Landscape Change Index as a Tool for Spatial Analysis

IOP Conf. Series: Materials Science and Engineering **245** (2017) 072014 doi:10.1088/1757-899X/245/7/072014

Landscape Change Index as a Tool for Spatial Analysis

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Abstract. This study analysed spatial and temporal changes in protected landscape of Ślęża Landscape Park in Poland, covering an area of 7724 ha. The main objective was to determine level of landscape change of the research area after Polish accession to European Union by comparing land-cover maps from 2004, 2009 and 2014. With the use of prepared land cover maps, we developed a database of the surface of the main elements constituting the background landscape of the research area. The data obtained made it feasible to assess the level of change in two different periods of time (2004 - 2009 and 2009 - 2014) by means of the landscape change index (LCI). This indicator is described by one value which is the result of all the change types taking place in the background landscape in a given period of time. Comparing the index of different parts of Ślęża Landscape Park helped to identify areas where the landscape changes were the highest and areas where the changes were hardly noticeable. The results show that when we take into account whole research area landscape changes are much more intense in the second of the analysed periods of time (2009 - 2014) (LCI=1,91) then in years 2004 - 2009 (LCI=0,71). The same analysis was done for each part of municipalities located within the Park. This made it possible to determine which part of the park is the most threatened by spatial transformations. In this context, it should be emphasized that the highest rates of landscape changes were recorded in the municipalities where the largest new residential area was located – in the municipalities Sobótka and Łagiewniki. Whereas municipality Dzierżoniów with a high percentage of forests inside the Park and unchanging area of arable land have the lowest landscape change index.

1. Introduction

The number of research in the field of landscape change in the context of time and space has been constantly growing in the last 10 years. It is considered to be in relation to the changes that appear in agriculture, industry and transport that cause more significant landscape transformations [1]. In the countries of central-east Europe, especially in Poland in the period after 1989, we observe the intensification of landscape changes as the effect of political transformations [2, 3]. New possibilities of investment founding resulting from being a member of European Union also caused landscape changes [4]. The current economic development associated with technology growth, wealthier society and the phenomenon of urban sprawl is causing an increased demand for space, especially in suburban areas located nearby protected areas [5]. Research in the field of landscape change are performed by different groups of scientists: the landscape ecologists, landscape architects, geographers or economists in many different scales and aspects. These include, among others, rural landscapes [6], landscapes of metropolitan areas [7] or protected landscapes [8]. They mainly focus on identifying the type of transformation and their reasons [9] or analyse their driving forces [10, 11], also called "key processes" [12]. There is still a need for further research on the landscape to understand better the

occurring changes and the use of acquired knowledge in the sustainable landscape management [13]. Knowledge about the scale of landscape changes and the ability to identify the risk areas is important especially in the context of the formal order of landscape audit at the regional level in Poland [14 Solon]. This document will determine the implementation of the European Landscape Convention in Poland and will influence the planning documents at regional and local levels and protection plans of nature conservation forms. [15]. That's why it is desired to search for indicators that will determine the level of changes in the landscape and identify particular areas of transformation risk. The indicator should be used in easy way on the stage of spatial planning documents preparation. This possibility gives the landscape change index (LCI) defined by Woodward and Fuhlendorf [16] as the total change in vegetation and land use at the landscape level by combining the absolute average changes of all land-cover types into one value. LCI is described by one value which is the result of all types change taking place in the background of the landscape in a given period of time. Łowicki [2] use index of landscape transformation. He defined it as the ratio of biologically active area where natural processes are dominant to the area where anthropogenic processes were dominant.

The aim of our research is to determine the level of change in the landscape of Ślęża Landscape Park in 10 years after the Poland joined European Union (years 2004 - 2014) and the identification of areas where these changes were most intense. To achieve this goal, we performed comparative analyses based on land cover maps from 2004, 2009 and 2014. Orthophoto maps were the basis for the development of a land cover type's database on a local scale and were used to calculate landscape change index in the analysed period of time.

2. Study area

The research was conducted within the Ślęża Landscape Park - a protected area with exceptional values in the scale of Lower Silesia region in Poland, part of the metropolitan area of Wroclaw. One of 12 protected areas of this type in Lower Silesia is located in the central part of Lower Silesia region, in the south-western Poland. The study area includes the area of 5 municipalities around the mountain Ślęża – Sobótka, Łagiewniki, Jordanów Śląski, Dzierżoniów and Marcinowice. The study area is divided into 3 parts with a total area of 7724.5 ha (Figure 1). The area of landscape park buffer zone (7450 ha) is connecting all parts of study area and protecting it from external threats resulting from human activities. The largest part of the landscape park includes the mountain Ślęża (718 m.a.s.l.) with Oleszeńskie Hills. In the foothills is situated the only one city within the landscape park - Sobótka. Jańska mountain is located to the east and Kiełczyńskie Hills are located to the southern-west from Ślęża mountain.

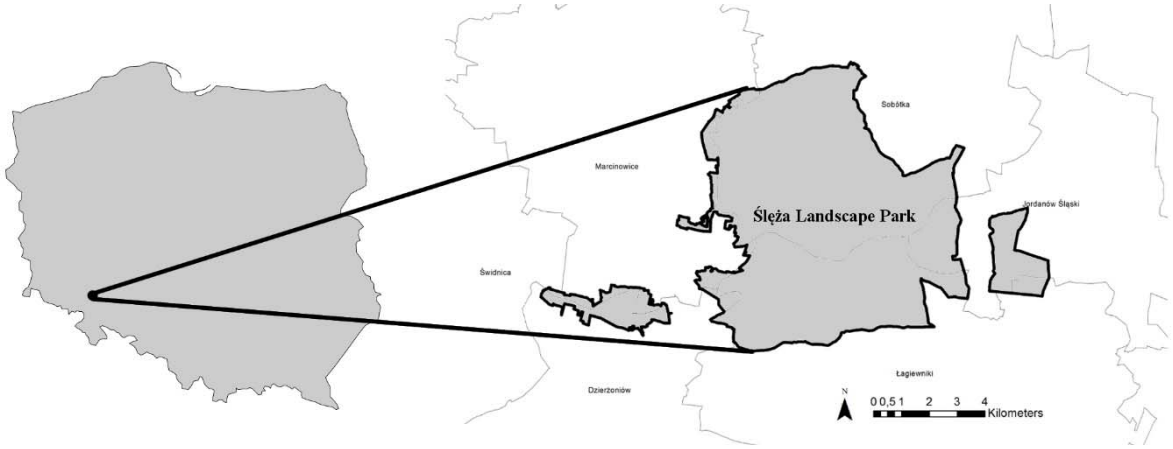

Figure 1. Location of study area

The study area has been protected since 8th of June 1988. The aim of protection is preserving the landscape of Ślęża mountain range, including the preservation of landscape character, scale of housing

in the historically developed settlements and undeveloped space in the open landscape of forest, fields and meadowland, as well as protection of diversified natural, geological and geomorphological values. The largest area within the park (62 %) is covered by forests located at more inclined slopes of Ślęża mountain and the surrounding hills. Low-lying, less steep and flat areas are covered by arable land or grassland. The largest area of built-up areas is located in the northern part of the landscape park within the limits of Sobótka city. Settlement system is formed by small villages evenly distributed among the agricultural land.

3. Materials and methods

Determination of the landscape change level in years 2004 – 2014 in each municipality within case study area is our main aim of the study. We analyse land cover change based on orthophoto maps from 2004, 2009 and 2014. With the use of land cover maps prepared in ArcGIS, we develop a database of the surface of the main landscape components in the research area. We use input data to assess the level of change in two different periods of time (2004 - 2009 and 2009 - 2014). We define landscape change index as the sum of the absolute values of the changes in the types of land cover, having the most significant impact upon the perception of the landscape, assuming both a decrease and an increase in the area of different types of land cover in the landscape. The essence of the method of relative data deviation in this case is to compare the values obtained by quantitative area analysis of each landscape component in the selected time period, with the value from analysis of previous time period called reference criterion. Deviation from the reference criterion gives information about changes of landscape components. A summary of all values allows to determine the landscape change index. The output data was used to answer the question which of the analysed periods featured the greatest changes in the landscape. Assessment methodology of the index consists of four stages:

1) The first phase includes creating land-cover maps in ArcGIS showing current and past landscape structure in 3 different time periods – 2004, 2009 and 2014. On the basis of the orthophoto maps and field inventory research area has been divided into 14 landscape components:

1) main roads;
2) secondary roads;
3) local roads;
4) residential area;
5) service area;
6) industry area;
7) sport and leisure area;
8) forest and forest succession area;
9) meadows and pastures;
10) arable land;
11) orchards;
12) allotment gardens;
13) water reservoir;
14) other not categorized areas (like cemeteries, bus stations etc.).

2) The second step is to create the database concerning the area of the elements of landscape structure for each analysed time interval. The maps created in the first step form the basis for the database.

3) The third phase consists of determining the level of percentage deviation between the reference criterion and data from next time interval, for each element of the landscape structure. The percentage for the reference criterion = 0, and the change from initial value by 1 %, with reference to whole area of research, is equal to the deviation of +1 or -1.

4) The last step consists of summing the absolute values of deviation level for all analysed components of the spatial structure in all time sections, under the assumption that both increase and decrease of value indicates landscape change. The result has been called landscape change index (LCI).

4. Results and discussion

In this research, we prepared three maps using ArcGIS software showing the structure of Ślęża Landscape Park in years 2004, 2009 and 2014. This is the period of 10 years after Poland has become a member of the European Union. We analyse the landscape change index in two 5-years long periods 2004 - 2009 and 2009 - 2014. Detailed information about the area of each landscape component shows table 1. The main component of the landscape is the area of forest and forest succession (65 %). This landscape type remained almost unchanged in the analysed periods of time. Other important elements of the landscape are arable land covering more than 20 % of the research area, meadows and pastures – 7 % and residential areas - 3.5%.

Table 1. Area of landscape components in Ślęża Landscape Park

Landscape component	Area in 2004 [ha]	Area in 2009 [ha]	Area in 2014 [ha]	Area in 2004 [%]	Area in 2004 [%]	Area in 2004 [%]	Landscape change in years 2004-2009	Landscape change in years 2009-2014
Main roads	12.16	12.16	12.16	0.16	0.16	0.16	0.00	0.00
Secondary roads	5.58	5.59	5.97	0.07	0.07	0.08	0.00	0.00
Local roads	6.4	7.23	16.05	0.08	0.09	0.21	0.01	0.11
Residential area	257.6	277.61	291.1	3.34	3.59	3.77	0.26	0.17
Service area	7.64	8.46	8.46	0.10	0.11	0.11	0.01	0.00
Industry area	7.26	7.31	7.62	0.09	0.09	0.10	0.00	0.00
Sport and leisure area	15.76	15.76	15.76	0.20	0.20	0.20	0.00	0.00
Forest and forest succession	4982.65	4985.31	4989.4	64.51	64.54	64.60	0.03	0.05
Meadows and pastures	579.23	558.74	485.77	7.50	7.23	6.29	-0.27	-0.94
Arable land	1783.72	1776.49	1823.32	23.09	23.00	23.61	-0.09	0.61
Orchards	45.56	48.9	47.04	0.59	0.63	0.61	0.04	-0.02
Allotment gardens	4.47	4.47	4.47	0.06	0.06	0.06	0.00	0.00
Water reservoir	10.58	10.58	11.49	0.14	0.14	0.15	0.00	0.01
Other not categorized areas	5.39	5.39	5.39	0.07	0.07	0.07	0.00	0.00
						LCI=	**0.71**	**1.91**

Next step was to determine the level of percentage deviation between the reference criterion and data from next time interval (e.g. for data from 2009 reference criterion are data from 2004), for each element of the landscape structure. This calculation of LCI assessed landscape change in the two 5-years long periods – 2004-2009 and 2009-2014. For the first analysed period indicator received a value of 0.71 and for the second the value of 1.91. This result allows us to assume that more intensive changes in the landscape in the Ślęza Landscape Park took place in years 2009 - 2014. During this period, we should seek the main causes of changes in the landscape. This was influenced mainly by reducing the area occupied by meadows and pastures, which are currently being re-used as arable land. Some of them have been designated for residential areas or forest. During this period, there was also a significant increase of the area of local roads.

Similar analyses were performed for the areas of individual municipalities within the Ślęża Landscape Park. It aims to determine in which part of the landscape park and in which municipality the changes were most significant. Values of landscape change index in individual municipalities of research area in the analysed periods of time are presented in Table 2.

Table 2. Landscape change index (LCI) for parts of municipalities located within Ślęża Landscape Park.

Municipality	Area of municipality within the Park [ha]	Landscape change index in years 2004-2009	Landscape change index in years 2009-2014
Dzierżoniów	325.25	0.08	0.20
Łagiewniki	2464.10	0.23	3.53
Marcinowice	393.20	0.38	1.96
Jordanów Śląski	719.24	0.16	2.75
Sobótka	3824.72	1.37	1.44

It needs to be highlighted that the highest rate of landscape change index in years 2004 - 2009 was recorded in the municipality of Sobótka, where most of residential areas were created. The highest rate of landscape change index in years 2009 - 2014 was calculated in the municipality of Łagiewniki because of the transformation of a large area of meadows and pastures to arable land. However, in the municipality of Dzierżoniów due to the high percentage of forests inside the landscape park and unchanging area of arable land, landscape change index in both periods of time had the lowest rate. The results of analysis for each municipality clearly shows that the period 2009 - 2014 was crucial for the transformation of the landscape in the last decade, and the reasons for these changes we should seek mainly in the municipalities of Łagiewniki and Jordanów Śląski.

The research results show that it is possible to describe the level of change in the landscape with a single, easy-to-use index. It is possible to use it in planning documents on local level, especially during the development of physiographic studies that indicate, among others, the best location for residential areas. On this basis, we can distinguish immutable landscapes of high value that should be protected from changes caused by e.g. the location of the new industry or residential area. Landscape change index may also complement the analysis of driving forces of landscape change [17, 18], indicating in which period of time we should seek for the main causes of change, the forces and actors that have caused them [19]. Knowledge of the level of the current transformation of the landscape is necessary in the decision-making process for the sustainable management and landscape planning at local level.

5. Conclusions

The presented case study identifies the level of landscape changes in the Ślęża Landscape Park in two 5-years periods of time - from 2004 to 2009 as well as 2009 and 2014. The results clearly show that in the second of the analysed periods the transformations were more intense. They were caused mainly by designation of new residential areas and the restoration of agricultural land in the area of meadows and pastures. The use of landscape change index is simple and does not require complex analysis and therefore has great potential as a tool in the planning phase of physiographic studies. However, despite these advantages landscape change index gives the general information only, in which period and in which areas the changes were more or less intense. It does not include information about changes in quality. Only further analysis to identify types and subtypes of changes could provide such data.

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