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THE IMPACT OF LAND-USE CHANGES ON THE ECOLOGICAL QUALITY OF THE ROZTOCZE LANDSCAPE PARKS

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Abstract. Changes in the land use structure, which are observed in recent years, generally indicate their negative impact on ecological quality considered in the landscape scale. Therefore, the aim of this study was to determine whether such a trend also applies to protected areas, such as landscape parks (LP). As research areas four parks located within the Roztocze and Solska Forest (Poland) were selected. Three factors were analyzed as an surrogate indicators of the ecological quality: the degree of anthropogenic transformation of land cover forms, landscape diversity and the degree of landscape fragmentation. The study included data for the years 2004 and 2012 and was based on the GIS and orthophotomaps analysis. The results showed a lack of general trends for the whole analyzed region. The impact of changes in the land use structure on the ecological values can be defined as positive for Krasnobród LP and South Roztocze LP. In the case of Szczebrzeszyn LP and Solska Forest LP the impact is difficult to determine due to the different results obtained on the basis of selected indicators. Therefore, in order to totally illustrate the analyzed dependence the landscape structure in other periods of time should be analyzed, as well as the correlations between the defined changes and a variety of natural and cultural considerations.

Key words: landscape quality, landscape parks, Roztocze, Solska Forest, land use changes

INTRODUCTION

In areas used by people, land-use changes are largely the result of direct and indirect human impacts. Natural, socio-economic, historical, cultural, regional, technical and civilization factors affect the scope and scale of these changes [Myga-Piątek 2001, Wu 2008]. Since the fifties of the twentieth century, as a result of the acceleration of urbanization processes, the most significant have become economic and technical factors. In the structure of land use in Poland may be noted five major trends. The first is a decrease of arable land as a result of standardizing the structure of crops and increasing in the average size of farms

[Krysiak 2006, Nalej 2016]. Besides, afforestation of arable land often occurs. As a result, the last years are characterized by an increase in forest cover, associated with afforestation on poor soils for agriculture and processes of secondary succession. These processes cause a significant increase in the forest cover of the country [Kurowska *et al*. 2014]. According to GUS data, in 1945, the share of forests and shelterbelts in the total area of Poland was 20.8% and in 2015 more than 29% [GUS 2016]. A rapid increase also applies to the share of built-up areas, which arise both from the transformation of agricultural land into forests and fallow lands [Łowicki and Mizgajski 2005]. The scale of changes illustrates the fact that, according to the GUS in 2000 was built a little over 50 000 single – and multi-family buildings, while in 2009 this number increased to more than 91 000, and in 2015 it amounted to about 180 000 [GUS 2016]. The increase in surface of built-up areas is also associated with an increase in the density of paved roads network, which are often ecological barriers contributing to the fragmentation of the landscape. Besides, transportation routes have a significant, adverse impact on species diversity, pollution of air, soils, and waters, cause the decrease in vegetation productivity, the distribution of water cycles, and even changes in local microclimates [Jaeger and Fahrig 2004] Progressive urbanization processes have particularly strong pressure on the hydrogenic landscapes. More than 54% of the total length of watercourses in Poland has been regulated, and more than 11% – embanked [Chmielewski 2007]. Compared to the 50s XX, in some regions more than 80% of the peatlands and swamps were drained. Only approx. 2% of these valuable ecosystems have survived in an unaltered state [Chmielewski 2001, Chmielewski and Chmielewski 2014].

The main directions of changes in the structure of land use in Poland, observed in the past half-century have an adverse impact on the ecological quality. Often, as a result of these changes, the natural structure of ecosystems has been divided into smaller parts, separated from each other by anthropogenic barriers [Kędziora and Ryszkowski 2006]. This causes a decrease in the size of individual patches of land cover, an increase in the length of the boundaries of landscape, geometrization the shape of patches and a decrease in the surface of natural habitats. These processes leads to the formation into the landscape of unstable structure, where the natural ecological processes are inhibited [Jaeger *et. al*. 2007]. Such disadvantageous changes may also relate to protected areas, in particular landscape parks, characterized by a much lesser degree of protection than national parks, that are multifunctional areas. Therefore, the aim of this study was to determine the effect of changes in the structure of land use that have been observed in the last 10 years, on the ecological quality of selected landscape parks located in the south-eastern part of the Lublin region.

METHOD

As research areas four parks located within the Roztocze and Solska Forest (Poland) were selected. These areas are characterized by a considerable diversity of landscape forms. The Roztocze mecoregion is located on uplands and is characterized by diverse landscape structure. Loess ravines and traditional, multi-stripe field mosaic in characterized for its west part (Szczebrzeszyński LP), carbonate rocks covered with diverse forest ecosystems for the middle part (Krasnobrodzki LP), and silicate rocks or periglacial plains covered with a mosaic of leafy forests, fields and villages for its south part (Południoworoztoczański LP). The Solska Forest represents an alluvium landscape with dunes covered with pine forests with small complexes of peatbogs (Solska-Forest LP) [Sowińska and Chmielewski 2011].

The basis for determining the changes in the structure of land use was the interpretation of orthophotomaps from the years 2004 and 2012, of size of 0.25 m. The minimum mapping unit was 0.1 ha. Then, the impact of changes on ecological quality were analysed based on the four criterions, treated as a surrogate landscape-based indicators of ecological values. They were: (1) the share of areas of differ level of anthropogenic transformation, (2) diversity on landscape level, and (3) level of fragmentation.

The classification of land cover forms into the groups of different levels of anthropogenic transformation was based on the Land Cover Classification System (FAO 2005]. As a result, to the group of natural forms were assigned non-transformed peat-bogs, non-transformed meadows, and natural forests. As semi natural forms were treated: extensively used meadows, semi-natural forests, self-sown patches of trees, clearings, and fallow lands. Anthropogenic land cover forms were divided into two types. The first one included undeveloped areas such as fields, managed forests, plantings around roads and ponds. The second built-up areas.

Diveristy on landscape level was based on the Shannon's Evenness Index**.** It was assumed that this index is positively correlated with species diversity indices [Nagendra 2002, Listopad *et al*. 2015] and thus being one of the factors affecting ecological quality.

$$(a)\ SHEI = \left[\left(\frac{-\sum_{i=1}^{s} P_i * lnP_i}{\ln s}\right)\right]$$

where:

P_i – proportion of the landscape occupied by a given patch type,
S – total number of patch types present in the landscape.

$$0 \ll SHEI \ll 1$$

SHEI = 0 when the landscape contains of 1 patch (i.e., no diversity),
SHDI = 1 when distribution of area among patch types is perfectly even (i.e., the highest possible diversity).

Fragmentation was assess based on the number of metrics such as: Number of patches (NP), patch density (PD), mean patch size (MPS) and edge density (ED) metric, where:

$$(b)\ ED = \frac{E}{S} * 10.000$$

where: E – total length (m) of edge in landscape,
S – total landscape area (m^2),
ED > 0, without limits,
ED = 0 when the entire landscape consists of a single patch.

RESULTS

Level of anthropogenic transformation of landscape

The analysis revealed four general tendencies referring to all the analysed parks: (1) the stagnation of the area occupied by the natural land cover forms; (2) the increase of semi-natural forms; (3) the decrease of the anthropogenic forms type 1; and (4) the slight increase of the anthropogenic forms type 2 (Fig. 1). During the analysed period the biggest land-use changes refer to the share of area occupied by semi-natural land cover forms in the case of Szczebrzeszyński and Krasnobrodzki LP – (3.88 and 4.37% respectively) and to anthropogenic land cover forms type 2 in the case of Solska Forest and of type 1 in the case of the South Roztocze LP (1.01% and 1.41% respectively) (Table 1). The land-use structure, however, widely differ among analysed areas.

About 84% of the Szczebrzeszyński LP area was covered by anthropogenic land cover forms, mainly fields (46% in 2004 and 44% in 2012) and managed forests (32% and 34% respectively). Moreover, the park features the lack of the natural land cover forms. From the land use changes perspective, the fields area was reduced to 2% and the peat-bogs, meadows and fallow lands to almost 1% (Fig. 2A). The changes in water, forests, afforestation and settlement was very low. Exceptions is managed deciduous forests which areas expended to about 1%.

The Krasnobrodzki LP land-use structure is characterized by the 80% share of the anthropogenic land cover forms, mainly managed coniferous forests and fields. Besides, more than 4 % of its area is covered by built-up areas. On the other

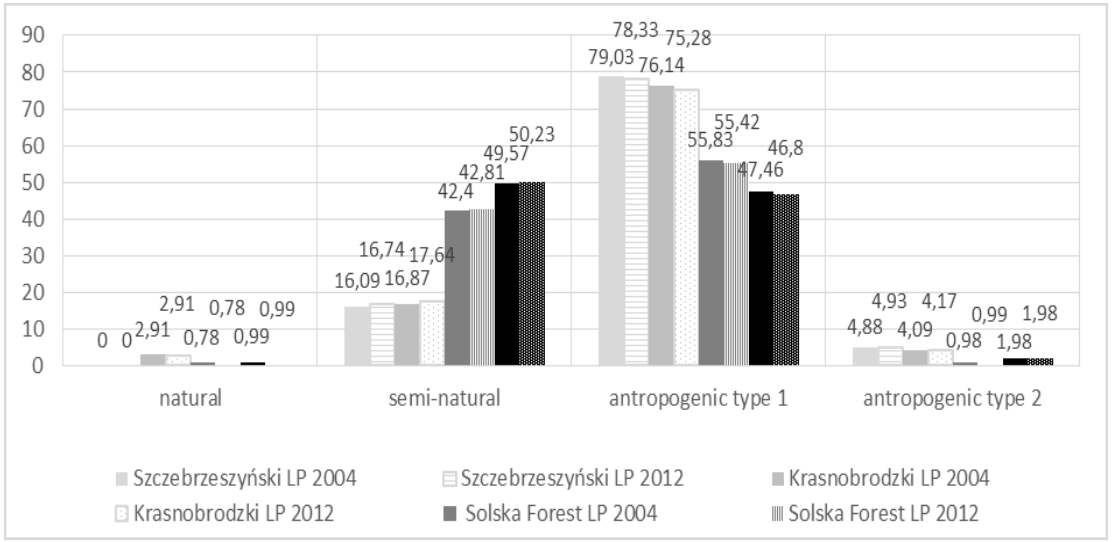

Fig. 1. Share of land cover form of different degree of anthropogenic transformation in 2004 and 2012. Note: as natural land cover forms were only treated areas of natural reserves

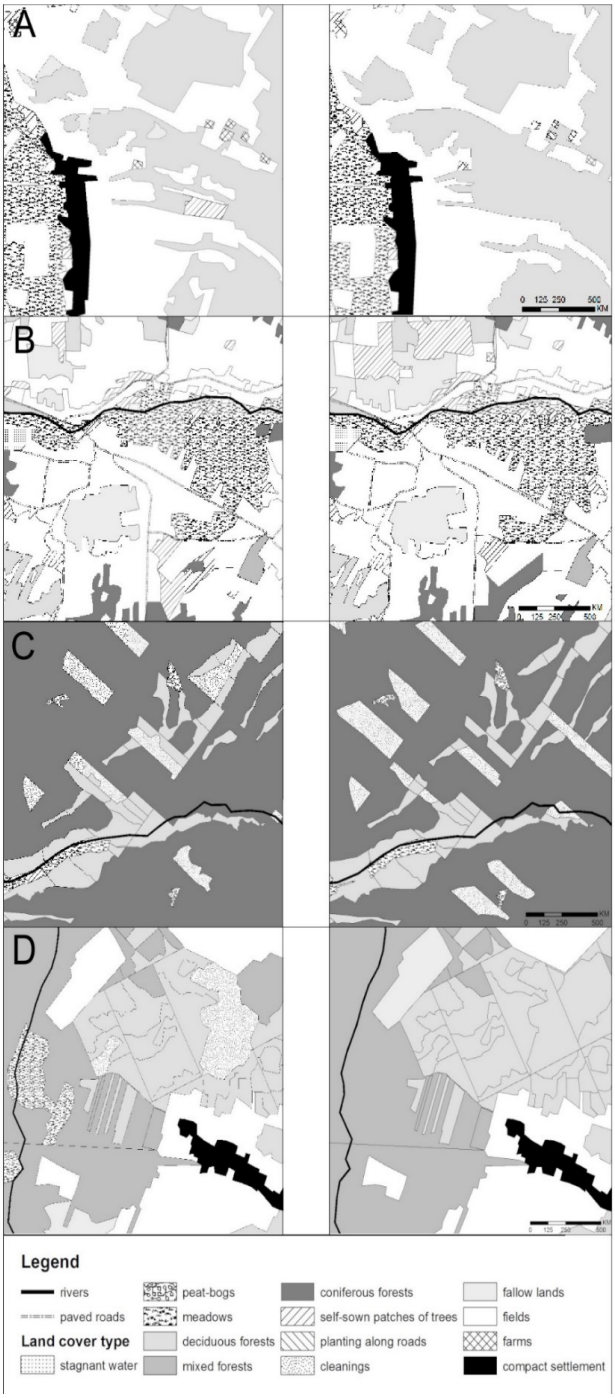

Fig. 2. Main land-use changes of analysed landscape parks:
A) Szczebrzeszyński LP; B) Krasnobrodzki LP; C) Solska Forest LP; D) South Roztocze LP

hand, this park features the highest share of natural forms – almost 3% composing 2 natural reserves. In the land-use changes, noteworthy is the decrease of area occupied by fields (24.07% in 2004 and 21.13% in 2012) and the slight increase of managed coniferous forests (28.45% in 2004 and 29.50% in 2012) and managed mixed forests (13.53% in 2004 and 14.48% in 2012) (Fig. 2B).

The Solska Forest LP features the relatively high share of natural and semi natural land cover forms (about 43%) and the fact that less than 1% of the area is covered by build-up areas. While analysing landscape structure, the important changes refers only to the cleanings which area was doubled (from the 345.23 to 688.87 ha). On the result they occupied 1.17% of the park in 2012 and 2.34% in 2012. Other changes were of less significance and includes: the decrease of coniferous semi-natural forests of 0.75% and of managed deciduous forests of 0.33% (Fig. 2C).

The South Roztocze LP features the lowest share of anthropogenic land cover forms (about 47%) and the highest of semi-natural (about 50%) mainly composing of deciduous forests and mixed forests. Besides, 1% of park is covered by natural forest complexes and not-transformed peat-bogs composing 3 natural reserves. The main changes in land cover include: the decrease of area occupied by the extensively used meadows (from 1.84% to 0.94%) and cleanings (from 0.70% to 0.10%) and the increase of the area covered by self-sown patches of trees (from 1.17% to 1.65%) and fallow lands (from 2.38% to 2.84%). Small fluctuations, between 0.01% and 0.66%, also refers to the area of almost all forest types (Fig. 2D).

Landscape diversity

The result showed that Krasnobrodzki and Solka Forest LP are of the considerably highest diversity than the two other parks. Besides, in their land-use structure can be distinguished, respectively, 19 and 20 different land cover forms. The same amount – 19 – features the landscape structure of the South Roztocze LP. Whereas, considerably lower number of classes characterized the Szczebrzeszynski LP – 16.

From the land-use changes perspective, the analysis generally revealed very slight changes of landscape diversity during the analysed period. The clear differences among parks, however, can be indicated. In the case of the Szczebrzeszynski LP the Shannon's Evenness Index has not been changed. The Krasnobrodzki and Solka Forest LP showed a slight increase of the index value – 0.02 and 0.01 respectively. Whereas, the South Roztocze a slight decrease – 0.01 (Table 1). Besides, the number of land use classes revealed to be constant in both analysed periods.

Table 1. The SHEI values obtained for landscape parks in analysed periods

Year	Szczebrzeszyński LP	Krasnobrodzki LP	Solska Forest LP	South Roztocze LP
2004	0.58	0.70	0.55	0.73
2012	0.58	0.72	0.56	0.72

Table 2. Fragmentation metrics calculated for landscape parks in analysed periods

Landscape Park	Year	Fragmentation metrics			
		number of patches (NP)	patch density (PD), number of patches /100ha	mean patch size (MPS), ha	edge density (ED), m/m^2
Szczebrzeszyński	2004	845	4.39	22.78	59.83
	2012	762	3.96	25.26	56.99
Tendency and scale of changes, %		9.82⇓	9.79⇓	10.89⇑	4.75⇓
Krasnobrodzki	2004	694	7.33	13.63	66.08
	2012	655	6.92	14.45	65.20
Tendency and scale of changes, %		5.62⇓	5.59⇓	6.02⇑	1.33⇓
Solska Forest	2004	865	2.94	34.00	35.00
	2012	876	2.98	33.57	37.07
Tendency and scale of changes, %		1.27⇑	1.36⇑	1.26⇓	5.91⇑
South Roztocze	2004	741	3.66	27.32	54.87
	2012	667	3.31	30.35	52.47
Tendency and scale of changes, %		9.99⇓	9.56⇓	11.09⇑	4.37⇓

Landscape fragmentation

The highest number of patches in both analysed period possess Solska Forest LP – about 870 (Table 2). However, it is a result of the maximum area of the park not of its high level of fragmentation, as the patch density is of the lowest value – almost 3 patches per 100ha. Whereas, this metrics is the highest in the case of the Krasnobrodzki LP – about 7 patches per 100 ha. This park is also characterized by the lowest mean patch size (about 14ha) and therefore the large edge density – about 66 m/m^2. Fragmentation metrics obtained for the Szczebrzeszyński and South Roztocze LP are quite similar. Distinct characteristic refer only to the NP which is considerably higher in the case of the first LP.

From the land-use changes perspective, the analysis revealed that same scale of changes for the Szczebrzeszyński and South Roztocze LP, and the same tendency also in the case of Krasnobrodzki LP. Whereas, Solska Forest LP is characterized by the occurrence of revealed trends, i.e. the increase of the number of patches and its density and related to it changes in patch size and edge density. Besides, the study generally suggested very slight changes of fragmentation metrics during the analysed period. It principally concerns the Krasnobrodzki and Solska Forest LP of the scale of changes between 1.26% and 6.02%. Whereas, the other two parks features higher variations of metrics, in particular in relation to NP and PD which decreased of almost 10% and MPS which increase of about the same value.

DISCUSSION

In the light of the results several remarks can be made. First of all, in relation to the level of anthropogenic transformation, the analysis revealed the increase of semi-natural forms, the decrease of the anthropogenic forms type 1, as well as the slight increase of the anthropogenic forms type 2. Those tendency are mainly the result of the increase of area covered by cleanings, fallow lands and self-sown patches of trees – which is generally consistent with nationwide trend [Łowicki and Mizgajski 2005, Kotańska *et al*. 2015]. Such tendencies do not directly indicate on the impact of changes on ecological quality. From the one hand, the reduction of surface of fields overgrow in a result of natural succession is a favorable process from the point of view of the ecological values. Typical for the west and middle Roztocze extensively used fields with wide balks and middle-fields trees, however, also may serve an important function being the habitat of many connected to agrocenosis species [Matuszkiewicz *et al*. 2013, Sanches-Oliver *et al*. 2014]. On the other hand, unfavorable is the process of the increase of built-up areas which sometimes occupied semi-natural forms and resulted in the increase of transportation routes being usually the ecological barriers [Jaeger and Fahrig 2004]. Nevertheless, this process is very slow with comparison to other regions [Łowicki and Mizgajski 2005].

Another analysing factor was the landscape diversity considered to be the predictor for biodiversity as diverse environmental conditions may be transpose to the possibility of existence of a higher number of ecological habitats being the place of leaving for a large number of species [Cassatella and Peano 2011, Listopad *et al*. 2015]. The result showed that no general tendency can be indicated. The Szczebrzeszynski LP features the same level of diversity, Krasnobrodzki and Solka Forest LP showed a slight increase of the index value, whereas the South Roztocze a slight decrease.

The last analysed factor was landscape fragmentation considered to be one of the major factor affecting the organization and function of ecological processes

[Jaeger *et al*. 2007]. In the view of the results it can be concluded that the land-use changes were meaningless from the point of view of ecological quality in the case of Solska Forest. Whereas, the level fragmentation of Szczebrzszyński, Krasnobrodzki and South Roztocze decrease as number of patches, as well as patch and edge density have significantly decreased.

Taking into account all above, it must be concluded that impact of land-use changes on ecological quality differ among analysed areas. Generally, transformation of the landscape structure observed between 2004 and 2012 have a positive impact on ecological quality of Krasnobrodzki and South Roztocze LP. In the case of Solska Forest the changes were generally of the adverse character, however, their scale was very so they be considered as meaningless from the point of view of the maintenance of ecological quality. No conclusion can be drown in relation to the Szczebrzeszyński LP, as fragmentation metrics indicate the positive direction of changes, diversity index is a constant value, whereas changes of areas covered by forms of different level of anthropogenic transformation are generally unfavourable from the ecological point of view. Therefore, the authors suppose that important factor deciding on the nature of impact of land-use was the initial landscape structure of each park, as well as different natural and cultural conditions.

Finally, it must be emphasize that on the basis of the results the conclusion on the relative level of ecological quality of analysed parks cannot be drown. The study only aimed at the indication of tendency and scale of changes during the analysed 10 years. Such conclusions can be provided only after the indexes calculation for adjacent area and parks located in other regions, and the comparison of obtained results. The result of study conducted by Sowińska-Świerkosz and Soszyński [2014], however, based on the spatial structure analysis indicated the insufficient degree of effectiveness of nature conservation in relation to the Roztocze landscape parks. In the light of the result, it may be concluded that this tendency is generally changing, especially in the case of Krasnobrodzki and South Roztocze LP, and as a result higher ecological quality od analysed areas may be expected hereafter.

CONCLUSIONS

1. The analysis do not indicate any general trend referring to the impact of land-use changes on the ecological quality of all analysed parks – this impact differ among areas.
2. The study revealed the positive tendency in relation to Krasnobrodzki and South Roztocze LP, whereas, changes observed in the landscape structure of Szczebrzeszyński and Solska Forest LP do not directly indicate any tendency.
3. To fully analysed the relation between land-use changes and ecological quality additional studies should be performed, including the analysis of land-

scape structure from other periods, both before 2004 and after 2012, and aimed at identification of correlation between defined changes and various natural and cultural conditions.

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WPŁYW ZMIAN STRUKTURY UŻYTKOWANIA ZIEMI NA JAKOŚĆ EKOLOGICZNĄ PARKÓW KRAJOBRAZOWYCH ROZTOCZA

Streszczenie. Zmiany w strukturze użytkowania ziemi obserwowane w ostatnich latach generalnie wskazują na ich negatywny wpływ na ekologiczną jakość rozpatrywaną w skali krajobrazu. Dlatego też celem pracy było określenie, czy tendencja taka dotyczy także obszarów chronionych, jakimi są parki krajobrazowe (PK). Jako pola badawcze wybrano cztery parki zlokalizowane w granicach Roztocza i Puszczy Solskiej. Analizom poddano trzy czynniki uznane za zastępcze wskaźniki jakości ekologicznej: stopień antropogenicznego przekształcenia form pokrycia terenu, różnorodność krajobrazu i stopień jego fragmentacji. Przeprowadzone badania obejmowały dane z lat 2004 i 2012 i zostały oparte na analizach GIS i analizie ortofotomap. Wyniki wskazały brak ogólnych tendencji w odniesieniu do całego analizowanego regionu. Wpływ zmian w strukturze użytkowania ziemi na walory ekologiczne można określić jako pozytywny w przypadku Krasnobrodzkiego i Południoworoztoczańskiego PK. W przypadku Szczebrzeszyńskiego PK i PK Puszczy Solskiej wpływ jest trudny do określenia z uwagi na różne wskazania obliczonych wskaźników. Dlatego w celu pełnego zobrazowania badanej zależności należałoby dokonać analizy struktury krajobrazu w innych okresach oraz przeanalizować korelacje pomiędzy zdefiniowanymi zmianami a różnorodnymi uwarunkowaniami naturalnymi i kulturowymi.

Słowa kluczowe: jakość krajobrazu, parki krajobrazowe, Roztocze, Puszcza Solska, zmiany użytkowania ziemi