Main directions of landscape changes in Poland in the years 1995-2009

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Abstract: Based on analysis of relative changes in the share of forest, arable land, grassland and including population changes in the years 1995-2009, this paper presents typological classification of municipalities based on key processes shaping the spatial structure of landscape. Six key municipality types have been defined. Municipalities representing each type are not equally distributed around the country, but grouped in clusters of regional nature. The analysis indicates significant differences between eastern and western regions of Poland, where differences in dominant processes and frequency of each type of municipality may only partially reduce the differences in the spatial structure of landscape in both parts of the country. Further, the paper discusses ecological and landscape related effects of changes observed in the years 1995-2009 with special focus on impact on the biodiversity on various levels of biosphere.

Key words: afforestation, biodiversity, land cover, landscape spatial structure, typology

Introduction

Recently, a definition of landscape as a space-and-time unit including various hierarchic, interrelated systems, has prevailed. Usually, three systems are identified: (a) anthropogenic system including landscape forms identified, grouped and analyzed as objects of importance for human life; (b) abiotic system regarding objects and their spatial relations, as well as functioning of elements and components identified based on their abiotic characteristics; (c) biological system organized around selected groups of organisms (populations, species, biocenoses) and entire ecosystems (Solon 2002; Richling, Solon 2011). Also, land cover (determining both anthropogenic and biotic systems in place) is among frequently analyzed landscape elements. Compared to biotic and abiotic elements, the land cover changes relatively fast, distribution of these changes in time being irregular. Periods of relatively high stability are separated with short series of fast and intense changes, which often result in modification of the key practical function of the landscape as a whole (Solon 1999, 2000, 2009).

Changes in the land cover result from a number of various interrelated factors, the key including: (a) the presence of initiators and attractors (Antrop 1993), such as new roads or national parks, which start new directions of development in an area; (b) changes in profitability of agriculture, which may result in agricultural intensification or land abandonment, that may slow down the process either of urbanization or depopulation in the countryside (Van Eetvelde and Antrop 2004) - both under the influence of habitat quality (Solon 2007); (c) the legislative and administrative decisions concerning environmental protection and landscape planning; and (d) the individual, independent and hardly predictable decisions of people who maintain small pieces of land (Antrop 2000). These partly independent reasons result in a sequential model of changes, which may be defined both in statistical and spatial terms.

The purpose of this paper is to present changes in the share of key land cover types that occurred in the years 1995-2009.
1995-2000 and to interpret these changes in terms of composition and functioning of the landscape both on the regional and local level.

**Input data and analytical approach**

Input data used in the analysis come from publicly available Local Data Bank (www.stat.gov.pl). They include area (expressed in hectares) in individual municipalities occupied in each year by: (a) forest in any ownership form; (b) arable land; and (c) grassland. The analysis covers the years 1995-2009, although for forests, only the period from 2000 to 2009, due to absence of comparative data. The analysis does not include information regarding area occupied by buildings since relevant data have not been available, either. This gap has been filled with population numbers for the years 1995 and 2009, used as a surrogate indicator. Please note that the data regarding areas used are charged with a systemic error resulting from changes in data collecting methods. Information regarding the period 1995-2005 comes from the land register, while data for the years 2002-2009 have been collected by Instytut Geodezji i Kartografii (Institute of Geodesy and Cartography) and transferred to the Main Statistical Office. Despite differences in absolute values of figures derived from various sources, they can be composed since they refer to the same trends in changes (fig. 1).

Changes in the share of various land cover types (and population) in municipalities in 1995-2009 have been expressed in relative numbers as percentage of the area occupied in 1995, in accordance with the following formula:

\[
\text{Change} = \left\{ \frac{\text{Figure}_{2009} - \text{Figure}_{1995}}{\text{Figure}_{1995}} \right\} \times 100\%
\]

The calculated change values have been presented as cartograms.

The adopted method of presentation is infrequently used in professional publications. Presentation of changes in absolute numbers or as a percentage of the total reference area (e.g. a municipality) is more popular. Importantly, though, the adopted approach indicates directions of recent processes and their role in landscape composition changes.
Results

Changes in afforestation

Forests are unequally distributed around the country. According to 2009 data, in over 790 municipalities (mainly urban areas) afforestation does not exceed 10%, in other 720 is up to 20%, while as many as 565 municipalities have the afforestation indicator of more than 40% (in 52 municipalities it has exceeded 70%).

In the years 2000-2009 a decrease in afforestation by at least 1 hectare was seen in 526 municipalities (in total over 54000 ha), out of which 84 municipalities witnessed a drop in excess of 100 ha (totaling to over 43000 ha) and other 63 ones lost 50 to 100 ha of forest (in total exceeding 4400 ha). In the same period, 2398 municipalities increased their afforestation by at least 1 ha (the total growth exceeded 350000 ha). Please note that as many as 109 municipalities saw an increase in excess of 500 ha (totaling to over 125000 ha) and in 788 afforestation growth ranged from 100 to 500 ha (in total, approximately 169000 ha).

In the years 2000-2009, afforestation dropped by at least 5% in 134 municipalities, out of which 23 (urban areas only) saw disappearance of more than half of the area occupied by forest in 2000. Increases in afforestation were more significant. In as many as 117 municipalities the forest-occupied area grew by at least one-fifth, with 17 witnessing over twofold increase.

Municipalities that observed a significant curtailing of the forest-occupied space are relatively evenly distributed around the country and include chiefly urban and suburban areas (fig. 2). There is only a slight difference between north-western Poland, characterized with smaller deforestation, and the southern Poland (in particular, Śląskie and Małopolskie Provinces) where concentration of deforested municipalities is high.

Municipalities with a small afforestation increase dominate in most provinces except from Śląskie and Małopolskie. The relative afforestation increase is more significant in a number of municipalities located in central Poland and on the lower Wisla river.

Fig. 2. Relative afforestation changes in municipalities in the years 2000-2009
In the years 1995-2009, the share of arable land decreased by at least 100 ha in 1132 municipalities, totaling to nearly 0.6 million ha. In other 197 municipalities a drop in the share of arable land ranged from 50 to 99 ha totaling to 14473 ha. In 453 municipalities, the share of arable land increased by at least 100 ha, totaling to 177200 ha growth. In other 126 municipalities a growth in the share of arable land ranged from 50 to 99 ha totaling to 9285 ha. The total balance shows a drop in the share of arable land of nearly 0.43 million ha on the national level.

The largest relative decreases in the share of arable land (compared to 1995) occurred in Małopolskie, Świętokrzyskie, Mazowieckie Provinces and the western part of Podlaskie Province. Municipalities with the highest relative increase in the share of arable land are grouped in Opolskie, Dolnośląskie Provinces (fig. 3).

In the years 1995-2009, the share of grassland decreased by at least 100 ha in 636 municipalities, totaling to over 0.2 million ha. In other 222 municipalities a drop in the share of grassland ranged from 50 to 99 ha totaling to 16351 ha. In 553 municipalities, the share of grassland increased by at least 100 ha, exceeding the total of 245000 ha. In other 183 municipalities an increase in the share of grassland ranged from 50 to 99 ha totaling to 13258 ha. The total balance shows an increase in the share of grassland of nearly 15000 ha on the national level.

The largest relative increases in the share of grassland (compared to 1995) occurred in Małopolskie, Świętokrzyskie, Łódzkie, Mazowieckie Provinces and the western part of Podlaskie Province. Municipalities with the highest relative decrease in the share of grassland are grouped in western Poland (fig. 4).

Fig. 3. Relative changes in the share of arable land in municipalities in the years 1995-2009
Population changes: urbanization and suburbanization

In the years 1995-2009, population decreased by at least 100 people (totaling to –1.8 million) in 1755 municipalities. Out of this number, 377 municipalities saw a drop ranging from 1000 to 10000 people, with 15 towns/cities losing more than 10 thousand inhabitants.

In the same period, population increased in 945 municipalities by at least 100 people (totaling to approx. 1.3 million), with 319 municipalities growing by 1000 to 10000 people and seven towns/cities where the increase exceeded 10000.

In relative terms, the most significant drop in population, exceeding 15% of the numbers from 1995, took place in 91 municipalities, with 26 located in the eastern part of Podlaskie Province and the other being fairly evenly distributed in central and southern Poland (fig. 5).

Municipalities with population decline of 5-15% (totaling to 1009 ones) are concentrated in Lubelskie, Podlaskie, Mazowieckie, Świętokrzyskie and Łódzkie Provinces, as well as in the northern part of Warmińsko-Mazurskie Province and the southern part of Opolskie and Dolnośląskie Provinces.

Location of municipalities that saw a relative increase in population is quite different. In 351 municipalities, population grew by 5 to 15% compared to 1995. In 152 municipalities, the increase ranged from 15 to 50%, with 27 municipalities witnessing an increase in excess of 50%. Municipalities with significant increases in population epitomize fast development of suburban areas and urban sprawl. They surround all province capitals and other large cities, as well as a significant number of towns. Only in Pomorskie and (to a lower extent) Małopolskie Provinces most municipalities saw an increase in population regardless of their distance from large urban agglomerations.
Based on the identified land cover and population changes, Polish municipalities may be divided into several types depending on domination of specific processes and their effects on natural environment (fig. 6). Type A is characterized by present and projected decline in the share of arable land accompanied with an increase in the share of grassland. It has two sub-types: A1 with a more than 10% drop in the share of arable land compared to the initial level, accompanied by at least 10% increase in the share of grassland compared to 1995. A1 municipalities are located only in certain regions of Poland, mainly in Małopolskie and Świętokrzyskie Provinces, in northern parts of Mazowieckie Province and the western part of Podlaskie Province, and minor clusters representing this sub-type distributed in Podkarpackie, Lubelskie, Łódzkie Provinces and the central part of Mazowieckie Province. Only single municipalities of the sub-type occur in the remaining parts of Poland. Importantly, most of A1 municipalities in Małopolskie Province saw an increase in population ranging from 5% to 15% compared to 1995. The remaining municipalities included in the sub-type suffered significant depopulation. A2 is similar to the previous sub-type, with smaller changes in the land cover. Its decline in the share of arable land ranges from 5% to 10% of the initial share, and is accompanied with an increase in the share of grassland within the same range compared to 1995. This sub-type is concentrated mainly in Łódzkie Province, in the eastern part of Mazowieckie Province and in the north-western part of Podlaskie Province. Type B is characterized with a decrease in the share of grassland accompanied with an increase in the share of arable land. It has two sub-types: B1 with a more than 10% drop in the share of grassland compared to the initial level, accompanied by 10% or higher increase in the share of arable land compared to 1995. A1 municipalities are located in two regions: the first includes Opolskie and Dolnośląskie Provinces and the second, the eastern part of Pomorskie Province and certain parts of Warmińsko-Mazurskie Province. Minor clusters of municipalities included in the sub-type can be present in the remaining parts of Poland. Importantl, most of A1 municipalities in Małopolskie Province saw an increase in population ranging from 5% to 15% compared to 1995. The remaining municipalities included in the sub-type suffered significant depopulation.

**Land cover changes typology**

Fig. 5. Relative population changes in municipalities in the years 1995-2009
found in north-western part of Lubelskie Province.

B2 is similar to the previous sub-type, with smaller changes in the land cover. Its decline in the share of grassland ranges from 5% to 10% of the initial share, and is accompanied with an increase in the share of arable land within the same range compared to 1995. Distribution of the sub-type is very similar to the distribution of B1 municipalities.

Please note that nearly all type B municipalities (except from a few located in Pomorskie Province) are characterized with depopulation or flat number of inhabitants.

Type C includes municipalities dominated by afforestation. It has two sub-types:

C1 includes municipalities where at the same time the share of grassland and arable land decreased by at least 10% compared to 1995. This process was accompanied by increased afforestation, although in a number of municipalities the increase was insignificant. Importantly, the sub-type includes municipalities characterized by various changes in population; in many of them, increased afforestation is accompanied with a growth in population and urban areas. Single C1 municipalities occur in many provinces, with the highest concentration in Mazowieckie Province.

C2 includes mainly municipalities where increased afforestation (with few exceptions) is accompanied with a reduction in the share of agricultural areas, most frequently both arable land and grassland, with varying proportion of changes in the share of each, but never exceeding 10% of arable land and 10% of grassland. The increased afforestation is accompanied with depopulation. The highest number of C2 municipalities occurs in Lubelskie, Podlaskie and Warmińsko-Mazurskie Provinces with smaller representation in Zachodniopomorskie, Lubuskie and Dolnośląskie Provinces.

Type D is characterized with changes in the share of agricultural used of land with insignificant modification of its general share. It includes a small number of municipalities, where the share of arable land or grassland increased by at least 10% compared to the initial status in the years 1995-2009. At the same time, no arable
land is replaced with grassland (as in type A) or the other way around (as in type B).

Type E includes municipalities that do not meet the land cover change criteria that characterize the former types, with the population growth of 5% in the years 1995-2009 compared to 1995. They surround all province capitals and other large cities, as well as a significant number of towns and are related to development of suburbs. Please note that the group includes a significant number of municipalities in Pomorskie Province, where they occupy a strip of land from the Tricity to the southern province border.

Type F includes other municipalities, where changes in the land cover and population in the years 1995-2009 were insignificant, up to 5% compared to 1995. This type municipalities occupy a strip of land reaching from Kujawsko-Pomorskie Province, across Wielkopolskie Province, down to Lubuskie Province and (to a less extent) to Zachodniopomorskie Province. This type is seldom represented in the remaining regions.

**Ecological and landscape-related effects of changes in the land cover: discussion**

The detailed analysis of collected data indicates that over the last ten-fifteen years, there were two different scenarios of change in the structure of agricultural use of land: under the first one, arable land was replaced with grassland; in some regions it marked a drop in agricultural business, in other, development of milk cattle production. Under the second one, crop production was developed and intensified. These scenarios fairly well correspond to the varying spatial structure and efficiency of agricultural production, professional activity of rural population, structure and economic status of farms. Thus, the rural landscape of Poland is clearly divided into two different models, which in broad terms may be defined as north-western and south-eastern ones.

Changes in the agricultural use of land result in further modification of the spatial landscape structure, involving defragmentation and biological unification in the case of intensified agricultural production and progressing renaturalization in the case of growing share of grassland or extensive agricultural production.

An increase in afforestation and changes occurring in the growing and use of forest have resulted in significant changes in the structure of species, both in terms of trees and undergrowth. Observed processes include among others a decrease in biodiversity of the undergrowth for most forest types (Matuszkiewicz 2007) and changes in the geographical ranges of many forest types, including their extinction on the regional or national level. This results in, at least partial, spatial and typological unification of Polish forests, which may cause further decrease in biodiversity, both on the level of species and ecosystems.

The growing population results in an increased share of area occupied by buildings, mainly in the suburban zone. Therefore, the traditional border separating urban from rural areas is disappearing. The urban sprawl causes, at least initial, increase in diversity of species and ecosystems in the landscape, with those considered rare and endangered becoming extinct. At the same time, growing population in municipalities located far away from urban centers proves the existence of new, distributed housing development in so-called attractor regions that include places attractive for tourists (protected areas with their buffer zones, lake shores, forest buffers) and traffic concentration spots (crossings and speedway connections). This results, among others, in strong synanthropization of landscape and decreasing share of natural and semi-natural ecosystems in regions where previously no strong pressure occurred.

Changes in the share and distribution of various land cover types bring far-reaching consequences in the form of modifications in the general spatial landscape structure. Research covering the period of last 40-50 years (Solon 2007, 2009) indicates that differences between small spatial units within regions of little abiotic diversity tend to be eliminated. Reduction of these differences relates to the share of each land cover form, balanced biodiversity indicators and unification of the human pressure level. At the same time, differences between municipalities representing various natural and economic potential tend to grow.

Effects include among others contrasting spatial structure (different directions of changes in land cover diversity, increasing domination of determined land cover types) and clear development divergence, which results in establishing of separate regions with domination of specific processes. Identical conclusions have been drawn from analysis of spatial distribution of municipalities characterized by various types of land cover changes in the years 1995-2009 (see Fig. 6).
In light of most frequent processes that accompany land cover changes, modified forestry and agricultural practices, as well as data included in professional publications (see among others Solon 1999, 2000, 2009; Matuszkiewicz 2007; Krysiak 2008) key directions of changes in biological and landscape diversity that have occurred in recent years may be indicated with high probability (tab. 1).

Table 1. Key directions in changes in diversity of species and landscape in clusters of municipalities divided by directions in land cover changes

<table>
<thead>
<tr>
<th>Types</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
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<tbody>
<tr>
<td>Diversity of species</td>
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<tr>
<td>species occurring in woods and thickets</td>
<td>+</td>
<td>+</td>
<td>-/0/+</td>
<td>0</td>
<td>-/0</td>
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<tr>
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<td>0</td>
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<td>segetal species</td>
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<tr>
<td>ruderal species</td>
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<tr>
<td>Priority species</td>
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<tr>
<td>listed in Habitats Directive, protected and endangered</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>non-native species, including expansive ones</td>
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<tr>
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<td>ruderal</td>
<td>+/(a) -/(b)</td>
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<td>0/+</td>
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<tr>
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<td>-</td>
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<td>-</td>
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<td>0</td>
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</tbody>
</table>

Comments:
+ growth (a) S Poland
- reduction (b) N Poland
0 no significant changes

Closing comments

Analysis of landscape changes in terms of land cover is a popular approach, both in analysis of long periods, with the basic materials of maps coming from various years (e.g. Pit 2009, 2010) and for the recent decades (e.g. Łowicki 2008a, 200b). Often, administrative units are used as base fields since they allow the use of available statistical data. Such an approach, applied herein, having a number of well-known shortcomings, has certain advantages as well, since it provides the average image, indicating key trends in changes resulting from human activities regardless of local habitat conditions.

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