POLISH ASSOCIATION FOR SPATIAL INFORMATION
ANNALS OF GEOMATICS 2008 ❍ VOLUME VI ❍ NUMBER 1

DIVERSITY OF SPATIAL ORGANISATION IN EUROPE BASED ON LAND COVER AND LAND USE

ZRÓŻNICOWANIE ZAGOSPODAROWANIA PRZESTRZENNEGO W EUROPIE NA PODSTAWIE POKRYCIA I UŻYTKOWANIA TERENU

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Keywords: spatial organisation, land cover, land use, land cover changes, CORINE Land Cover
Słowa kluczowe: zagospodarowanie przestrzenne, pokrycie terenu, użytkowanie ziemi, zmiany pokrycia terenu, CORINE Land Cover

Introduction

Spatial organisation refers to the arrangement of natural and artificial objects on the Earth's surface. Most of the problems, approaches, as well as the process of thinking in the geo-information sciences are connected with spatial organisation, namely location, distance, direction, density, arrangement and diversification. However, the basic theme and the object of study is the recognition and understanding the spatial pattern of geographical features and the way in which it has changed. The main data sources used in such studies are land cover and land use databases, accompanied by statistical data. Changes in spatial organisation are driven by changes in land use and land cover, which have a positive or negative impact on the ability of environment to support human needs.

An understanding of the implications of change in land cover and land use is a fundamental part of planning for sustainable spatial organisation and development. Transformation of land cover/use by human activity can affect the integrity of the natural resource system and the output of ecosystem goods and services. Careful planning of the spatial organisation of new patterns of land cover and use can enhance the well-being of people (Millennium Ecosystem Assessment, 2005).

This article presents the source databases for storing information on land cover/use and land cover change and shows some examples how land cover change reflects the differences in spatial organisation within Europe, as well as the impact of policy against particular land cover types e.g. arable lands, forests, artificial surfaces.

Source data

Information concerning land cover and land use is recognized by decision-makers as crucial for spatial analysis at different territorial levels. Within the European Commission Services, as well as different European organisations, is a growing need to use spatial analysis for integrated environmental assessment, mainly assessing the impact of policy against regional development, planning, and agriculture. That is why, in the middle 80s of the 20th century, the European Commission implemented the CORINE Program. The main goal of that program was to establish an information system on the state of the European environment including, among others, information on land cover and land use (Heymann et al., 1994). As the diversity of land cover and land use reflects differentiation in spatial organisation, these data are of utmost importance for monitoring spatial organisation in Europe, especially in the geographical context.

The CORINE Land Cover (CLC) is a globally unique, independent inventory, built on a single European classification of land cover types, which makes it an invaluable tool for Europe-wide assessments and for comparisons between countries, regions and other zones of interest. The first CORINE Land Cover database was finalised in the early 1990s. Since then, information on land cover and land use in Europe was updated twice, in the years 2000, and 2006. Since 2006, land cover monitoring is included as a part of the Global Monitoring for Environment and Security (GMES) programme. The source data for retrieving information on land cover were satellite images. For the first inventory Landsat 5 TM images were used, for the second, Landsat 7 ETM+, and for the third, SPOT 4 HRVIR, SPOT 5 HRS, IRS P6 LISS and AWIFS images (Butner, Kosztra, 2007).

The land cover classes distinguished in the CORINE Land Cover program are organized hierarchically on three levels. The first level embraces the five main types of coverage of the Earth's surface: artificial surfaces, agricultural areas, forests / semi-natural areas, wetlands, and water. On the second level, these types are further refined into 15 classes of land cover, which can be portrayed in maps at scales of 1:500 000 to 1:1 000 000. The third level, in turn, distinguishes a total of 44 classes. This level of classification detail has been employed in developing land cover databases in all the countries of Europe. CLC databases store only polygon data, with a minimum area of 25 ha and width of at least 100 m (Bossard et al., 2000; Feranec et al., 2006). However, in the CLC2006 inventory some novelties were introduced. To meet the ever growing demands of CORINE Land Cover data users, it was decided that the inventory of changes in land use and land cover will be carried out in greater detail than in the year 2000. Hence, the minimal mapping unit for land cover change detection was 5 ha, regardless of whether a change polygon is adjacent to an already existing polygon or not, and creates so-called isolated change[1] .

CLC databases have some limitations, related mainly to the methodology used. Land cover types distinguished during CLC inventory are recognised in satellite imagery on the basis of their physiognomy, especially shape, colour, texture and pattern. The smallest mapped and classified unit in CLC is 25 ha. Thus, more or less all CLC classes monitored from satellite imagery, may include significant heterogeneous micro-areas of less than 25 hectares. The CLC, therefore, cannot deliver a very accurate assessment of surfaces, for example as needed for agriculture statistics used for calculating crops and related subsidies. As a result

[1]In the CLC2000 the isolated change was mapped when its area was greater than 25 ha.

of the 25-ha limitation, the CORINE classification also includes mixed classes ('discontinuous urban fabric' and 'land principally occupied by agriculture with significant areas of natural vegetation'). These classes have a high interest from an ecological perspective (Heymann et al., 1994). CLC land units will disappear or come out when they come just below or just above the 25-ha threshold. This is consistent with monitoring landscape systems.

The strength of the CLC is in its use with other spatial environmental databases, as well as with statistical data on the European, regional and national levels. The method of analysing patterns of spatial organisation, expressed in the arrangement of activity on the earth's surface, is called spatial analysis. In general the method of spatial analysis follows three steps. First, a description of what is where; what the pattern of spatial organisation looks like, is made. Next, in the second step, we explain why the activities are arranged in such a pattern. And finally, spatial modelling is performed to explain how that pattern developed over time, what process led to it and how the pattern might look like in the future.

The article presents selected examples of the pattern of spatial organisation in Poland against the European background, and gives some explanations why the activities are arranged in such a pattern. It is mainly based on the research work carried out by author as well as on the EEA reports.

Land cover changes in Europe

Information on land cover, and land cover change, is important both in terms of the total amount or change in types of cover, and the precise locations where these changes occur. It reflects spatial organisation evolving over place and time. In Europe, as in Poland, land cover is dominated by agricultural areas, arable lands, pasture and meadows, complex cultivation patterns, which comprise 55% of Europe and 65% of Poland (Fig. 1). Forest and semi-natural areas cover about 34% of Europe, and 30% of Polish territory. Artificial areas in Europe occupy nearly 5% and in Poland a little above 3%. The remaining 5% of European territory and 3 % of Poland is classified as wetlands, water or open space (Ciołkosz, Bielecka, 2005; EEA, 2005).

Analysing the changes in land cover between 1990 and 2000 in Europe, one can observe increases in urban and other artificial land, increases in forested area, and a decrease in agricultural and natural areas. However, in Poland the dominant changes occurred within forest and agriculture areas (Tab. 1).

Table 1. Types of land cover changes in 1990–2000 in Poland

Main types of land cover changes in Poland		
Changed area (ha)	Land cover 1990	Land cover 2000
70 076	Coniferous forest	Transitional woodland shrub
31 538	Transitional woodland shrub	Coniferous forest
20 621	Pastures	Arable land
12 867	Arable land	Pastures
12 399	Transitional woodland shrub	Mixed forest

Source: Ciołkosz, Bielecka, 2005.

In the following sections, the three major processes of change in land cover and in spatial organisation are analysed in more detail, both at the European level and for Poland. The three major processes are:
- spread of urban and other artificial land,
- decreases in the agricultural area, resulting from a range of changes in use,
- increases in the area of forest and decreases in the area of natural land.

Urban sprawl and other artificial land development

Change in artificial land area is a good indicator of urban sprawl, which is mostly an irreversible one-way process. According to the EEA investigations (EEA, 2006b), urban sprawl was a key process in Europe in the 1990s, driven by economic growth and increasing consumption, suburbanisation and the implementation of the internal market, and including transport infrastructure. This sprawl is partly at the expense of arable and natural land. In addition to demographic trends in rural areas, which in many places took the form of depopulation, changes in agriculture and forestry can be ascribed mainly to the extension of the Common Agricultural Policy, combined in some countries with rapid economic growth fostered by their accession to the EU and access to the internal market. Figure 2 clearly shows that in the 1990-2000 period, urban and infrastructure development in eastern Germany was much intensive than in Poland. The explanation of this fact has a historical background: Eastern Germany has benefited from large monetary transfers from western Germany since 1990, making it one of the fastest changing regions in Europe. Further east, in Poland, where EU membership is more recent, there has been less change during 1990–2000 so the contrast with Germany is still highlighted (EEA, 2005).

The green background index presented in the map shows a percentage of pastures, mosaic agriculture, forests, semi-natural land, wetlands and water bodies in 10 km grid.

Decreases in the agricultural area

Agriculture is the most dominant land use type in Europe and also in Poland, covering twice as much land as forestry and more than 10 times as much as urban areas. European agriculture comprises a diverse mosaic of farming systems. The second half of the 20th century saw the transformation of many areas of traditional rural landscape into modernised, more intensive agriculture. The main trend in Europe was aimed at a conversion of arable land and permanent crops to pasture, set-aside and fallow land (EEA, 2006a). The European Environmental Report of 2005 (EEA, 2005) states that there are three major aspects to consider: the conversion of agricultural land to urban sprawl, described above; conversion and rotation from pasture to arable land and vice versa within agriculture areas; withdrawal of farming with or without forest creation and conversion of forested and natural land to agriculture land.

Long-term conversion between pasture and arable land is often linked to a switch between intensive arable agriculture and extensive livestock grazing. At the European level, conversion of forest and natural land to agriculture is balanced by withdrawal of farming with or without woodland creation. In most countries, including Poland, the agricultural area has decreased at the expense of cropland or pasture/mosaic land. Withdrawal of farming varies between countries, with high turnovers observed in Italy, Hungary, Poland and Slovakia, where withdrawal of farming is the main component; in Spain, where conversion to arable land are the main change; and in Portugal, where both processes take place (Fig. 3). In Poland, withdrawal of farming is mainly connected with the process of urbanisation and forestation (Ciołkosz, Bielecka, 2005).

Increases in the forest areas and decreases in the area of natural land

The total forested area of Europe has increased by 0.5 % in 10 years, and 0,2% in Poland. During that decade, however, the forest territory has experienced significant rotations, up to 8 %, mainly as a result of felling and replanting. Out of 1 million ha of new-forested land, a quarter is the result of the withdrawal of farming (EEA, 2006b). Afforestation of farmland is often an alternative source of income for farmers in regions where agriculture faces difficulties and has been subsidised by the CAP. Afforestation of previously agricultural and natural land is a significant factor of development in some countries, for example in Ireland, the Netherlands, Spain, and the United Kingdom. The deforested areas were on average small in size, but it should be noticed these changes have an impact on the regional ecosystem in some cases.

Diversification of land cover

Analysis of land cover diversification, reflecting spatial organisation differences, becomes a basis for macroeconomic and environmental research. As with land cover much depends on the relief, lithology and water conditions, its diversity might be compared also with the landscape variability. In research into geographical environmental variety, a complex of indices is used, however only a few are considered to be crucial. These are: number of classes, number of patches, patch density, edge density, Shannon diversity index and interspersion and juxtaposition index (Eden et al., 2000).

The analysis of land cover diversification in Poland was based on three of them: number of patches (*NP)*, Shannon entropy (*SHDI)* and interspersion and juxtaposition (*IJI).* The analysis began from the classification of values of particular indices, which further on are turned into an analysis of anomalies to normalize the indices. Such a concept led to creation of the Complex Land Cover Diversity Index and the values range, which were typical for the Polish landscape. This index is a sum of the metrics anomalies, multiplied by parameters determined by the dispersion level of the chosen metrics (Bielecka et al., 2007, Luc et al., 2008).

Standard deviation analysis of the obtained values presents the highest significance of the *NP* metric, then *SHDI* and the lowest of *IJI* metrics. Among the anomalies of the NP and anomaly values of their entropy, the directly proportional dependencies are stated. This means that dispersion increases along with the increase of the number of patches. Between the anomalies of the previous two metrics and anomalies of the juxtaposition index, the inversely dependencies are noticed. An increase of the arrangement between the separated land cover units and the decrease of the patch number and dispersion are related (Bielecka et al., 2007). Finally values of the Complex Land Cover Diversity Index were grouped in five classes, one (in light yellow) shows land where diversification of land cover is normal, two classes in red show places where land cover diversification is much above normal, and two in green – much below normal. An analysis of the land cover and spatial organisation diversity in Poland (Fig. 4) shows that southwest part of Poland is much more diversified then the north.

Moreover, there are observed bigger clusters of land of higher or lower than typical level of diversity in central and southern part of Poland than in the northern part. Anthropopressure in urbanised areas of big agglomerations influenced high diversity of land cover and spatial organisation. Also, the Complex Land Cover Diversity Index is much more above normal in the agricultural parts of areas of upland, low mountains and Carpathian Foothills, while a lower level of spatial organisation diversity is observed on lowlands, especially in the region of Great Poland. The research conducted by Węcławowicz et al. (2006) proved that the diversity of spatial organisation has both historical and geographical background. It is influenced by basic components of environmental space relief, soil cover, water and vegetation, economy and policy, especially social activity and some historical events, such as Partitions of Poland.

Summary and conclusions

Over the past decade, tensions over the use of land in Europe were analysed and it was observed that the European environment is deteriorated by urbanisation, transport growth, shifts in agricultural priorities, new forms of tourism, evolving societal aspirations around mobility and housing, and demography.

The CORINE Land Cover is a key set of databases (CLC90, CLC2000, CLC2006 and CLC Changes 1990-2000 and 2000-2006) for European integrated environmental assessment and a better understanding of our environment at any level. The CLC data gives an insight into the overall European spatial organisation, and shows that over half of Europe's land cover is agriculture, while about one third consists of forests and semi-natural areas. The land account shows that urban sprawl appears to be the main type of change. Urban areas have expanded largely at the expense of agriculture area. Loss of agricultural lands results also in the process of afforestation.

A minimal mapping unit of 25 ha considerably limits the exploitation of the CORINE Land Cover databases for regional and local analysis of spatial organization. Also, mapping only land cover changes greater than 5 ha does not reflect the majority of changes. In Poland, a substantial majority of change in land cover occupied less than 2 ha (Adamski, Ciołkosz, 2006). Another bottleneck in usage of the CLC data is the limitation in width of linear features, more than 100 m, caused by a lack of linear investments (like roads, railways, channels).

Because of the historical, political, economic and social background, diversity of spatial organization in Poland differs from other European countries. The dynamics of urban sprawl are considerably slower, also losses in agricultural areas are not so intensive. In the CLC2006 inventory, the preliminary results of land cover change detected in the years 2000–2006 is less than expected, and in most European countries does not exceed 1%, in Poland it is about 0,5%.

Land use is never static, but it is constantly changing in response to dynamic interaction between drivers and feedback from land use change to these drivers. According to Lambin et al. (2003) changes in land use are driven by a combination of five fundamental causes:

1) resource scarcity leading to an increase in the pressure for production of resources,
2) changing opportunities created by markets,
3) policy intervention,
4) loss of adaptive capacity and increased vulnerability,
5) changes in social organisation, in resource access, and in attitudes.

Systematic analysis of land use change, conducted over a space and time, help to uncover general principles to provide an explanation and prediction of new land use change. Improved understanding of the processes of land use/cover change lead to a shift from a view condemning human impact on the environment as leading mostly to a deterioration of earth system processes to emphasis on the potential for ecological restoration through land management.

Integrated analysis of spatial organisation, especially of land use trends in urban areas, agriculture and forestry through assessments of their current and future impact on water, soils, air quality, biodiversity and landscape, is crucial to assess the impact of new societal demands, demographic and technological trends on the natural environment and as a basis for policy evaluation and feedback into related sectoral and environmental policies. The analysis of interaction, coherence, or conflict between social and biophysical responses to change in both ecosystem services and earth system processes caused by land use change is still a largely unresearched area.

References

Adamski R., Ciołkosz A., 2006: Expending of CORINE Land Cover data base. *Polish Cartographical Review*, t. 38, No 3 p. 225-232 (in Polish).

Bielecka E., Luc M., Szmańda J., 2007: Attempt to assess a land cover differential based on a complex, multivariate analysis – case study of the Odra and Vistula river valleys. [In:] Doliny rzeczne. Przyroda-Krajobraz-Człowiek. Red. U. Myga-Piątek, Sosnowiec, s.41-50 (in Polish).

Bossard M., Feranec J., Otahel J., 2000: CORINE Land Cover Technical Guide-Addendum 2000. EEA Technical report No 4, Copenhagen.

Butner G., Kosztra B., 2007: CLC2006 Technical Guidelance. ETC Terrestrial Environment, Barcelona.

Ciołkosz A., Bielecka E., 2005: Land cover in Poland. CORINE Land Cover databases. Biblioteka Monitoringu Środowiska, Warszawa (in Polish).

Eden G., Kayadjanian M., Vidal C., 2000: Quantifying Landscape Structure: spatial and temporal dimension. [In:] From Land Cover To Landscape Diversity In The European Union. http://land_cover_diversity/europa.eu.int/comm./agriculture/public/landscape/index.htm

EEA, 2005: The European Environment. State and outlook 2005, Copenhagen.

EEA, 2006a: Land accounts for Europe 1990-2000. Towards integrated land and ecosystem accounting. EEA Report No 11/2006, Copenhagen.

EEA, 2006b: Urban sprawl in Europe. The ignored challenge. EEA Report No 10/2006, Copenhagen.

Feranec J., Bittner G., Jaffrain G., 2006: CORINE Land Cover Technical Guide-Addendum 2006. EEA, Copenhagen.

Heymann Y., Steenmans Ch., Croissille G., Bossard M., 1994: CORINE Land Cover Technical Guide. EUR12585, Luxemburg.

Lambin E.F., Geist H.J., Lepers E., 2003: Dynamics of land use and land cover change in tropical regions. *Annual Rev. Environ. Resour.* 28, p. 205-241.

Luc M., Bielecka E., Szamańda J., 2008: From land cover diversity to landscape variety in Poland. Raster data analysis. Proceedings of Geoinformatics Forum, Salzburg, 1-4 July 2008.

Millennium Ecosystem Assessment, 2005: http://www.millenniumassessment.org/en/Synthesis.aspx

Węcławowicz G., Bański J., Degórski M., Komornicki T., Korcelli P., Śleszyński P., 2006: Spatial organisation of Poland at the beginning of the 21st century. IGiPZ PAN Monographies 6, Warsaw, p.212 (in Polish).

Abstract

Information about land cover and land use is recognized by decision-makers as crucial for spatial analysis at different territorial levels. Within the European Commission Services, as well as different European organisations, there is a growing need to use spatial analysis for integrated environmental assessment, mainly assessing impact of policy against regional development, planning, and agriculture. In all cases a key reference data is complete, reliable, and up to date land cover and land use data. That is why in the middle 80s of the 19th century the European Commission implemented CORINE

Program. The main goal of that program was to establish an information system on the state of the European environment. Since then, information on land cover and land use in Europe was updated twice, in the years 2000 and 2006. As the diversity of land cover and land use reflects differentiation in spatial organisation, this data is of utmost importance for monitoring spatial organisation in Europe especially in the geographical context.

The article presents the source databases storing information concerning land cover/use and land cover change and shows some examples how land cover change reflects the differences in spatial organisation within Europe, as well as impact of policy against particular land cover types e.g. arable lands, forests, artificial surfaces. It is mainly based on the research works carried out by author as well as on EEA reports. The three major processes of changes in land cover and in spatial organisation are analysed in more detail, both at the European level and Poland. These are: development of urban and other artificial land, decreases in the agricultural area resulting from a range of changes in use, and increases in the area of forest and decreases in the area of natural land.

Streszczenie

Informacja o pokryciu terenu i użytkowaniu ziemi jest niezbędna do prowadzenia analiz przestrzennych o różnej szczegółowości i na różnych poziomach administracji, a także wielu organom Unii Europejskiej, do prowadzenia polityki w zakresie środowiska, rozwoju regionalnego i rolnictwa. A zatem, aby sprostać rosnącym wymaganiom unijnej administracji publicznej w zakresie wykorzystania tych informacji, Komisja Europejska uruchomiła w połowie lat osiemdziesiątych dwudziestego wieku program CORINE. Celem tego programu było utworzenie systemu informacyjnego przechowującego dane o stanie środowiska w Europie, w tym danych o sposobach użytkowania ziemi i formach pokrycia terenu. Dane te były już dwukrotnie aktualizowanie, w latach 2000 i 2006. Ponieważ zróżnicowanie pokrycia terenu i użytkowania ziemi odzwierciedla zróżnicowanie w zagospodarowaniu przestrzennym dane te są niezwykle istotne do monitorowania zagospodarowania przestrzennego w Europie, szczególnie w kontekście lokalizacji geograficznej.

Artykuł zawiera krótką charakterystykę baz danych o pokryciu terenu i użytkowaniu ziemi i pokazuje, na licznych przykładach, jak zmiany w pokryciu terenu wpływają na zróżnicowanie zagospodarowania przestrzennego w Europie oraz jaki wpływ na zróżnicowanie poszczególnych typów pokrycia terenu (grunty rolne, lasy, tereny zabudowy miejskiej) ma polityka Unii Europejskiej. Przykłady pochodzą głównie z badań prowadzonych przez autorkę oraz z raportów Europejskiej Agencji Środowiska (EEA). Szczegółowiej zostały zilustrowane trzy główne procesy prowadzące do zmian w pokryciu i użytkowaniu terenu oraz zagospodarowaniu przestrzennym. Są to: rozwój (rozprzestrzenianie się) miast i innych terenów sztucznych, ubytek gruntów rolnych, wzrost terenów leśnych oraz ubytek terenów pokrytych roślinnością naturalną.

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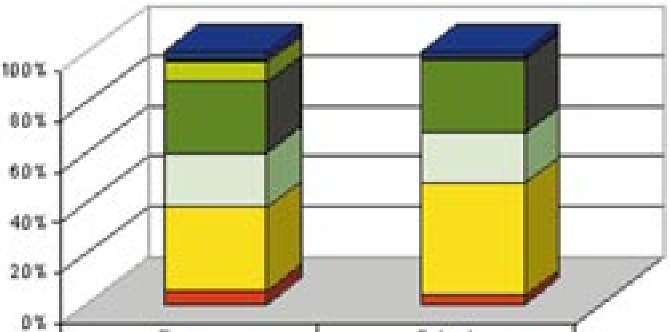

	Europe	Poland
water bodies	3	2
wetlands	1	0,3
semi-natural vegetation and open space	8	0,2
forests	28	30
pasture and mosaics	22	20
arable lands and permanent crops	33	45
artificial areas	5	3

Figure 1. Percentages of CORINE land cover types in Europe and in Poland

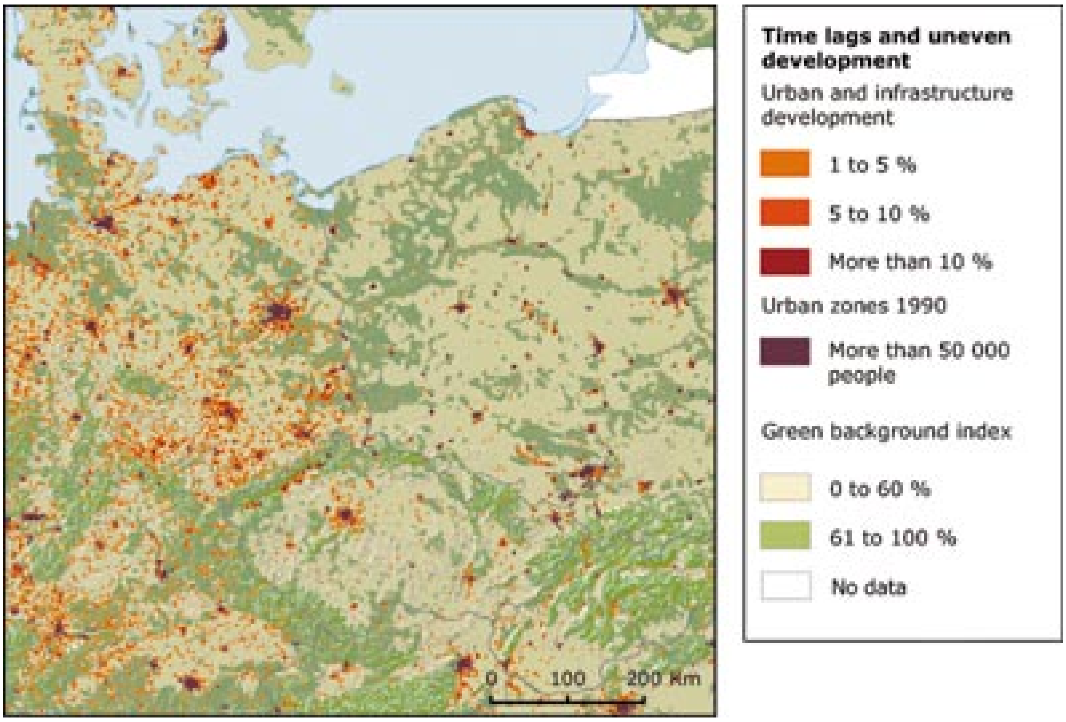

Figure 2. Urban sprawl in eastern Germany and Poland (EEA, 2006a)

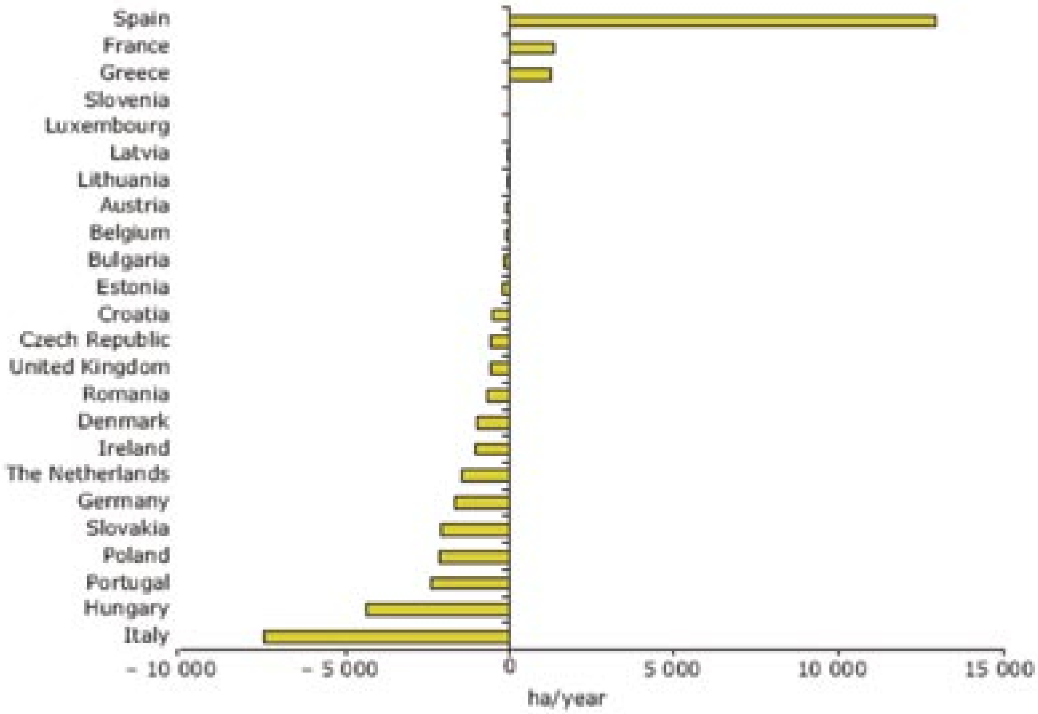

Figure 3. Transformation of land between agriculture and forest and semi-natural cover types across Europe

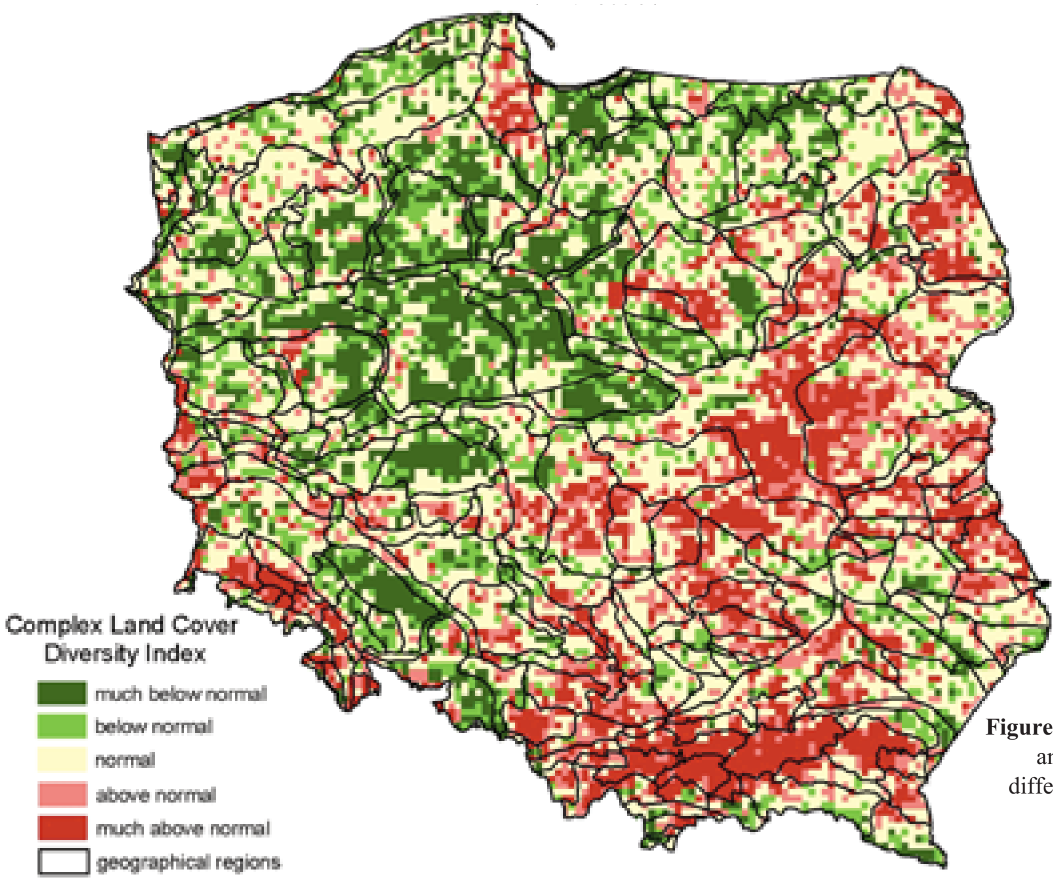

Figure 4. Land cover and spatial differentiation in Poland