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Geographical location and key sensitivity issues of post-industrial regions in Europe

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Abstract Primary objectives of our work were to spatially delineate post industrial areas of the EU-27 and indicate key environmental, social and economic sensitivity issues for these regions. The density of industrial sites within NUTS-x regions for EU-27 countries was assessed by using CORINE 2000 land cover layer. A development of postindustrial society in Europe represents a strong geographic diversity. There are distinct historical and current differences between regions which form major groups, comprising similar internal characteristics and definable trends in environmental and socioeconomic sense. Regions grouped into postindustrial clusters are fundamentally different from the European average, and are facing specific problems related to global market and political changes. Eastern postindustrial regions can be characterized as socially and economically weak, exhibiting high unemployment rate, low GDP, negative population growth and a strong environmental pressure, represented by a high density of dump sites. Most of the western EU postindustrial areas have been successfully recovered and moved into new economy as shown by most of the indicators. In urban postindustrial zones, however, emission sources of pollutants seem to continually be a major problem—not necessarily in terms of exceeding thresholds, but through a remarkable difference in the amount of pollutants produced relative to other regions.

Keywords Cluster · Dump site · Economic variables · Emissions · Environmental variables · Post-industrial regions · Sensitivity · Social variables · Unemployment

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Introduction

Postindustrial areas are of special character, as they are usually highly populated, and are often facing social and environmental instabilities. History of heavy industry in the EU-25 dates back to the nineteenth century and its peak development took place in the sixties and seventies of the twenties century. Technologies used in that period did not consider a proper care for waste management, wasteland remediation and emissions control of contaminants which was resulting in often extensive soil and water pollution (Ferguson et al. 1998; Huttl 1998; Kasamas et al. 2001; Ferber and Grimski 2002). Both industrial emissions and waste management were not sufficiently, or at all, regulated.

The unique feature of industrial regions is a complex pattern of land use fragmentation, where different land use functions, such as industry, transport, agriculture, forest and sometimes semi-natural areas, appear in the same landscape and often collide with each other. For example, there are many active agricultural areas existing in a direct neighborhood of industrial installations or dump sites, which causes a strong exposure to contaminants and degradation of ecosystem's functions. In the last 20 years the excessive emissions have ceased or were substantially reduced, thanks to environmental law enforcement, however there is a significant environmental and health risk associated with historical sites, which have not been reclaimed yet, and are producing substantial secondary emissions—e.g. dump sites, underground tanks, large industrial sites, abandoned waste land etc. (Licsko et al. 1999; Wcislo et al. 2002; Stuczynski et al. 2007).

Economic and technological changes, as well as global trends, have been leading to a decline of a traditional industrial production in the former EU-15 which is being transferred to new member states or often the Asian region. Due to these changes a problem of so called brownfields appeared (Grimski and Ferber 2001). Brownfields are abandoned and underused industrial properties with real or perceived contamination problems (Simons 1998). The problem of brownfields results from two concurrent factors: high number of closed plants and the environmental legislation holding specified parties liable for the cost of cleanup at contaminated sites (Alberini et al. 2005).

There is an increasing interest in revitalization of post-industrial areas and bringing them into new functions (Kasamas et al. 2001; Ferber and Grimski 2002). In the new member states a decline of heavy industry was quite immediate and associated with a massive collapse of state controlled businesses, which were technologically outdated and were not able to compete in the emerging market economy.

A major challenge in surveying post-industrial and other sensitive areas is insufficient availability of harmonized indicators and data, which could provide a satisfactory spatial and temporal resolution coverage for Europe (Ferber and Grimski 2002; Oliver et al. 2005; European Commission 2004). Regardless to the fact that the resolution of the EU-25 statistical data goes down to NUTS-3 regions, only very limited number of indicators can be integrated without major gaps and inconsistencies, either temporal or spatial. Detail and resolution required to compare regions throughout Europe involved a NUTS-x level, which is a combination of NUTS-2 and 3 units of a similar size. NUTS (Nomenclature of Territorial Units for Statistics) is a geocode introduced by European Union to reference administrative division of EU countries for statistical purposes. NUTS-0 level refers to a country while NUTS-1, 2 and 3 correspond to regions of increasing resolution within a country.

It is clear that there is a significant geographic discrimination of mechanisms and patterns of land use change, as well as social and economic environment throughout Europe. It is well known that the status and rate of changes occurring in southern EU regions is different than in northern Europe—accession of new member states makes these contrasts even more visible. Therefore it is essential that analysis of so called sensitivity issues is conducted within more or less homogeneous areas, representing similar social, economic and historical backgrounds and mechanisms.

Objectives and scope of the study

This European survey of sensitive areas provides an overview of key impact issues referring to policy assessment guidelines (European Commission 2002, 2005) and covers environmental, economic and social aspects of the EU-25 post-industrial regions. We used PanEuropean datasets such as CORINE land cover (European Commission DG JRC 2005) and EUROSTAT data, bearing in mind their limitations in meeting purposes of this survey. On the other hand, it seems that a focus on a limited number of indicators helps the clarity and allows identification of major problems and issues given in simple terms, useful for scenario modeling. The overall objective of this survey was to delineate vulnerable zones within post-industrial regions which are susceptible to policy impacts. Understanding vulnerability of these regions as well as their social, economic and environmental balance is critical for predictions of policy effects—policy measures can potentially have a stronger impacts on landscapes here as compared to regular areas.

Materials and methods

Geographical identification of post-industrial regions

The density of industrial sites within NUTS-x for EU-25 and 2 new member countries (Bulgaria and Romania) was assessed by using CORINE 2000 land cover layer to separate post-industrial regions. Original CORINE layer distinguishes three types of industry related classes: a combined industrial/commercial, dump sites and mineral extraction sites (European Commission DG JRC 2005). Combining commercial and industrial areas into one class does not allow for a precise delineation of typical industrial zones. There is also no recognition between industrial and post-industrial sites.

Proxy identification of post industrial sites was extracted from CORINE land cover 2000 by using 5× 5 km moving window—Erdas module (ERDAS 1999). Extraction of post-industrial areas from commercial/industrial class was based on the assumption that historical sites were often surrounded by dump and excavation sites, which are appearing within a close neighborhood. In fact, industrial activities until the seventies of the 20th century generated large amounts of wastes which resulted in relatively large number of dump sites scattered within industrial zones. Technically, each 100×100 m pixel of commercial/industrial class was classified as post-industrial if, when being in a center of 5×5 km window, was accompanied by at least one pixel of dump site or mineral extraction class. Finally, delineated post-industrial sites were combined with dump sites and mineral extraction sites into "post-industrial sites" and expressed as percent of the total area of each NUTS-x for the EU-27. NUTS-x regions with post-industrial area of at least 0.3% of the total territory were defined as post-industrial. The value 0.3% was based on literature search (Oliver et al. 2005)—mean area of brownfields in most western countries is approx. 0.2–0.4% of total country area. These regions were subjected to further analysis of key sensitivity issues.

Analysis of sensitivity issues

Since a development of postindustrial areas in Europe represents a strong geographic diversity and there are distinct historical and current differences between regions we combined post-industrial NUTS-x regions using clustering into groups of similar character and behaviour based on basic socioeconomic and environmental parameters. Then available socio-economic and environmental indicators were analyzed within each group of regions in terms of their present status and temporal trends in order to identify the most sensitive regions and key sensitivity indicators.

Cluster analysis was performed to classify post-industrial regions into relatively homogenous groups of regions within the EU-25, which would represent a similar environmental, socioeconomic, agricultural and geographical profile. Cluster analysis was performed by K-means for NUTS-2/3 EUROSTAT data for 2001 or 2002 across the EU-25. Bulgaria and Romania were not included in the clustering due to incomplete data for their NUTS-x regions in EUROSTAT databases. Indicators used as variables in the cluster analysis (called here as input indicators) were subjectively preselected to cover key social, environmental and economic issues and ensure distinction of various types of regions in terms of social, environmental and economic conditions. Correlation analysis between preliminary set of input indicators was performed to exclude less important ones which were intercorrelated with those selected for clustering procedure. Input indicators used to distinguish clusters included: density of post-industrial sites (% of total area), length of vegetative period (days), mean precipitation in vegetative period IV-X (mm), unemployment rate (%), gross domestic product (GDP) (Euro per inhabitant), population density (inhabitants/ km^2), economically active population (% total population), crude birth rate (nr/1,000 inhabitants), crude death rate (nr/1,000 inhabitants), employment in industry (% economically active population). Clustering procedure was performed in Statistica Data Miner 7.1 software (Statsoft 2005).

Qualitative trend assessment was performed within different types of post-industrial regions to track changes in population density, GDP, natural population growth and employment structure within these homogenous areas throughout Europe. The timeframe for this observation was depending on available statistics in EUROSTAT database.

Data sources, assumptions and limitations

EUROSTAT database was used as a main data source for NUTS 2/3 within the EU-25. All essential

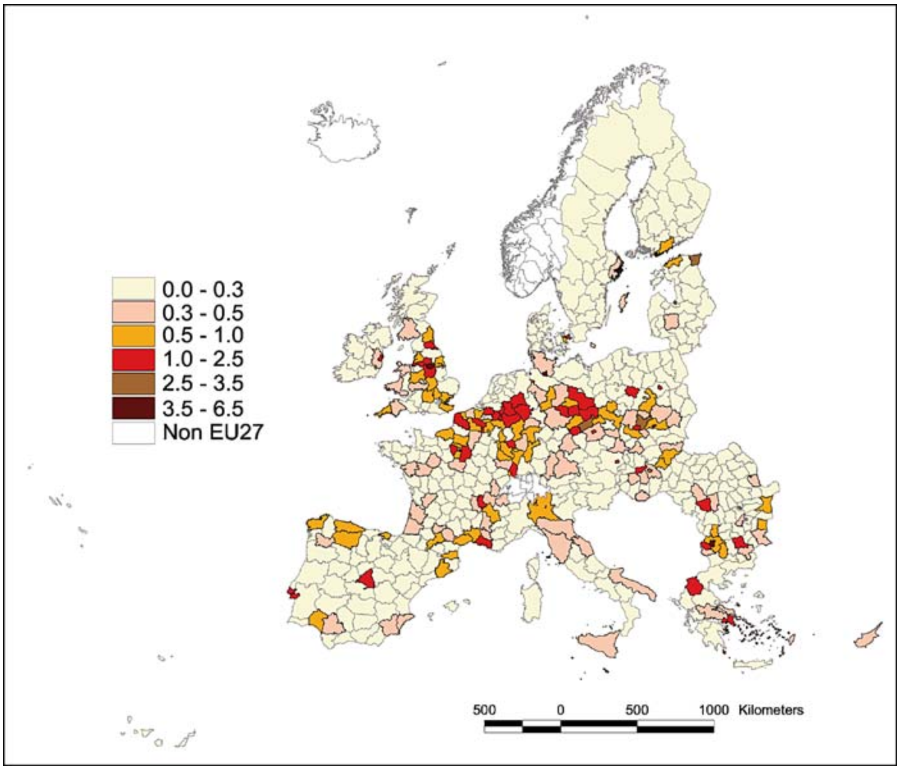

Fig. 1 Density of post-industrial sites (delineated post-industrial plus dump and extraction sites) in NUTS x within Europe based on CORINE 2000

parameters were collected at the largest possible temporal resolution to observe their trends—data from 1995/1997 up to 2003 were obtained for the EU-25. EUROSTAT database provides data grouped into various social, economic and environmental catalogues.

To account for biophysical conditions of the EU-25 we used climatic data such as length of vegetation period, precipitation, and average temperatures obtained from the Intergovernmental Panel on Climate Change (IPCC), which was established to provide basis for understanding of human induced climate change and its consequences (Tonn 2007).

Landscape metrics were calculated for EU-25 regions as indicators of landscape heterogeneity and pattern. High landscape diversity is considered to be indicative of land buffering capacity and resistance to various anthropogenic pressures (Johnson et al. 1992; Antrop 2004). Such metrics as Patch Density, Edge Density and Shannon Diversity Index were calculated by using Fragstats software (McGarigal and Marks 1994) and CORINE land cover as the data source for 2000. Patch density (PD) is a number of patches in the landscape divided by the total landscape area. Edge density is a sum of the length of all edges divided by the landscape area. Shannon Diversity Index (SHDI) represents diversity metrics being based on two components: the number of different patch types and the proportional area distribution among patch types (McGarigal and Marks 1994; European Commission 2000).

Both dump sites and mineral extraction sites densities were calculated for each cluster based on CORINE land cover dataset from 2000 and expressed as area of these sites per cluster area. Density of dump sites might potentially be an indicator of pressure of former industrial or urban activities on the environment and population or to characterize development of waste management system.

Present emission data was obtained from European Pollutant Emission Register (EPER). The database contains facilities responsible for approximately 90% of emissions in Europe. The database is divided into contaminant (metals, organic compounds and gaseous compounds) and activity categories (e.g. smelting, refineries, combustions, etc.) (Brand et al. 2004). The database is limited to EU-15 countries. We combined emissions generated by all facilities within a region and expressed them in tonnes/km^2 as total metal, organic and gaseous emission from a region.

Table 1 Means of selected socio-economic indicators within post-industrial density classes for 2002 data

Indicator	<0.3[a]	0.3–0.5	0.5–1.0	1.0–2.5	>2.5
Population density (inhabitants/km^2)	292	235	407	806	1,937
Economically active population (% of total population)	45.2	44.9	46.6	46.7	47.5
Crude birth rate (births/1,000 inhabitants)	10.3	10.5	11.1	11.4	9.8
Crude death rate (deaths/1,000 inhabitants)	10.3	9.7	9.6	9.4	11.8
Natural population growth (nr/1,000 inhabitants)	0.0	0.8	1.5	2.0	−2.0
Unemployment rate (% of total economically active population)	9.6	9.0	9.7	8.6	9.4
Total employment (% of total economically active population)	87.5	87.3	88.9	87.8	73.8
GDP (EUR/inhabitant)	18,215	17,909	20,179	21,676	15,063

[a] Values in column titles are densities of post-industrial sites expressed as percent of total region area

Results and discussion

Density of post-industrial sites in EU-25

As shown on the map (Fig. 1) the density of post-industrial sites delineated within NUTS-x may be as high as 6.5% of the total area. However, the density of post-industrial areas in almost 65% of all NUTS-x is below 0.3% of their total area. We assumed 0.3% density to be a "threshold value"—this finally gave 184 NUTS-x regions qualified as "post-industrial" regions. These regions cover 25% of a whole EU-27 territory.

For such countries as Austria, Denmark, Finland, Lithuania or the Netherlands only single regions can be considered as post-industrial as based on assumed criteria. Belgium, Bulgaria, Czech Republic, France, Germany, Hungary, Poland, Spain and UK had more such regions including those heavily filled with post-industrial sites (over 1% of total area). In certain cases high density of post-industrial sites might be related to character of the country or region, e.g. Malta—islands may have higher concentration of dump sites than regular areas.

Approximately 50% of EU-25 population lives in regions selected as post-industrial. This population may potentially face various social, economic and environmental problems related to post-industrial areas. Three percent of population lives in NUTS-x with density of post-industrial sites over 2.5% of region area.

Analysis of unemployment and other variables revealed that there are no clear general trends within post-industrial NUTS's (Table 1). For example there are post-industrial units posing serious unemployment problems while other areas with similar density of post-industrial sites have low unemployment rate, indicating successful recovery into alternative functions (Table 2).

There are no clear relationships between density of post-industrial sites and such social indicators like share of economically active population or total employment when all post-industrial regions taken as a whole. Population density increases above 0.5% density of post-industrial sites. Natural population growth increases up to 2.5% post-industrial density, but is negative in the most dense class (Table 1). All regions located in this density class were characterized by strongly negative natural population growth in 2002 except one French region.

Region types

Since there are no clear relationships between density of post-industrial sites and socio-economic situation for overall EU-25 and there are strong differences in

Table 2 Distribution of unemployment classes in post-industrial density classes expressed as number of NUTS-x

Post-industrial density classes	Unemployment rate classes					
	<5	5–8%	8–12%	12–18%	18–31%	Total
<0.3%	73	88	57	41	37	296
0.3–0.5%	18	15	14	8	6	61
0.5–1.0%	14	12	10	14	4	54
1.0–2.5%	9	11	6	7	1	34
>2.5%	1	4	0	1	1	7

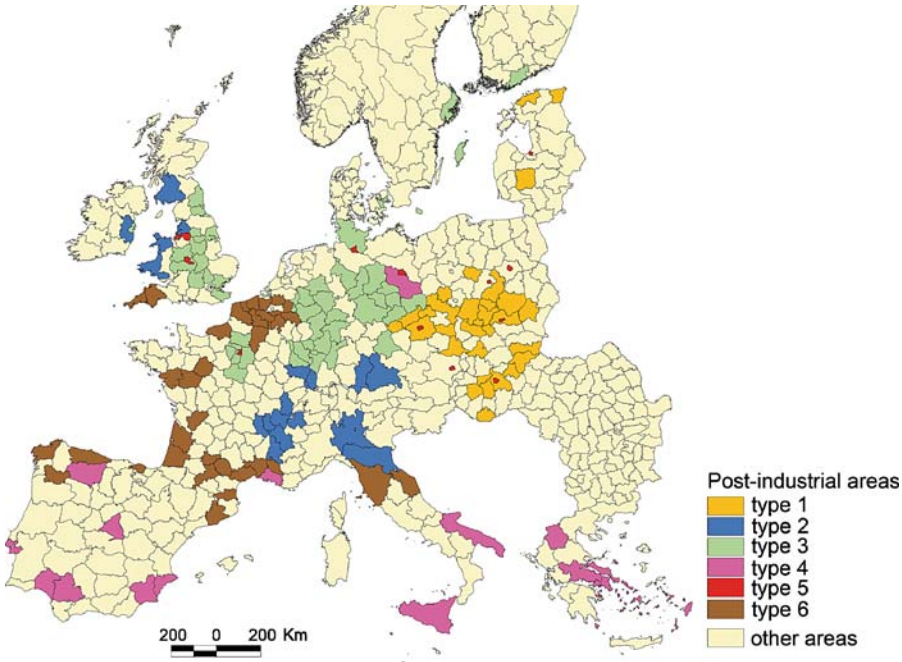

Fig. 2 Spatial distribution of NUTS-x regions within six types of post-industrial regions

socio-economic pattern over Europe we combined regions into geographically and economically similar types using cluster analysis. There are significant contrasts between such delineated types in social and economic parameters so that they may require different level and type of interventions.

Spatial distribution of six types of post-industrial regions is shown on the map (Fig. 2). Table 3 demonstrates standardized means of input indicators for each cluster. These means are indicative of factors deciding an allocation of NUTS-2/3 regions into a given type. Means can be used for comparisons of behavior of different indicators between groups. For example value of −1.54 for GDP in group 1, which is the lowest among all groups, indicates that that regions within this type demonstrate the lowest GDP which is the main factor behind classifying these of regions into one group.

The produced groups of regions can be defined as following types:

Type 1 Eastern transitional industrial, socially and economically weak
Type 2 Western, economically and socially strong (medium density of post-industrial sites)
Type 3 Western, economically and socially strong (high density of post-industrial sites)
Type 4 Southern, socially and economically weak
Type 5 Urban
Type 6 Western socially weak

Table 3 Standardized means of input indicators in cluster analysis for post-industrial NUTS-x of EU-25

Input indicators	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Density of post-industrial areas (%)	0.09	0.01	0.07	0.95	−0.88	−0.24
Length of vegetative period (days)	−0.85	−0.33	−0.35	1.54	−0.38	0.96
Mean precipitation in vegetative period	0.06	1.71	−0.25	−1.69	−0.15	0.23
Unemployment rate (%)	0.80	−0.60	−0.38	0.71	−0.15	−0.09
Gross domestic product (GDP) (Euro per inhabitant)	−1.54	0.60	0.65	−0.32	0.21	0.15
Population density (inhabitants/km^2)	−0.40	−0.35	−0.13	−0.29	2.91	−0.33
Economically active population (% total population)	−0.05	0.03	0.61	−1.02	0.73	−0.76
Crude birth rate (nr/1,000 inhabitants)	−0.44	0.53	0.16	−0.29	−0.23	0.10
Crude death rate (nr/1,000 inhabitants)	0.58	−0.29	−0.28	−0.21	0.32	0.02
Employment in industry (% economically active population)	1.23	0.38	−0.32	−0.30	−0.88	−0.34

Table 4 Area and number of NUTS-x within types of post-industrial areas of EU-25

Type of regions	Area (ha)	Share		Number of NUTS x
		% of all post-industrial	% of EU 25	
Type 1	17,738,817	17.8	4.47	31
Type 2	15,635,535	15.7	3.94	18
Type 3	27,899,605	28.0	7.02	52
Type 4	16,643,667	16.7	4.19	15
Type 5	782,022	0.78	0.20	14
Type 6	21,044,217	21.1	5.30	34
All post-industrial NUTS-x	99,743,863	100	25.1	164
EU 25	397,279,298	x	100	473

Type 1 covers 4.5% of total EU-25 area comprising 31 NUTS-x (Table 4)—mostly Czech, Hungarian, and Polish and single regions from Slovakia, Lithuania and Estonia. This group of regions represents relatively high density of post-industrial sites—on average 0.88%.

Over 5% of total EU-25 population living in these regions meet social and economic problems. NUTS of type 1 face serious unemployment—mean of total unemployment rate 13.7% and 28.1% for population under 25 (Table 5). Increase of unemployment was observed up to 2001 however it has been stable since that date (Fig. 3). Population density is the lowest among all types and well below mean for non post-industrial regions. There has been an obvious trend of population decrease over last years in the region (Fig. 4). This is the only type with clearly negative value of mean natural population growth (−1.5/1,000 inhabitants in 2002)—it has been negative since 1995. Interestingly, natural population growth decreases with the increase of employment in industry (correlation coefficient r=−0.49). Mean Gross domestic product (GDP) value is dramatically lower than for other types—it is equal to 1/4 of overall EU-25 mean (Table 5). Relative GDP growth is relatively high—9.5% but a real distance to other groups expressed in EUR is increasing (Fig. 5). GDP value is closely correlated to unemployment rate in this group (r=−0.57)—the higher unemployment the lower GDP. Mean share of population employed in industry is one

Table 5 Mean actual values of selected indicators in types of post-industrial NUTS-x within EU-25 calculated using 2002 data

Indicator	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	EU-25
Area of the region (km^2)	5,679	8,661	5,342	11,067	558	6,159	8,207
Post-industrial sites density (% of total area)	0.88	0.53	0.98	0.81	1.99	0.60	x
Agricultural area (% of total)	58.1	52.7	60.5	46.9	25.2	58.3	52.0
Annual average population (1,000 inh.)	790	1,756	1,564	2,062	1,619	1,105	959
Population density (inh./km^2)	152	194	397	281	2,977	210	372
Economically active population (% of total population)	44.9	46.7	48.3	43.1	48.6	43.5	45.8
Crude birth rate (births/1,000 inh.)	9.4	12.2	11.9	10.5	10.7	10.9	10.5
Crude death rate (deaths/1,000 inh.)	10.8	9.2	9.1	8.8	10.8	10.0	10.2
Natural population growth (pers./1,000 inh.)	−1.49	3.08	2.81	1.64	−0.05	0.88	0.36
Total unemployment rate (% of total economically active)	13.7	5.54	7.00	14.8	7.83	9.36	9.40
Unemployment rate for males (% of males economically active)	13.1	4.70	6.67	10.5	7.74	7.26	8.20
Unemployment rate for females (% of females economically active)	14.3	6.54	7.42	21.7	7.82	12.0	11.2
Unemployment rate under 25 years (% of under 25 economically active)	28.1	12.3	11.6	32.6	15.3	21.9	20.1
Total employment (% of total economically active)	76.4	92.6	91.5	84.8	84.9	90.5	87.4
Employment in agriculture, hunting, forestry and fishing (% of total economically active)	11.0	2.92	1.81	7.29	0.42	4.78	7.40
Employment in industry (% of total economically active)	26.9	28.1	23.3	20.9	17.7	23.1	23.7
GDP (EUR/inh)	5,275	24,718	25,154	16,350	21,132	20,647	18,627

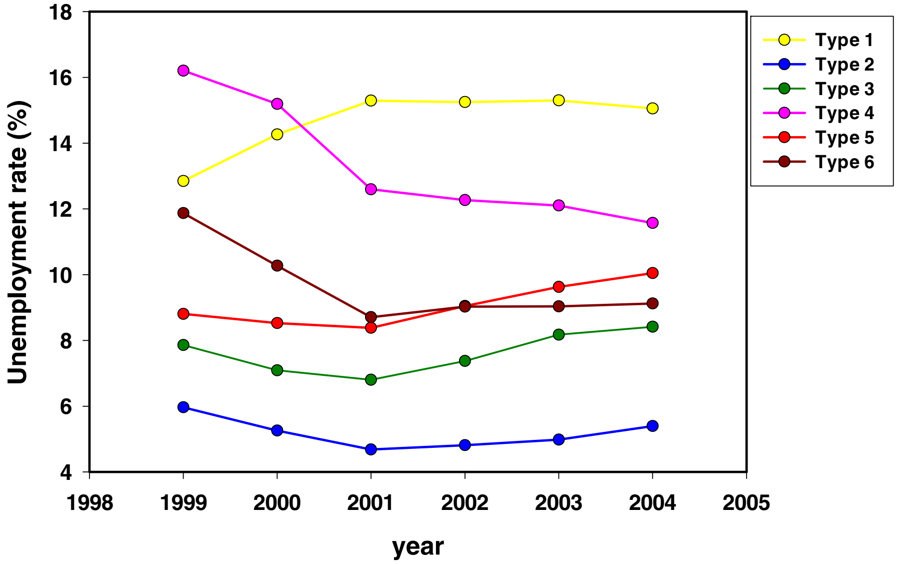

Fig. 3 Temporal changes of weighted unemployment rate within various types of post-industrial regions

of the highest between types (Table 5). This combined with high unemployment may indicate very limited recovery of areas into alternative functions.

Type 2 combines 18 NUTS-x regions covering 3.94% of total EU-25 area (Table 4). The population is equal to 6.96% of the total EU-25 population. The group comprises ten French regions in eastern part of the country, two northern Italian, two German, three British, Luxemburg and one region in Eastern Ireland (Fig. 2). Delineation of this group was mainly driven by high natural population growth, low unemployment and high GDP (Table 3). Mean density of post-industrial sites is lower than in cluster 1—0.53% (Table 5). Unemployment rate is the lowest between types and is almost twice lower than mean for all EU-25 regions—5.5% and 9.4%, respectively. It has been constantly below 6% since 1999 (Fig. 3). Unemployment rates within females and under 25 are also low. Natural population growth expressed as a mean within NUTS was the highest among all groups (Table 5)—over three persons per 1,000 inhabitants. This was driven by high growth in French and Irish regions of the cluster. The indicator has been slightly increasing since 1995. Population density is relatively low—194 inhabitants per square km, well below mean of all EU-25 regions (Table 5) which is related to that fact there are no big agglomerations within the group. However it has been increasing over last decade (Fig. 4). Mean GDP value is 25% higher than mean calculated for all regions (Table 5). GDP trend of relative growth equal to 4.77% over last decade let GDP to remain the highest between the types when calculated as a weighted mean (Fig. 5). Weighted mean share of population employed in industry has remained the highest between types within period for which the data is available (1999 to 2002).

Type 3 is the largest group of NUTS-x regions covering 7% of EU-25 area and comprising 52 units (Table 4) with 17.9% of all EU-25 population. Cluster is mainly located in central part of EU, including most of German post-industrial regions, several French regions, all three post-industrial regions from Denmark, most of British units and few units from Finland, Sweden and Ireland. Mean density of post-industrial sites is higher than in most of clusters—0.98% (Table 5). Regions of this type are characterized by good social indicators and high GDP (Table 5). Mean unemployment rate is lower than mean for all EU-25 regions—7.0% comparing to 9.4%. Weighted unemployment rate was remaining within the range 7.0–8.2% from 1999 to 2004 (Fig. 3). Mean unemployment in this group is increased by high unemployment in Eastern German regions with unemployment rate 13–17%. Mean natural population growth within NUTS is high comparing to mean for all EU-25 regions: 2.81 and 0.36, respectively (Table 5). The indicator has been slightly increasing since 1995. Population density is the highest except type 5 that mostly consists with cities. Further increase of population is observed (Fig. 4). Share of economically active population is strongly correlated to GDP and unemployment rate (r=0.72 and −0.68,

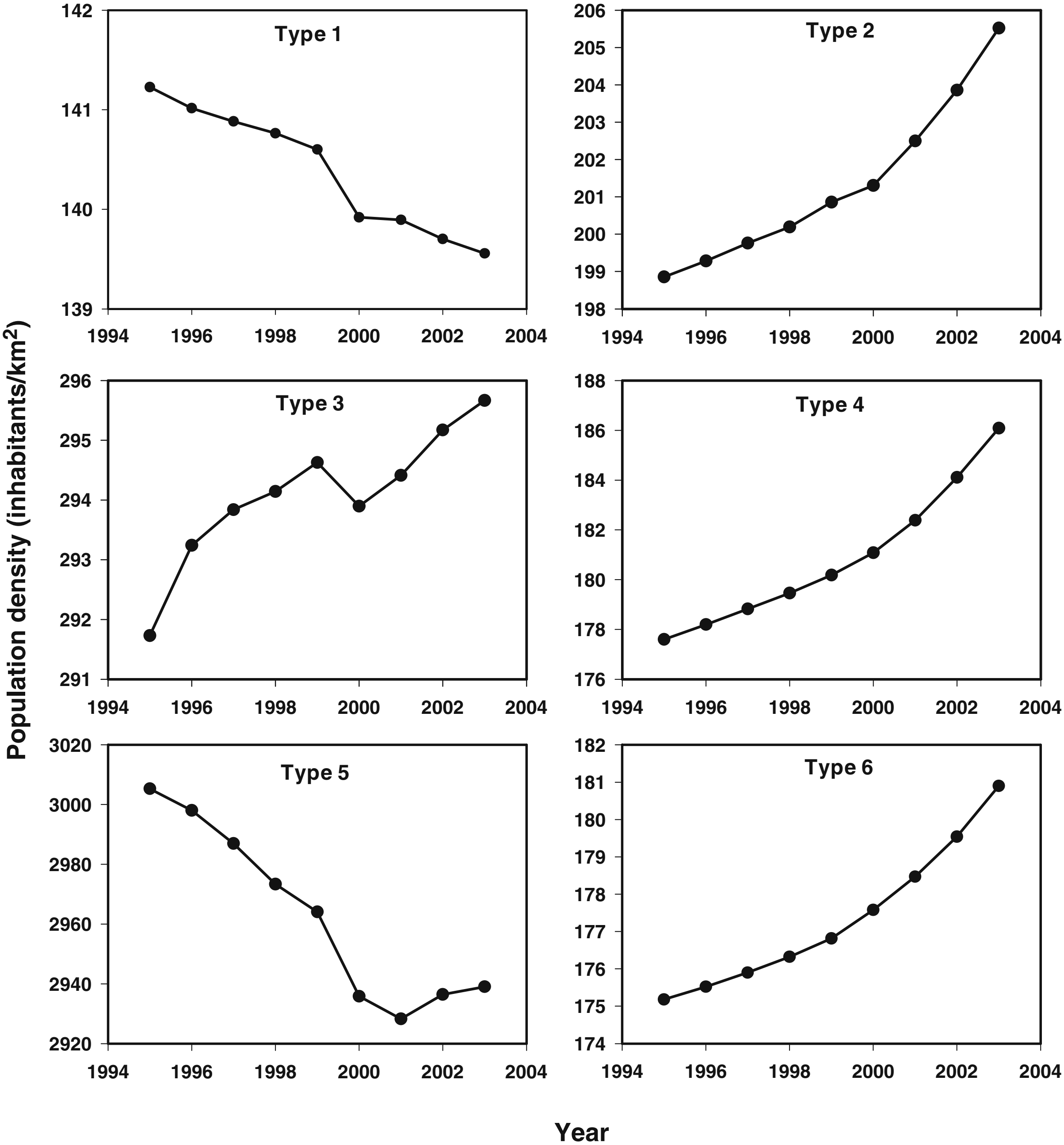

Fig. 4 Temporal changes of weighted population density in different types of EU post-industrial regions

respectively)—rich regions without unemployment problems attract population at productive age. Arithmetic mean GDP value exceeds 25,000 EUR per inhabitant being the highest between all clusters and 30% higher than mean calculated for EU-25 (Table 5). Relative growth of GDP expressed as weighted mean is lower than for EU-25 and the lowest between all groups, however it increased from 20,000 to above 25,000 EUR within 1995–2002 period (Fig. 5).

Type 4, besides climatic conditions, was delineated basically by high unemployment and low share of economically active population. The type covers 4.2% of total EU-25 area consisting with 15 regions located in southern part of Europe—mostly Spanish

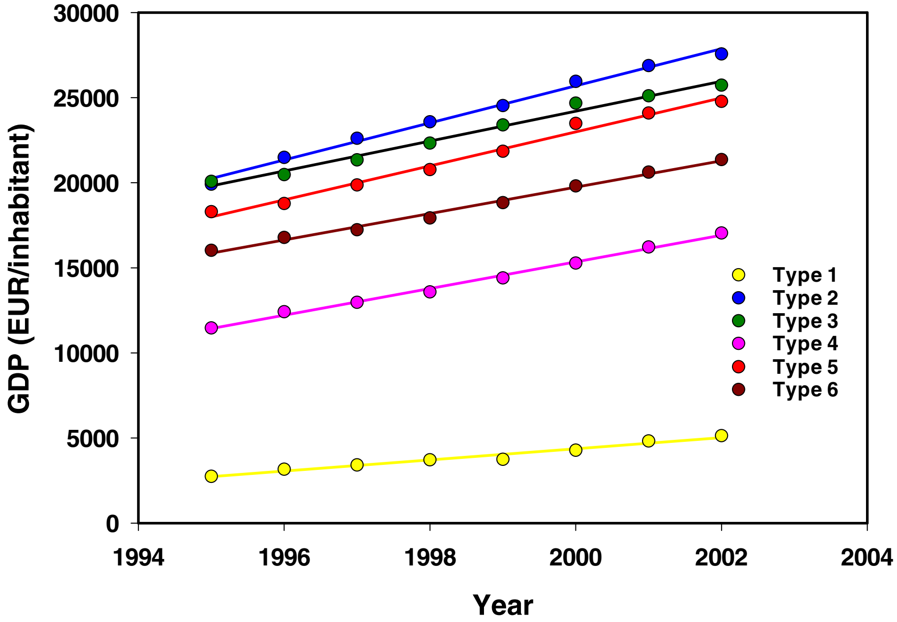

Fig. 5 Temporal trends of GDP within various types of post-industrial regions

and Greek and single regions from Italy, France, Portugal and Germany (Fig. 4). Mean density of post-industrial sites is equal 0.81% of total area (Table 5). Regions of this type face strong social problems. Mean total unemployment rate was in 2002 the highest between all types—14.8% (Table 5). However, it has been significantly decreasing since 1999—weighted unemployment rate was in 2004 significantly lower than in type 1 (Fig. 3). There is a drastic difference between unemployment rate for males and females—10.5% and 21.7%, respectively. Serious social problem is an unemployment within young generation—rate 32.6%. Share of economically active population is the lowest comparing to other types (Table 5). Population density is lower than mean for EU-25 (281 vs. 371 inhabitants per square km) (Table 5) but it has been increasing over last decade (Fig. 4). This trend is partly related to a rate of natural population growth—since 1995 weighted value constantly above 1 with strong increase since 1999. Mean GDP (16,350 EUR) is significantly lower than mean for EU-25 (Table 5, Fig. 5). Most of regions within this group is within a range of 13,000–15,000 EUR/inhabitant but the group overall mean is elevated by regions with urban agglomerations such as Madrid and Lisbon. There is a strong relationship between density of post-industrial sites and GDP in this group of regions (r=0.62) which means that industrial zones in certain regions are active and do not have a post-industrial character or these areas has recovered into different functions.

Type 5 is the smallest group of post-industrial regions in terms of covered area—only 0.2% of EU-25 area. However population that lives in this cluster is equal 5% of total EU-25 population. The group comprises 14 urban units of such cities as e.g. Prague, Budapest, Warsaw, Berlin or Vienna. The highest population density and share of economically active population were main factors combining regions into this cluster. Mean population density is eight times greater than mean for all EU-25 regions (2,977 vs. 372 in 2002) (Table 5). The population was strongly decreasing up to 2001 but this trend has been stopped (Fig. 4). The decrease of population density was partly an effect of negative values of natural population growth and likely outflow migrations. Presently social issues are well balanced in the regions—crude birth rate is equal to crude death rate, share of economically active population is high (48.56% comparing to mean 45.8% for all EU-25 regions) (Table 5). However further growth of economically active population may affect labour market raising unemployment. Presently unemployment rate is low (mean 7.8%) and balanced—with similar values for male and females unemployment. There is no clear temporal trend for unemployment rate, however slight increase has been observed since 2001 (Fig. 3). Mean gross domestic product value exceeds mean within all

EU-25 regions by approx. 15%, but it needs to be noted that there is a large variability inside this group. Employment in industry is the lowest between all clusters—mean value 17.65% of economically active population (Table 5) with strong decrease observed between 1999 and 2002.

Type 6 represents 8.28% of total EU population consisting with 34 regions that cover 5.3% of EU-25 territory (Table 4). The group comprises 17 French regions, all post-industrial regions of Belgium, northern Spanish regions and few NUTS from Italy and UK. The regions are relatively less dense with post-industrial sites, their density is comparable to type 2. Similarly to type 4, share of economically active population is low (43.5% of total population whereas the mean for all EU regions is 45.8%) (Table 5). Population density is far below mean for all EU regions—210 and 372 inhabitants per square kilometre, respectively (Table 5). Population has been increasing over last decade (Fig. 4). This was likely an effect of inflow migrations since natural population growth was very little above 0 within this period. Unemployment level is similar to the mean for all EU regions (9.4%). Similarly to type 4, large difference is observed between unemployment statistics for male and female (Table 5). Total unemployment rate decreased between 1999 and 2001 from 12% to 9% and remained at this level to the end of the period for which the data is available (2004). Mean GDP value is similar to that of type 5 and slightly higher than mean for all EU regions (20,062 and 18,627, respectively) (Table 5). Significant negative correlation between GDP and the density of post-industrial sites ($r=-0.39$) indicates that post industrial areas of these regions face economic problems and may require structural changes.

Sensitivity issues

A sensitivity can be defined in a different manner, however in the context of this paper it is understood as a risk for social, environmental or economic instability (non-sustainability) relevant to a spatial unit of interest (natural e.g. watershed or administrative e.g. NUTS region). Sensitivity can be a product of interactions between political, economic and social factors in a given timeframe and given geographic location, which are controlling a vulnerability of the ecosystem, and humans to existing pressures and conflicts. Environmental sensitivity can be defined as a magnitude of ecosystem responses to above external factors which can cause degradation impeding its functions—erosion, contamination etc. An example of social sensitivity is a response to environmental or economic changes, occurring in the post-industrial region, leading to unemployment, lack of social coherence and to social exclusion. Many post industrial areas which were exposed to a sudden and dramatic economic transition, prompted by the collapse of traditional industrial structures have been facing both environmental and social sensitivities (Thornton et al. 2007). A pace of social and environmental recovery may vary greatly, from one region to another, depending on the strength of economy, ability to attract investment of high tech industry and non-industrial service sectors. Usually post-industrial regions have a good growth potential related to high population density which creates a substantial amount of market opportunities. Obstacles however, may come from a poor infrastructure and a limited adaptation skills of traditional industrial sectors' employees such as mining and smelting—this is particularly relevant to some of the new member states. In general, however, these areas concentrate a tremendous amount of technical expertise which can be mobilized by proper re-training. On the environmental side, rate of recovery process strongly depends on the magnitude of environmental damage, density of historical pollution sources such as dumps and abandoned industrial sites, and the level of risk manifested by these sites.

Ten variables have been selected based on all available data sources as potential indicators of sustainability within post-industrial regions (Table 6). An approach we used to identify sustainability issues was focused on types of post-industrial regions recognizing that each type is more or less homogenous unit and regions belonging to each group are representing a similar set of socioeconomic and environmental properties. Since the data for sensitivity issues defined in the EU guidelines (European Commission 2005) were very scarce only a basic set of parameters was analyzed to address major problems. This is certainly a limitation with regard to the scope of intended characterization of problems occurring in postindustrial zones but on the other hand basic indicators which are covered usually correlate with other variables which are not covered—e.g.

Table 6 Sensitivity indicators within different types of post-industrial regions (X in type column means sensitivity of a given indicator within this type)

Indicator	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Economic						
GDP	X			X		
Social						
Unemployment rate	X			X		
Unemployment under 25	X			X		
Female unemployment				X		
Population density decline	X				X	
Negative natural population growth	X					
Low share of active population				X		X
Environmental						
Gaseous emissions	No data		X		X	
Metal emissions	No data			X	X	
Organic compounds emissions	No data				X	
Dump sites density	X				X	
Landscape diversity				X		

unemployment rate of women can be indicative of poor inclusion and protection of particular groups of the society—if percentage of female unemployment greatly exceeds that of man social coherence is evidently at risk.

Also environmental data are limited and therefore we used some aggregated indicators such landscape metrics as surrogates indicative of biodiversity—it is generally well accepted that low values of landscape metrics reflect "monolithic" landscapes with a simple pattern of limited number of land use classes. This may suggest a limited buffering capacity of the ecosystem and high vulnerability to degradation. Some landscape metrics well reflect species biodiversity within a landscape (Dauber et al. 2003; Honnay et al. 2003).

We qualitatively identify key sustainability issues within types of postindustrial areas of the EU-25. Matrix presented in Table 6 shows problems which are crucial for social and environmental stability within different types and available indicators reflect high potential for unfavorable development concerning issues marked with X. The way a specific issue was identified as unfavorable was by comparing the status of indicator characterizing this issue with a mean value for non-industrial areas or that of EU. For example, in eastern and southern postindustrial types (1 and 4) there is a dramatically higher unemployment in all age groups but in particular under the age of 25, relative to the EU (Table 5). Moreover this is also apparent in strong negative trends of unemployment in some of these areas—other groups demonstrate significantly different behavior in terms of unemployment status, which is lower even by more than two folds, and in terms of a better stability of the workforce as indicated by unemployment changes over observed period.

Bulgaria and Romania that became EU members in 2007 were not included in post-industrial type classification due to data limitations. However all post-industrial regions of these two countries can be defined as sensitive as their GDP was twice lower than that of Eastern EU post-industrial units.

As already mentioned economic variables were poorly represented within available data, however, GDP can serve as an aggregated indicator of economy's strength and social welfare (Islam and Clarke 2002). This variable is a measure of consumption, investments and governmental expenditures. GDP is defined as the market value of all final goods and services produced within a region in a given period of time (UNSNA 1993).

Drastic differences were observed between EU-25 regions. Mean GDP in group 1 was 3.5 times lower than mean value for all EU regions (Table 5). This reflects weakness of transitional economy of Eastern postindustrial regions located in new member states. Low GDP was also recognized as a sensitivity issue in southern type 4, combining mostly regions in Italy, Spain, Greece, Southern France and Portugal.

Unemployment rate is a common variable describing social status of a community. It is a number of unemployed workers divided by total labour force. It is not only an indicator of social status of society but in long term, a driving force for weakness of economy, poverty increase or even crime (Carmichael and Ward 2001). Both unemployment rate and temporal trends of unemployment might be used as indicators of sustainability. Total unemployment rate and unemployment rate under 25 in groups 1 and 4 drastically exceed mean values for all EU-25 regions (Table 5). Wide differences between male and females unemployment were observed in regions of type 4 and 6 (Table 5). This indicates unequal right of women and limited access to employment opportunities—in such social conditions an equality of treatment is at stake.

Low share of economically active population is an indicator of ageing of population. In a long run this may affect economic growth, reduce competitiveness and labour market. Southern and western socially weak groups of regions (4 and 6) face a serious risk for a labour force decline as the percentage of economically active population in these regions is significantly lower than in the EU-25 and even relative to other postindustrial regions.

Negative natural population growth is a robust indicator of a future potential of the economy and social stability including pension system, social and health expenditure, etc. There is a dramatic risk for a demographic crisis within eastern postindustrial regions where population growth is negative as oppose to slightly positive growth in the entire EU—moreover it continued declining over the last decade.

Table 7 Total emissions of various groups of contaminants in regions classified as various types of post-industrial regions

Area	Number of facilities	Gases	Organic compounds	Metals
	nr/1,000 km^2	Tonnes/km^2 year		kg/km^2 year
Type 1	No data	No data	No data	No data
Type 2	3.10	380	0.20	1.8
Type 3	3.85	1,697	0.27	3.1
Type 4	1.24	1,148	0.09	8.1
Type 5	27.1	3,507	2.75	13.3
Type 6	3.33	732	0.16	5.0
Other areas	0.82	194	0.10	0.8

Table 8 Density of delineated post-industrial sites, mineral extraction and dump sites within various types of post-industrial regions expressed as percent of total area

Area	Delineated post-industrial objects	Mineral extraction sites	Dump sites
Type 1	0.69	0.32	0.19
Type 2	0.91	0.22	0.01
Type 3	1.19	0.39	0.08
Type 4	0.56	0.45	0.03
Type 5	7.50	0.19	0.21
Type 6	0.84	0.27	0.03
Other areas	0.18	0.07	0.01

As mentioned, gaseous, organic and metal emissions were taken from EPER database which is accounting for more than 90% of industrial emissions in Europe. Table 7 shows a summary of total emissions of gaseous and organic pollutants covered by the database in tonnes per square kilometre per year, as well as heavy metals in kilogram per square kilometre per year in the six postindustrial groups of regions and other non-industrial areas, serving as a reference. There is no data for new member states, however. These emission data indicate that regions of type 4 and 5 for are under certain pressure of metal emissions to the environment. In urban regions (type 5) however, it overlaps with considerable emissions of gaseous and organic compounds, at a much higher than in the EU and as compared to other industrial regions (Table 7).

Dump sites density calculated based on the CORINE data supplements indicators of anthropogenic pressures related to industry and urbanization on the ecosystem. Eastern postindustrial regions grouped in type 1 and urban type 5 represent the

Table 9 Landscape metrics calculated within various types of post-industrial regions

Area	Edge density	Shannon diversity index	Patch density
Type 1	24.1	1.36	0.40
Type 2	19.8	1.37	0.28
Type 3	21.0	1.34	0.34
Type 4	16.0	1.34	0.21
Type 5	17.8	1.17	0.33
Type 6	17.8	1.17	0.33
EU 25	19.9	1.23	0.29

highest density of dump sites (Table 8). In case of eastern regions this confirms a long term poor management of waste which was not regulated for decades and industrial development was at the expense of environmental quality—the dump density here is almost 20 times higher as compared to non-industrial areas and over two times higher relative to western socially and economically strong postindustrial regions (type 3). In urban regions dump sites density is even higher, however this is to be expected as these areas are highly populated and these sites are likely to be of municipal character.

Analysis of landscape metrics puts some light on the landscape quality in analyzed regions. Data summarized in Table 9 allows for an assessment of landscape diversity, which is indicative of biodiversity and buffering capacity of a land. Complex and diverse landscape may enhance protection against various degradation processes such as erosion, eutrophication or loss of species habitats. Landscape pattern has been recognized to strongly affect landscape biodiversity measures such as species richness (Dauber et al. 2003; Honnay et al. 2003; Ernoult et al. 2006). Comparing metrics calculated within six groups of post-industrial regions does not show tremendous differences, however diversity was the lowest for groups 4 as shown by low values of patch and edge density (Table 9). There may be significant differences and changes over time on a sub-regional or a local level (Herzog et al. 2001; Ernoult et al. 2006; Hahs and McDonnell 2006) but it is not depicted in this analysis which is intended to detect important European trends.

Summarizing, a development of postindustrial society in Europe represents a strong geographic diversity. There are distinct historical and current differences between regions which form major types, comprising similar internal characteristics and definable trends in environmental and socioeconomic sense. These types can be well defined for their social and economic strength or weaknesses, as well as environmental quality. Distinguishing between postindustrial and other regular areas throughout the EU-25, and making it spatially explicit is somewhat subjective, however it appears that CORINE land cover, after a proper treatment can serve as a reliable source of information. It seems that high density of dump sites around industrial/commercial areas can be used as a practical indicator of post-industrial nature of the area of interest. Regions grouped into postindustrial types are fundamentally different from the European average, and are facing specific problems related to global market and political changes. In a subsequent paper land use changes and their driving forces in EU post-industrial regions will be discussed.

Geographically there is a visible divine between southern, western and eastern EU. Eastern postindustrial regions can be characterized as socially and economically weak, exhibiting high unemployment rate, low GDP, negative population growth and a strong environmental pressure, represented by a high density of dump sites. A positive trend in this region is a fast growth of GDP attracting investment and creating new jobs. Similarly, southern postindustrial regions demonstrate a social instability related to ageing population unequal opportunities of some social groups, such as women, and a serous risk for social marginalization, among younger generation which does not have an adequate access to employment. Regions in eastern and southern Europe are areas of concern for social and environmental reasons and these may require more attention and specific polices facilitating their recovery and better social and economic coherence. Most of the western EU postindustrial areas have been successfully recovered and moved into new economy as shown by most of the indicators. In urban postindustrial zones, however, emission sources of pollutants seem to continually be a major problem—not necessarily in terms of exceeding thresholds, but trough a remarkable difference in the amount of pollutants produced relative to other regions.

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