto the country's ecological network is most conspicuous in urban areas with a population of at least several dozen thousand residents where the average developed area is 20.8% of their total area. The danger for the continuity of the nature system is best seen in the north western Poland, where artificial surfaces interference in towns and cities is largest. The analysis performed identified 82 towns and cities, in which the preservation of the continuity of the ecological network should be a priority in spatial management because of a higher than average index of the presence of valuable habitats and links between them and large proportion of artificial surfaces in those areas.

Keywords: urban development; spatial conflicts; regional planning; Poland

1. Introduction

Urbanisation, and particularly intensive development within urban open space causes the fragmentation and isolation of green areas (Byrant, 2006; Uy and Nakagoshi, 2007; Swenson and Franklin, 2000). Therefore the development of Polish cities and towns situated within areas of highly valuable natural environment, being part of the country's ecological network has a significant influence on its spatial form and functioning.

The significance of preserving valuable habitats and links between them in urban space has been observed both on the national and international level. This was manifested by EU member states' adopting the Thematic Strategy on the Urban Environment, which is one of seven thematic strategies envisaged within the Sixth Environment Action Programme (2002-2012) aiming of improve the environmental condition and quality of urbanised areas. Also the provisions of the National Strategy for the Protection and Moderate Use of Biodiversity point to the

necessity to protect green areas within cities through applicable provisions in spatial management plans and studies on conditions and directions of spatial management of communes.

The literature concerning the designing process of urban green space is vast but to a large extent it consists of case studies (Beatley, 2000; Hough, 2004), conceptual papers (Ahern, 1995) or qualitative studies (Chmielewski, 2001).

This paper encompasses a diagnosis of interferences between urbanization and areas functioning as part of the country's ecological network using quantitative methods, which make it possible to compare and identify the urban areas where spatial management is crucial for the preservation of the spatial integrity of the ecological network of Poland.

1.1. Purpose and scope of study

Areas with outstanding natural assets or those functioning as links between them should form a spatially connected network, which is important for the preservation of the assets and proper functioning of natural environment (Liro, 1998, Jędrzejewski, 2005). Links between highly valuable habitats were particularly marked out without considering administrative boundaries¹ and as a result are also located within cities and towns, where development has the most intensive form. This paper aims therefore to diagnose spatial relations between areas with highly valuable environment features and urbanised areas of Polish cities and towns, which resulted in the determination of the following:

- diversity of the presence and proportion of valuable habitats and links between them
- in urban areas in different regions of Poland,
- proportion of urban artificial surfaces in areas of valuable habitats and links between them,
- differences in the presence of valuable habitats and links between them in urban areas in relation to the population and location.
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The analysis performed permits the identification instances of interference resulting from spatial management of urbanized areas significant for the nature conservation in Poland. It further led to the determination of the urban areas which, despite a large population, preserved an unobstructed (unaffected by artificial surface land cover) ecological network as well as those in which development of anthropogenic land cover interferes with valuable habitats and links between them.

¹ Wildlife corridors connecting NATURA 2000 sites were in most cases designed so as to avoid areas with dense development.

1.2. Study area

The study area included 891 administrative units having the town status and located in Poland.

In respect of natural features Poland can be divided into five main landscape belts stretched latitudinally. These are: the South Baltic Shoreland, lake districts, lowlands, highlands and mountains. The belts intersect with valleys of rivers running in the south-north direction, including the largest Polish rivers – the Vistula and Odra. Landscape is also influenced by land use diversity across regions, which is a result of different historical, economic, political and social conditions (Symonides, 2007). It is also observable in the degree of urbanisation, which is clearly lowest in the east, and highest in the south and southern west, being a result of, among other things, the presence of highly developed mining industry in the region.

2. Materials and methods

The research was conducted using GIS techniques which enabled to perform spatial cartographic analyses for 891 Polish cities and towns. The analyses concerned areas within the administrative boundaries because decisions on spatial management are made accordingly, which influences the character of land cover in the area and has reflection in the studies on conditions and directions of spatial management of communes, being a representation of their spatial policy.

Valuable habitats and links between them were defined as areas with outstanding natural assets in the nationwide perspective or areas serving as links between them. These included national and landscape parks, areas being part of the international EECONET² network, wildlife corridors connecting the areas of NATURA 2000³ and CORINE biotopes⁴.

The analyses were based on vector and statistical data (Table 1) which were used to create a database on valuable habitats and links between them in urban areas and proportion of artificial surfaces in those areas.

² National ecological ECONET network, composed of areas junctions and wildlife corridors of national and international significance. More on this: Liro (1998)

³ Network of wildlife corridors connecting Natura 2000 areas developed by the Mammal Research Institute, Polish Adcademy of Sciences (ISBPNPAN) in Białowieża. More on this: Jędrzejewski i et al (2005)

⁴ Two types of areas *Complex sites* and *subsites* designed within the CORINE progamme. More on this: EEA (1995)

Table 1. Data used for analyses

Theme	Scale	Source	Type
Protected areas (national parks and landscape parks)	1:250 000	General Geographic Database (GUGiK*)	Vector data
Wildlife corridors connecting NATURA 2000 sites	Not specified	IBS PAN	Vector data
CORINE biotopes sites	1:100 000	EEA	Vector data
ECONET	1:500 000	IUCN	Vector data
CORINE land cover 2000	1:100 000	EEA	Vector data
Population		GUS*	Statistical data

* GUGiK – Head Office of Land Surveying and Cartography; *GUS – Central Statistical Office

In order to classify Polish cities and towns with regard to the potential interference between artificial surfaces and valuable habitats and links between them, cities and towns featuring such areas were identified. Then the surface area and proportion of each type of valuable area were determined. Based on literature (Benedict and McMahon, 2002) it was found that the area size is significant for natural environment protection (*patch size effect*) and as a general rule the larger it is, the better. The surface area of valuable habitats and links between them in urban space depends to some extent on the surface area of the city itself. Thus the proportion of the presence of such areas was also taken into account. The proportion is inversely proportional to the size of areas not classified as valuable in respect of natural features, in which artificial land cover forms are not deemed negative for the preservation of the continuity of the country's ecological network. As a general rule the larger the proportion of valuable habitats and links between them, the smaller the surface area of land which could be used for development without interference. The data on the surface area and proportion of valuable habitats and links between them in urban space were analysed using the standardisation method according to the following formula:

$$z_i = (x - u) / q$$

where:

z_i - standardised value i ; x – standardised variable; q - standard deviation of the set; u - average for the set

As a result of the analysis conducted for Polish towns and cities the average value obtained for each variable was zero, and there was a positive number in the case of a value above the average and a negative number in the case of a value below the average. This permitted to compare directly quantitative urban areas characteristics expressed in different physical values.

Standardised data was used to formulate the index of presence of valuable habitats and links between them (WOPC) in urban areas:

$$WOPC_i = z_{pe} + z_{pk} + z_{poch} + z_{pcb} + z_{ue} + z_{uk} + z_{uoch} + z_{uch}$$

where:

z_{pe} - standardised surface area of ECONET areas; z_{pk} - standardised surface area of corridors connecting NATURA 2000 sites; z_{poch} - standardised surface area of protected areas (national and landscape parks); z_{pcb} - standardised surface area of CORINE biotopes sites; z_{ue} - standardised proportion of ECONET areas; z_{uk} - standardised proportion of corridors connecting NATURA 2000 sites; z_{uoch} - standardised proportion of protected areas (national and landscape parks); z_{uch} - standardised proportion of CORINE biotopes sites; i - city or town for which the index is calculated

In the analysis of the degree and form of pressure on valuable habitats and links between them in urban areas the CORINE land cover 2000 data was used. The data was generalised to 13 types⁵ of land cover observable in Polish cities and towns. The analysis focused on the pressure resulting from the affect of anthropogenic areas with artificial surfaces – such as urban fabric, industrial, commercial or transport areas, mine, dump and construction sites – within valuable habitats and links between them.

The proportion of the mentioned anthropogenic areas present in areas with valuable environment features was also standardised according to the z_i formula, which was further employed to formulate the index of anthropogenic land cover in valuable habitats and links between them WSZ_i .

$$WSZ_i = z_{uz}$$

where:

z_{uz} - standardised proportion of anthropogenic areas in valuable habitats and links between them; i - city or town for which the index was calculated

The next stage of calculation was to examine, if the index of anthropogenic land cover in valuable habitats and links between them in urban space differs by size of the settlement (expressed in terms of population). For this purpose, urban areas were divided into 3 groups with respect to population:

⁵ according to the classification adopted in the CORINE land cover programme

- below 10 000 (small towns),
- from 10 000 to 100 000 (medium-sized cities and towns),
- above 100 000 (large cities).

On the final stage a classification of urban areas differentiating 5 types were made. Classification was made based on the negative or positive value of index of presence of valuable habitats and links between and index of anthropogenic land cover. The following types of spatial relations between Polish urban areas and the ecological network were specified:

1. Urban areas where the index of valuable habitats and links between them and index of anthropogenic land cover in the ecological network are above the average.
2. Urban areas where the index of valuable habitats and links between them is below the average and the index of anthropogenic land cover in the ecological network is above the average.
3. Urban areas where the index of valuable habitats and links between them is above the average and the index of anthropogenic land cover in the ecological network is below the average.
4. Urban areas where the index of valuable habitats and links between them and the index of anthropogenic land cover in the ecological network are below the average.
5. Urban areas without valuable habitats and links between them.

The final component of the research consisted in the determination and presentation of the spatial diversity of the instances of interference in a regional perspective.

3. Results

3.1. Valuable habitats and links between them within urban areas

As shown in Table 2, valuable habitats and links between them could be found in over 70% of Polish urban areas. A majority of them are ECONET areas, which were set within approximately 62% of cities and towns in Poland, whereas a minority are CORINE biotopes sites, which along with national and landscape parks were noted in approximately 20% of the urban areas.

This shows that the problem of the management of environmentally valuable areas in cities and towns is widespread in Poland and concerns most urban administrative units.

Table 2. Presence of valuable habitats and links between them in urban areas

Voivodeship	Number of cities and towns with valuable nature areas:							
	1	2	3	4	5	6	7	8
Dolnośląskie	91	29	24	11	48	57	66	72.53
Kujawsko-Pomorskie	52	13	3	7	19	34	38	73.08
Lubelskie	41	11	11	4	20	29	32	78.05
Lubuskie	42	3	6	10	29	29	35	83.33
Łódzkie	43	7	2	4	12	18	24	55.81
Małopolskie	57	20	8	13	22	45	49	85.96
Mazowieckie	85	12	10	19	37	51	57	67.06
Opolskie	35	4	6	14	7	21	25	71.43
Podkarpackie	45	6	3	4	25	26	33	73.33
Podlaskie	36	8	15	6	28	24	31	86.11
Pomorskie	42	13	17	8	11	33	34	80.95
Śląskie	71	19	14	18	28	33	43	60.56
Świętokrzyski	31	9	9	8	13	18	22	70.97
Warmińsko-Mazurskie	49	7	9	10	23	33	39	79.59
Wielkopolskie	109	12	14	13	34	50	60	55.05
Zachodniopomorskie	62	12	24	18	31	52	55	88.71
Total	891	185	175	167	387	553	643	-
Proportion of cities and towns with valuable nature areas [%]	-	20.8	19.6	18.7	43.4	62.1	72.2	-

1: Number of cities and towns; 2: National and landscape parks; 3: CORINE biotopes complex sites; 4: CORINE Biotopes sub-sites; 5: Wildlife corridors connecting NATURA 2000 sites; 6: ECONET; 7: Any of the specified; 8: Proportion of cities and towns with any of the specified [%]

As many as 643 cities and towns with valuable habitats and links between them were identified nationwide, 245 of which show an above the average index of presence of valuable habitats and links between them, which constitutes 27% of Polish urban areas.

The largest number of cities and towns, within whose boundaries areas belonging to the country's ecological network were noted, is located in Dolnośląskie and Śląskie voivodeships, where the density of urban areas is highest, and in Zachodniopomorskie voivodeship. Evidently fewer cities and towns in which this index was above the average are situated in the eastern Poland, which features

highly valuable natural environment but has fewest urban areas. This suggests that in the eastern part of Poland urban areas are of little danger to the continuity of national ecological network because of their low density and location in surroundings of lower environmental significance.

3.2. Proportion of anthropogenic land cover in valuable habitats and links between them in urban areas

Anthropogenic areas in Polish cities and towns cover on average 16% of valuable habitats and links between them.

Urban areas classified as type 1 and 3 are characterised by above average index of presence of valuable habitats and links between them (with different index of anthropogenic artificial land cover), whereas type 1 and 2 cities and towns show above average index of anthropogenic land cover in valuable habitats and links between them (with a varied index of presence of those valuable areas). Type 4 cities in turn show a lower index of presence of valuable habitats and links between them and a below average degree of anthropogenic land cover.

In type 1 on average 28% of the surface area of valuable habitats and links between them was covered by artificial surfaces, and in cities such as Odolanów, Chojna, Sepólno Krajeńskie, Nowe even over a half (51-55%). In type 2 cities and towns on average 34% of valuable habitats and links between them was covered by artificial surfaces, however, in 21 cities the proportion exceeded 50% with the highest observed value reaching 98%. In type 3 cities and towns the average proportion of the surface area of environmentally significant areas used for anthropogenic land cover is 7%, and the highest value noted is 16%. Type 4 cities and towns showed the lowest average proportion of anthropogenic land cover, being 5%, and the maximum value observed was 16%. The most interference was noted for type 3 cities and towns, which are characterised by below average index of valuable habitats and links between them that are additionally covered to the largest extent with the highest degree of artificial land cover in those areas.

In cities with a population of several dozen thousand the proportion of anthropogenic land cover in valuable habitats and links between them is the largest and amounts to 20.8% on average. In urban areas with several hundred thousand residents the proportion is 16.2%, and towns with a population below 10,000 people have the smallest proportion of artificial surface in ecological network, being 13.8%. Table 3 presents urban areas with respect to their size and relation to valuable habitats and links between them.

Out of type 1 cities and towns, whose index of presence of valuable habitats and links between them is above the average and where anthropogenic land cover pressure is the strongest, most are middle-sized urban areas, while in the case of weaker pressure (type 3) the majority are small towns. Small towns are dominant also in the case of areas with a lower than average index of presence of valuable habitats and links between them and anthropogenic land cover pressure (type 4), whereas middle-sized cities are most numerous in areas with low index of presence of habitat and links between them and a larger proportion of artificial surfaces in such areas.

Table 3. Number of urban areas of different types with respect to the population

Type/Size	Small	Middle-sized	Large	Total
1	32	42	8	82
2	77	93	7	177
3	111	42	10	163
4	130	82	8	220
5	139	104	6	249
Total	489	363	39	891

Table 4. Number of cities and towns of different types according to voivodeships

Voivodeship	Number of cities and towns							Proportion of cities and towns [%]		
	type 1	type 2	type 3	type 4	types 1 & 3	types 1 & 2	with environmentally valuable areas	Total	types 1 & 3	types 1 & 2
Dolnośląskie	5	9	26	27	31	14	66	91	34.1	15.4
Kujawsko-Pomorskie	10	18	5	4	15	28	38	52	28.8	53.8
Lubelskie	5	6	6	15	11	11	32	41	26.8	26.8
Lubuskie	5	11	7	11	12	16	35	42	28.6	38.1
Łódzkie	0	10	2	12	2	10	24	43	4.7	23.3
Małopolskie	2	9	17	21	19	11	49	57	33.3	19.3
Mazowieckie	8	14	12	22	20	22	57	85	23.5	25.9
Opolskie	3	8	6	8	9	11	25	35	25.7	31.4
Podkarpackie	4	3	8	17	12	7	33	45	26.7	15.6
Podlaskie	4	3	9	15	13	7	31	36	36.1	19.4
Pomorskie	9	12	9	5	18	21	34	42	42.9	50.0
Śląskie	3	5	25	11	28	8	43	71	39.4	11.3
Świętokrzyskie	0	3	9	10	9	3	22	31	29.0	9.7
Warmińsko-Mazurskie	4	17	7	11	11	21	39	49	22.4	42.9
Wielkopolskie	10	29	4	16	14	39	60	109	12.8	35.8
Zachodniopomorskie	10	20	11	15	21	30	55	62	33.9	48.4
TOTAL	82	177	163	220	245	259	643	891	-	-

The voivodeship perspective (Table 4) permits to differentiate spatially and identify those urban areas which might interfere with valuable habitats and links between them, which should be treated as a priority in spatial policy as particularly important for the preservation of the continuity of the national ecological network. Cities and towns with a higher index of presence of areas especially important to the environment protection are those belonging to type 1 and 3, while those which show the largest proportion of anthropogenic areas with artificial surfaces in such areas are types 1 and 2.

3.3. Spatial diversity of interference of anthropogenic land cover with the ecological network

Valuable habitats and links between them in urban areas are endangered by the expansion of anthropogenic land cover. In only 81 out of 643 cities and towns anthropogenic areas are not located within the areas forming ecological network. The concentration of urban areas in which artificial surfaces interferes with valuable habitats and links between them to the largest extent is clearly seen in the north western Poland. In turn the cities and towns where the location of anthropogenic areas interferes with the ecological network to a smaller degree are mostly situated in the south.

As shown in Fig. 1, the largest concentration of type 1 cities and towns can be found in Wielkopolskie (10), Zachodniopomorskie (10) and Kujawsko-Pomorskie (10) voivodeships. This suggests that the north western Poland – with vast areas forming the ecological network and a dense settlement network – faces the most serious risk to the continuity of the country nature system. It is also this region that has the largest number of type 2 cities and towns, which are characterised by a large proportion of artificial surfaces in network of valuable habitats and links between them and a lower index of presence of such areas.

In contrast, type 3 cities and towns, which show a higher than average index of presence of valuable habitats and links between them and have less anthropogenic areas than type 1, are mostly located in southern Poland, in Dolnośląskie and Śląskie voivodeships. Likewise type 4 cities and towns are concentrated in Dolnośląskie and Małopolskie voivodeships, and also Mazowieckie voivodeship.

To sum up, the analysis performed shows that urban areas situated in north-west could be characterised with the highest percentage of valuable habitats and links between them affected by anthropogenic land cover, whereas cities and towns in the south, where the settlement network is most dense, show smaller proportion of artificial surfaces within ecological network boundaries. It is interesting because it is in the southern cities that mining industry and the accompanying type of

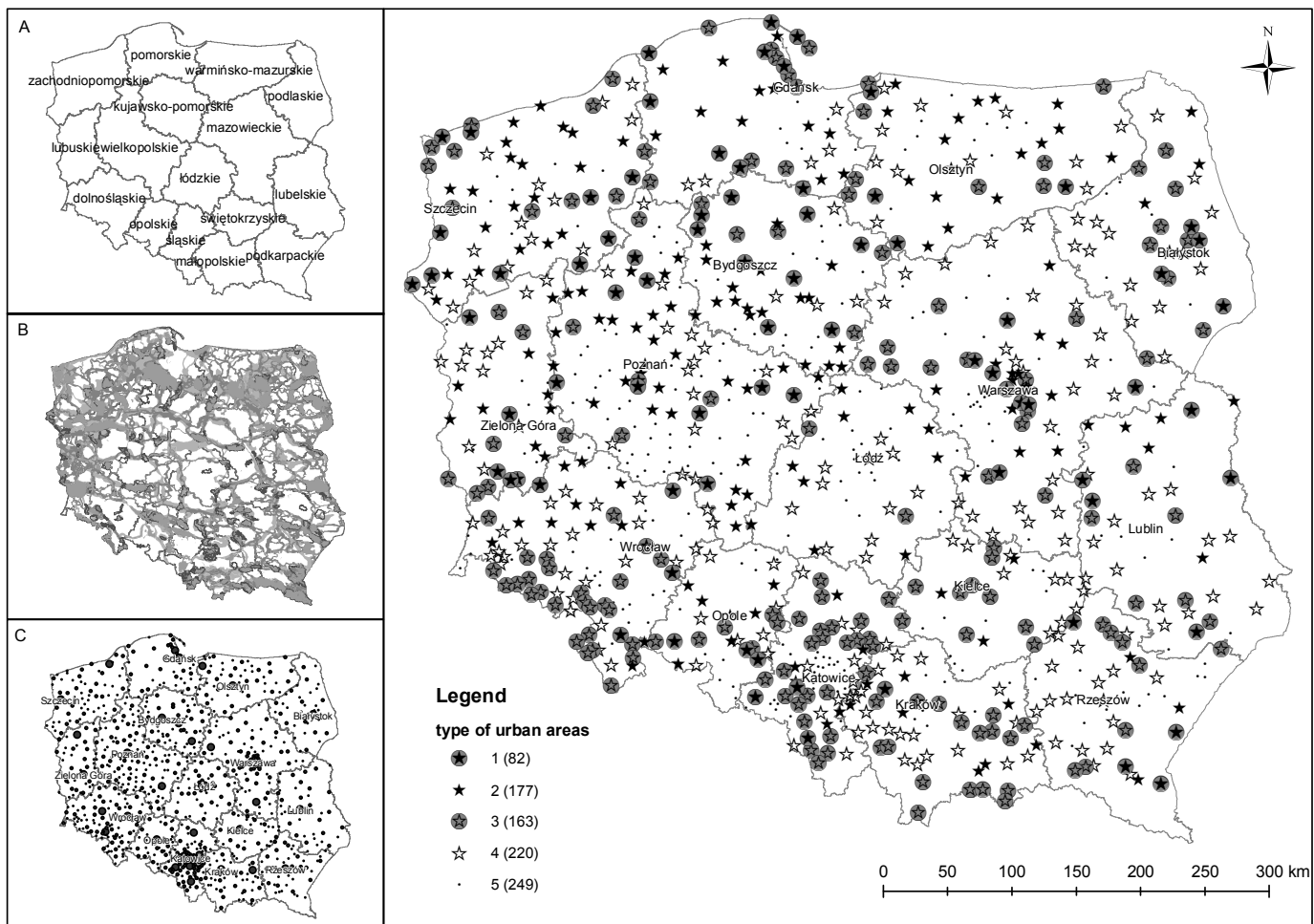


Fig. 1 Types of spatial relations between urban areas and links between them (1 – Urban areas where the index of valuable habitats and links between them and index of anthropogenic land cover in the ecological network are above the average; 2 - Urban areas where the index of valuable habitats and links between them is below the average and the index of anthropogenic land cover in the ecological network is above the average; 3 – Urban areas where the index of valuable habitats and links between them is above the average and the index of anthropogenic land cover in the ecological network is below the average; 4 - Urban areas where the index of valuable habitats and links between them and the index of anthropogenic land cover in the ecological network are below the average; 5 – urban areas with no valuable nature areas). A. Polish voivodeships; B. Presence of areas forming the ecological network in Poland; C. Location of cities

management is concentrated. However, in the spatial perspective anthropogenic land cover in this region is located outside highly valuable habitats and links between them and interferes with the national ecological network to a smaller extent. In this part of Poland urban development is largely concentrated in cities and towns with environmentally less valuable sites.

4. Conclusion and summary

The space of cities and towns is intensively urbanised and therefore areas valuable because of their natural assets or functions served in the environment (in particular the function of links between areas of highly valuable natural environment) are at particular risk of being affected by anthropogenic land cover.

The analysis performed showed that valuable habitats and links between them are common in Polish cities and towns. At the same time land cover of anthropogenic character, whose proportion is frequently several dozen percent, was noted in those areas.

In order to preserve the quality and functions of the national ecological network, it is vital to maintain its spatial continuity through rational spatial management of valuable habitats and links between them being part of it in cities and towns.

This study resulted in the identification of 82 cities and towns, whose development can have the most significant impact on the ecological network in Poland, and in which spatial planning should involve special consideration of the assets of natural environment.

The spatial distribution of anthropogenic land cover types in cities and towns in relation to areas forming the country nature system makes it possible to observe the interference of urbanisation with nature protection which occurs in Poland. It permits to identify the regions in which nature system is at the highest risk of breaking its spatial continuity. In order to restrict the fragmentation and isolation of this system its spatial relations with urban areas should be given special attention in the voivodeship spatial management plans.

The results of the analysis performed in the national scale permit to differentiate urban areas in respect of the presence of valuable habitats and links between them and the proportion of artificial surfaces land cover present in those areas, however because of the degree of detail of cartographic data they should be further specified in detail for individual voivodeships or towns and cities in a regional and local perspective respectively.

It was possible to determine the scale of the problem of anthropogenic areas with artificial surface within the nature system, which concerns most urban areas. Nonetheless, further and more detailed studies are indispensable to establish the degree of fragmentation of valuable habitats and links between them within urban open space and forms of influence affecting them, as well as to develop solutions restricting the spatial interference. Further studies should focus in particular on type 1 towns and cities, which are characterised by an high index of the presence of valuable areas in the nationwide perspective and a large proportion of anthropogenic land cover in those areas.

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