Land Use Changes Monitoring with CORINE Land Cover Data

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Abstract. The Corine Land Cover (CLC) data is a collection of information about land cover, which was created during the program that was implemented by the EU. In this article authors proposes new index of space fragmentation, which is based on the analysis of the length of the boundaries of the various forms of land use - Ex. This papers contains the procedure of designation the new index and two examples of its use for the two regions in the north – eastern part of Poland. These regions are characterized by a particularly high environmental values. Therefore, especially for these areas it is extremely important to study the fragmentation of landscapes as monitoring the increase of anthropopression. For visualization and spatial analysis authors used GIS technology.

1. Introduction
Changes in space use are an important part of the research into space and its development optimisation [1]. The increase of human pressure particularly affects places in close proximity to highly urbanised areas [2]. It is also present in less urbanised areas [3]. Changes in space uses are attributable to economic growth and the resultant increase in space value. Investors are in search of cost-effective locations for their projects. On the other hand, local authorities wishing to improve the economic situation of local government units are often open to such projects. Other reasons for changes in space uses are the change of the agricultural use of land or the process of land inheritance.

The changes mentioned here lead to space fragmentation and to the creation of a kind of chessboard pattern of use throughout entire regions [4]. This is particularly harmful to areas of high environmental quality. The fragmentation disturbs their stability and often causes a part of them to disappear.

Space fragmentation is a phenomenon studied by the scientific community, particularly by environmentalists and urban planners. There are numerous works available which refer to the problem of urban space fragmentation [5, 6, 7]. The studies described are of a local character and refer to the urban development of cities [8]. Another area in which the space fragmentation issue is a subject of extensive research is ecology. It is particularly landscape research for which the methodology has been developed to determine changes taking place in the landscape due to changes in the natural environment [9, 10, 11, 12].

Assuming that the fragmentation survey is a part of spatial structure research, it is worth mentioning the indicators that have been found relevant for landscape structure studies.
Table 1. Landscape structure change indicators, [13]

| No. | Indicator                        | Description                                                                                                                                 |
|-----|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Contagion/diversity              | Degree of aggregation of patch types (or the overall clumpiness of the landscape) and the diversity/evenness of patch types. Contagion and diversity are inversely related; clumped landscapes containing large, compact patches and an uneven distribution of area among patch types have high contagion and low diversity. |
| 2   | Large patch dominance           | Degree of landscape dominance by large patches.                                                                                           |
| 3   | Interspersion/juxtaposition      | Degree of intermixing of patch types.                                                                                                     |
| 4   | Edge contrast                    | Degree of contrast among patches, where the contrast is user-defined and represents the magnitude of difference between classes in one or more attributes. |
| 5   | Patch shape variability          | Variability in patch shape complexity, where the shape is defined by perimeter-area relationships.                                         |
| 6   | Proximity                        | Degree of isolation of patches from nearby patches of the same class.                                                                      |
| 7   | Nearest neighbour distance       | Proximity of patches to neighbours of the same class, based on the area-weighted average distance between the nearest neighbours.         |

The indicators mentioned are particularly useful in landscape structure studies (table 1). By mentioning them, the author leaves some freedom in formulating the ultimate shape of the indicators [1]. On the one hand, it makes it difficult to compare them, but on the other hand, it allows adjusting their ultimate form to the needs and objectives of the studies.

The indicators described are strongly related to ecology, and using them for space analysis typically requires specialist knowledge of the subjects of nature and ecology [15].

2 Sources of information on space use

The present development of spatial information provides vast opportunities for tracing the dynamics of space fragmentation [15]. There are extensive information resources available, making it possible to determine with various methods the changes taking place in space. One of these means is the Corine Land Cover database. It is a data set created in the framework of the Project CORINE Land Cover 2006 (CLC2006). It was a continuation of the CLC1990 and CLC2000 projects completed by the European Environment Agency (EEA), and its key objective was to further document the changes in land cover, and to collect and update comparable data in Europe [16].

Both CLC2000 and CLC2006, at the European level, were coordinated by the EEA, and the Inspectorate for Environmental Protection was responsible for performance at the national level [18]. Under the CLC2000 undertaking, a database of land cover forms in the territory of Poland in 2000 was created - the land cover map CLC2000, and a change database illustrating the dynamics of changes in land cover in Poland between 1990 and 2000 - map of land cover changes - CLC_Changes. The projects mentioned were created based on satellite images provided to Poland by the EEA. For the CLC1990 and CLC2000 projects the sources of information were satellite images made with the ETM scanner by the Landsat 7 satellite.

The CLC databases store only the surface data with a minimum area of 25 ha and at least 100 m in width. The land cover is mapped by means of the visual interpretation of satellite images. In the CLC 2006-2016 change base, the real changes with a minimum area of 5 ha and at least 100 in width, visible on images, are included [19].
3 Research methods
The method being described is based on the assumption that the greater the sum of lengths of usable area boundaries fragmented by the perimeter of the primary field and of the usable area boundaries, the higher is the space fragmentation level.
For the needs of this paper, the area fragmentation index was determined:

\[ E_{xi} = 1 - \frac{B_i}{B_i + \sum_{j=1}^{n} LB_{ij}} \]  

Where \( E_{xi} \) – area fragmentation index (expense) in an \( i^{th} \) primary field
\( B_i \) – length of the primary field boundaries
\( LB_{ij} \) length of the \( aj \) section of usable area boundaries according to CLC in an \( n \) number of sections located in an \( i^{th} \) primary field.

The \( E_{xi} \) index can take values from the range 0-1. If the primary field is used uniformly, then \( \sum LB_{ij} \) equals 0 and – according to the formula – the \( E_{xi} \) index will equal zero.

\[ \sum_{j=1}^{n} LB_{ij} = 0 \quad \Rightarrow \quad E_{xi} = 1 - \frac{B_i}{B_i} = 0 \]  

The more boundary sections of individual land use forms are found within the primary field, the greater the sum of their boundaries and, therefore, the \( E_{xi} \) index will be closer to value 1.

\[ \sum_{j=1}^{n} LB_{ij} \rightarrow \max \quad E_{xi} = 1 - \frac{B_i}{B_i + \sum_{j=1}^{n} LB_{ij}\max} \rightarrow 1 \]  

It is worth noting that \( E_{xi} \) is an index that takes into consideration the magnitude of the primary field selection for analysis. The length of the primary field boundaries, which is directly proportional to the surface area of those areas, when using geometric grids, is included in the formula. The percentage relation eliminates the direct influence of the primary field size on the index value.

Another advantage of the method is also that it includes the pattern of the boundaries. The more irregular it is, the less resistant to human pressure these are. In the formula proposed by the authors, the boundaries forming a kind of enclave will have longer runs and will negatively affect the ultimate index value.

The only risk lies in a random determination of the coordinates of the primary field corners. In the case of random coverage and failure to include the size of usage areas according to CLC, the analysis might deliver incorrect results. Should the primary field be too small, it’s \( E_{xi} \) index may equal zero, even though the area had been fragmented but it concerned an area greater than the basic field, and the coordinates of that field’s vertices were in the middle of the usage area according to CLC. The area of primary fields being too large is not appropriate either, since this might result in excessive generalisation of land use fragmentation.

The choice of the size of the primary field should therefore be done with expertise, based on a general description of the phenomenon being studied.

Conducting these studies would not be possible without the use of GIS technology. Complex and differentiated data structure in terms of CLC and on the other hand the developed data analysis procedure requires supporting tools of spatial analysis. The possibilities which creates GIS software in time with a set of tools for processing, analysing and presenting research results provide new opportunities for research structure of the area around us. In addition, the presentation of cartographic possible thanks to those instruments enhances the visualization of results, and thus a broader understanding of the processes occurring in the space [20].
4 Description of the study
The area of analysis covered two north-eastern provinces of Poland, namely Warmia-Mazury and Podlaskie. The provinces cover over 44 thousand km² of land altogether. Both are situated at the border of Poland, and both are distinguished by very high natural values. It was mainly that feature for which it was decided to analyse the specific area. There are over 3,000 lakes in Warmia-Mazury province, which is also called the land of a thousand lakes. Over 2,000 of them have an area above 1 ha. The great afforestation area of nearly 31% adds to the natural diversity of the region. There are eight landscape parks in the province [21].

Spreading out over 20 thousand square kilometres, Podlaskie province occupies a comparable area to that of Warmia-Mazury. It is also characterised by a high afforestation area of nearly 31%, as in the aforementioned province. The natural value is acknowledged by the presence of four national and three landscape parks in the province.

The demographic development is similar in both cases. Warmia-Mazury has over 1.4 million inhabitants, and Podlaskie over 1.2 million. The average population density is 60 people per km², and the urbanisation level is also similar and close to that of the country's average. For Warmia-Mazury province, it shows a slightly downward tendency, and as of 2013 it is a little above 59%. Similarly, for Podlaskie province, there is a slight increase apparent in urbanisation, and as of 2013 it was slightly above 60%.

For the needs of the analysis the area of study was divided into primary fields (number, area). Within the fields lines were marked corresponding to fragments of boundaries of investment areas identified in the CLC databases for 2006 and 2012.

All those factors affect the space usage. The fragmentation effect is an adverse condition in terms of preserving the natural values. Considering the fact that those provinces are characterised by a very low GDP level (about 72% GDP per inhabitant in relation to the country's average, being among the lowest figures), low fragmentation level, particularly in terms of dynamics, may be an indication of a halt in economic growth.

The space of both provinces was divided into squares with an area a 400 ha. As a result, 11461 primary fields were obtained, forming a grid of squares covering the spatial use map according to CLC for 2006 and 2012.

The perimeter of the primary fields sectioned the usage areas to fragments whose boundaries in individual squares were the sections $LB_{ij}$. Then, all sections of individual fields were summed and the fragmentation index $Ex$ was calculated for all of them, according to their formula. Further on, the fields were classified by dividing the results obtained. Analysing the distribution of values, their average and standard deviation, but also for the sake of clarity of results and ease of interpretation, it was decided to divide them into three classes in equal divisions.

The procedure was performed twice, for the counts presented in CLC databases for 2006 and for 2012. The indices obtained were compared to obtain a picture of the phenomenon dynamics. To this end, from the count calculated for 2006, the 2012 index was subtracted.

$$\Delta Ex_i = Ex_i^{2012} - Ex_i^{2006}$$  \hspace{1cm} (4)

Negative values proved no fragmentation to have occurred and, on the contrary, the areas with uniform usage were found to have been increasing. The positive difference of the indices showed the area fragmentation to have been progressing.

5. Discussion of the results
For the purpose of analysis result presentation, maps of $Ex$ index values were drawn respectively for 2006 and 2012, according to the data present in the CLC databases and methods described (figure 1, figure2). A/an 27-degree division of land cover detail level was assumed in the research, including the following areas: anthropogenic land, agricultural land, forests and semi-natural ecosystems, wetlands and water areas.
Figure 1. Maps of $Ex$ index values for 2006

Figure 2. Maps of $Ex$ index values for 2012
Another step was to present on a map (figure 3) and distribution graphs (figure 4) of the differences in Ex fragmentation factor calculated for all primary fields. The difference shows the changes in fragmentation of individual land use functions to have taken place between 2006 and 2012.
6. Conclusions

Land fragmentation is a phenomenon which, when analysed in various time frames, can show dynamics of changes in land usage. In terms of landscape, which is the most common context for analysis, an increase of fragmentation is usually desirable as it proves the diversity and an increase in biodiversity. However, if this concerns only the areas with high levels of human pressure, then, in terms of nature, it usually means the reduction of natural environment resistance to human activity. In economic terms, the index being low usually means a slowing down in economic growth, since no forms of space development emerge.

In the area studied, the $Ex$ index showed no great dynamics minimum difference $Ex$ is -0.7535, maximum difference $Ex$ is 0.7351, average difference $Ex$ is 0.0026, std. deviation is 0.0580). Due to the character of the space of very high natural values, this is a desirable effect, as it is indicative of the natural stability of the area. In the area studied, several fragments can be distinguished in which the index was above the average. In the areas concerned, the changes should be monitored in detail, so as to avoid degradation of the natural environment. However, it should be stressed that the changes are specific particularly for the areas located in the vicinity of urban spaces and are symptomatic for increasing human activity.

In economic terms, it is worth noting that low variability of area fragmentation usually involves low economic growth. The analysis performed has proven that. As already mentioned, the $Ex$ index in the area in question was subject to slight changes, which is apparent in the still low economic growth observed for years in the area.

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