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EXPLORATORY DATA ANALYSIS OF ENVIRONMENTAL GOVERNANCE AT LOCAL LEVEL IN THE SOUTH-WEST REGION OF POLAND

EKSPLORACYJNA ANALIZA ŁADU ŚRODOWISKOWEGO NA POZIOMIE LOKALNYM W POŁUDNIOWO-ZACHODNIM REGIONIE POLSKI

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Summary: Conducting integrated measures within the framework of sustainable development requires an objective identification of the needs for their implementation based on the results of multifaceted analyses of many complex, interrelated factors reflecting the state of the natural environment and the economic and demographic situation. The increasing functionality of Geographic Information Systems (GIS), has made GIS databases a tool supporting the implementation of sustainable development activities. The aim of the study was to recognise the spatial variability of the level of environmental governance in the south-west region of Poland. Methods of research on multidimensional data mining techniques and geo-spatial analyses were applied, resulting in a theoretical model describing the regularities in the relationships between the analysed indicators of environmental governance. The level of environmental governance was most strongly determined by indicators concerning climate change and biodiversity.

Keywords: environmental order, sustainable development, exploratory data analysis, spatial analysis, GIS.

Streszczenie: Prowadzenie zintegrowanych działań w ramach zrównoważonego rozwoju wymaga obiektywnego rozpoznania potrzeb ich wdrażania na podstawie wyników kompleksowych analiz wielu złożonych, powiązanych ze sobą czynników odzwierciedlających stan środowiska przyrodniczego i sytuację ekonomiczno-demograficzną. Wzrastająca funkcjonalność Systemów Informacji Geograficznej (GIS) spowodowała, że bazy danych GIS stały się narzędziem wspierającym implementację działań z zakresu zrównoważonego rozwoju. Celem pracy było rozpoznanie zmienności przestrzennej poziomu ładu środowiskowego w południowo-zachodnim regionie Polski. Zastosowano metody badań z zakresu wielowymiarowych technik eksploracji danych i analizy geoprzestrzenne, w wyniku których otrzymano teoretyczny model opisujący prawidłowości w zależnościach między analizowanymi wskaźnikami ładu środowiskowego. Poziom ładu środowiskowego najsilniej determinowały wskaźniki dotyczące zmian klimatu oraz bioróżnorodności.

Słowa kluczowe: ład środowiskowy, zrównoważony rozwój, eksploracyjna analiza danych, analizy przestrzenne, GIS.

1. Introduction

Sustainable development is one of the most important challenges in today's world. It is a process of complex changes that seek to ensure sufficiently high ecological, economic as well as social and cultural standards for all people living today and for future generations, applying the principle of intra-generational and inter-generational justice [Rogall 2010].

The current action plan for achieving sustainable development is the "2030 Sustainable Development Agenda" which sets out 17 headline goals (Sustainable Development Goals) and 169 sub-goals, which determine the three dimensions of sustainable development: economic, social and environmental. In Poland, sustainable development policy is implemented on the basis of the "Strategy for Responsible Development" (Strategia na rzecz Odpowiedzialnego Rozwoju), which is the overarching strategic document containing a development model for Poland, consistent with the vision of the world as defined in the Agenda by the United Nations.

Modern practice and science has many tools to monitor the implementation of the concept of sustainable development, using many sub-indicators taking into account the specifications of the region in terms of environmental protection, quality of life, economy and resources of the region, culture and tradition [Bartniczak 2012; Czarski (ed.) 2011]. The difficulties, however, concern insufficient modern mechanisms that would serve the purpose of a comprehensive analysis of these factors [Wiatkowska, Słodczyk 2018]. Monitoring the level of sustainable development in the context of its governance and making strategic decisions requires taking into account many complex and interrelated factors and their arrangements in geographic space. It is therefore necessary to transform the primary data and acquire new, useful spatial information that is invisible or difficult to recognise when analysing large primary data sets [GIS… 2007; Fiedukowicz et al. 2015]. Many of the issues impacting sustainable development can be analysed, modelled, and mapped within a geographic context, which in turn can provide the integrative framework necessary for global collaboration [Scott, Rajabifard 2017]. It is also necessary to take steps towards the rational shaping of sustainable development, taking into account and implementing the results of these analyses. Sustainable integration of sustainable development governance is facilitated by integrated actions, which should be implemented through sectoral policies and development programmes in the region, resulting in an improved quality of life [Heffner, Malik 2011].

A broadly applicable analytical tool for monitoring and achieving sustainable development objectives is the dynamically expanding Geographic Information Systems (GIS) [Băneş 2007; Scott, Rajabifard 2017]. These systems collect and integrate spatial data from various sources and enable the application of various analyses and operations on the data in the form of spatial queries, resulting in digital models presenting selected features of the geographic world [Longley et al. 2005; Gotlib et al. 2007; Sugumaran, DeGroote 2011; Urbański 2012; Olszewski 2013]. One of the techniques of acquiring new information from the data sets collected in the geo-base is Spatial Data Mining, which combines the capabilities of GIS packages and advanced statistical programmes [Perumal et al. 2015; Fiedukowicz 2015].

However, despite significant progress in geo-information technology, there is still a lack of awareness, understanding and dissemination of the role of geo-spatial information on a larger scale, in particular at the level of sustainable development decision-making [Scott, Rajabifard 2017]. In a very rich data and technology-driven global environment, there has been very little fusion between sustainable development and geo-spatial information, such as National Spatial Data Infrastructures [Pesch 2014].

The aim of the study was an exploratory analysis and assessment of the level of environmental governance in districts located in the south-west region of Poland, in the aspect of the implementation of the concept of sustainable development. The assessment included an analysis of sustainable development indicators of the following thematic areas: climate change, energy consumption, air protection, land exploitation, biodiversity and waste management. Indicators and metadata characterising environmental governance were obtained from the platform reporting sustainable development indicators developed by the Polish Central Statistical Office (GUS) and from the Corine Land Cover CLC database with respect to land cover and land exploitation forms and from the database of forms of nature protection. Those data were collected in the GIS Environmental Governance database developed for the purpose of this work and implemented in ArcGIS 10.6. A typology of the studied area was prepared due to the spatial variability of the sub-indicators of the environmental governance, and a theoretical model describing the regularities occurring between the analysed indicators was developed.

2. Study area

The spatial scope of the study included 30 districts of Lower Silesia Province and 12 districts of Opolskie Province, which are located in the south-western region of Poland (Figure 1). These areas are spatially differentiated in terms of environmental and demographic conditions and the level of social and economic development (Figures 2 to 4).

Figure 1. Location of the study area

Source: own study based on http://www.gugik.gov.pl/geodezja-i-kartografia/pzgik/dane-bez-oplat/dane-z-panstwowego-rejestru-granic-i-powierzchni-jednostek-podzialow-terytorialnych-kraju-prg.

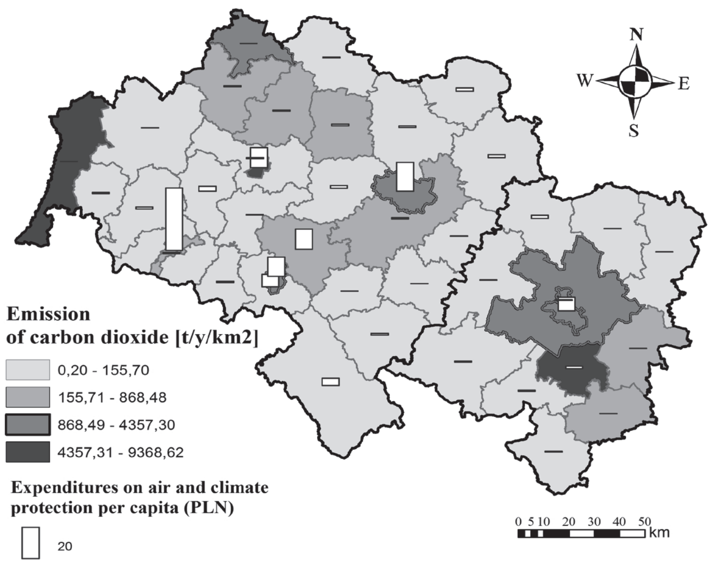

Figure 2. Spatial diversity of expenditure on air and climate protection against the background of emission of carbon dioxide

Source: own work on the basis of the GIS Environmental Governance Database.

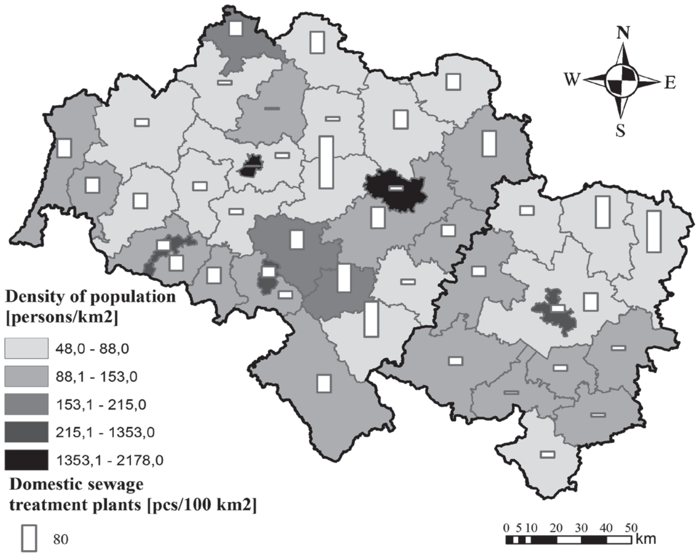

Figure 3. Spatial diversity of domestic sewage treatment plants against the background of density of population

Source: own work on the basis of the GIS Environmental Governance Database.

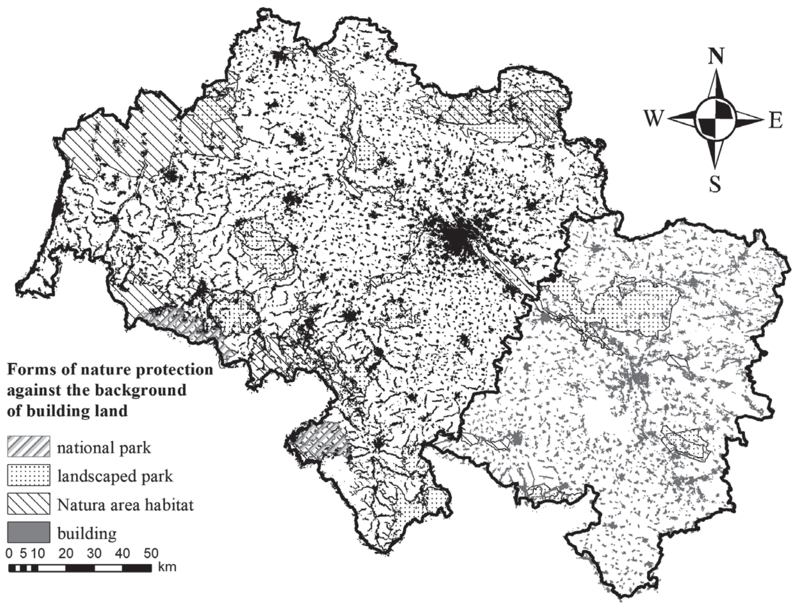

Figure 4. Spatial diversity of forms of nature protection against the background of building land

Source: own work on the basis of the GIS Environmental Governance Database.

3. Materials and methods

3.1. Data sources

The subject of multidimensional spatial analyses were the components of environmental governance characterised by fifteen sub-indicators, i.e. climate change, energy consumption, air protection, land exploitation, biodiversity and waste management, etc. (Table1).

Table 1. Set of partial indicators of the local level environmental order classified by thematic areas

Indicators of thematic areas	**Unit**
Climate change	
• Emission of carbon dioxide from particularly onerous industrial plants *per* km^2 of the total area of a district	t/y/km^2
• Commune expenditures on the protection of atmospheric air and climate *per capita*	PLN
Energy	
• Electricity consumption *per capita*	kWh
Air protection	
• Emission of gaseous pollutants from particularly onerous industrial plants per km^2 of the total area of a district	t/y/km^2
• Dust emission from particularly onerous industrial plants *per* km^2 of the total area of a district	t/y/km^2
• Share of gaseous pollutants (without CO_2) retained or neutralised in pollution abatement equipment in particularly onerous industrial plants in the overall amount of generated pollutants	%
• Share of dust retained or neutralised in pollution abatement equipment in particularly onerous industrial plants in the overall amount of generated pollutants	%
Land use	
• Share of forest areas in the total area of a district	%
Biodiversity	
• Share of legally protected areas in the total area of a district	%
• Share of green areas in the total area of a district	%
Waste management	
• Amount of mixed municipal waste from households collected within a year *per capita*	kg
• Share of urban and industrial wastewater treated in the overall amount of wastewater requiring treatment	%
• Number of domestic sewage treatment plants *per* 100 km^2 of the total area of a district	pcs/100 km^2
• Number of illegal landfill sites *per* 100 km^2 of the total area of a district	pcs/100 km^2
• Area of illegal landfill sites *per* 100 km^2 of the total area of a district	m^2

Source: own work based on [*Wskaźniki*… 2016].

In order to identify spatial variability and the structures created in the analysed area by environmental indicators conditioning the sustainable development of districts located in the south-west region of Poland and to present the results obtained in the form of geo-visualisation, spatial data in descriptive and vector forms were obtained from the following GIS databases:

- Database of Sustainability Indicators (Baza Wskaźników Zrównoważonego Rozwoju) for descriptive data and metadata on environmental governance indicators at local level (NTS4) in 2016, grouped by thematic areas corresponding to the directions of sustainable development monitoring in the European Union. Data from this database were obtained from the platform of Polish Central Statistical Office (Główny Urząd Statystyczny − GUS, http://wskaznikizrp.stat.gov.pl/info.jsf?poziom=lokal&parametr_inf=ml&symbol_wsk=&jezyk=en&panel=_offline);
- Database of National Register of Borders and Areas of the State Territorial Division Unit (Państwowy Rejestr Granic i Powierzchni Jednostek Podziałów Terytorialnych Kraju − PRG) [s] in the scope of data determining the course of borders and areas of administrative units, made available by Polish Head Office of Geodesy and Cartography (Główny Urząd Geodezji i Kartografii, http://www.gugik.gov.pl/geodezja-i-kartografia/pzgik/dane-bez-oplat/dane-z-panstwowego-rejestru-granic-i-powierzchni-jednostek-podzialow-terytorialnych-kraju-prg);
- Corine Land Cover (CLC) database on land cover and land exploitation, made available by the European Environmental Agency (EEA) on the Copernicus Land Monitoring Services (http://land.copernicus.eu/pan-european/corine-land-cover);
- Database of forms of nature protection obtained from Polish General Directorate for Environmental Protection (Generalna Dyrekcja Ochrony Środowiska) geo-service (https://www.gdos.gov.pl/dane-i-metadane);
- Polish Local Data Bank (Bank Danych Lokalnych − BDL) descriptive data and metadata on the economic, demographic, social and environmental situation made available by the API GUS, Portal of the Polish Central Statistical Office (http://api.stat.gov.pl/) as a source of data for geo-spatial analyses [Dygaszewicz 2012].

3.2. Data analysis

The article uses multidimensional data mining techniques and spatial analyses aimed at recognising the variability and structure of the factors determining the level of environmental governance of districts located in the south-west region of Poland in terms of their sustainable development.

The analysis of this complex phenomenon, described by a larger number of sub-indicators, was carried out according to several research stages. The first stage concerned the development of the GIS Environmental Governance database which was fed with spatial data and descriptive attributes obtained from external GIS databases. A relational data model was adopted, based on the entity representing individual research objects and their attributes [Longley et al. 2005]. The data were organised in the form of the following information layers: administrative division, environmental governance indicators, forms of land cover and GUS (Polish Central Statistical Office) data implemented in the ArcGIS Esri 10.6 programme. In order to identify spatial relations and attribute relationships between objects, overlay analyses were used to combine objects and attributes from several layers [Urbański 2012].

The next step was the verification of the sub-indicators of environmental governance in terms of their statistical variability, furthermore descriptive statistics and distribution measures were calculated [Statistics… 2011]. Irrelevant indicators that did not describe the study area in an objective manner, for which the coefficient of variation was lower than 10%, were eliminated. Indicators that were in high correlation with other indicators and for which the Pearson correlation coefficient was higher than 0.7 at the assumed materiality level $\alpha \leq 0.05$ were also rejected [Młodak 2006]. Subsequently, the sub-indicators of environmental governance were divided into stimulants and destimulants*, which were normalised. For this purpose the zero unitarisation method was used; see formula (1) [Kukuła 2000]:

$$Z_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \qquad Z_{ij}^* = \frac{\max_i x_{ij} - x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \tag{1}$$

where: Z_{ij} – normalised value of indicator j (j = 1, 2, …, n = 13) for district i (i = 1, 2, …, m = 42), $min\ \{x_{ij}\}$ – minimum value of the j-th indicator of environmental governance, $max\ \{x_{ij}\}$ – maximum value of the j-th indicator of environmental governance.

As a result of the transformation of the primary indicators, value “1” was assigned to the district with the highest value of the j^{th} indicator, and value “0” – to the area with the lowest value of the indicator. The normalised space of the set of sub-indicators was the basis for the construction of a synthetic environmental governance indicator (Q_i) for each district. For this purpose the method of non-model construction of synthetic measure was used, see formula (2):

$$Q_i = \sum_{j=1}^{n} Z_{ij} \tag{2}$$

where: Z_{ij} – normalised value of the partial indicator j (j = 1, 2,…, n = 13) in the i-th district.

The obtained results were interpreted as the average value of the optimal values achieved by districts in the south-west region of Poland. Then, on the basis of statistical criteria using the arithmetic mean and standard deviation, the classification of districts was made with regard to the level of the analysed phenomenon. Class I included districts with a high level of synthetic environmental governance measure while classes II, III and IV were districts with a medium, medium-low and low level of environmental governance respectively.

The strength of the influence of particular sub-indicators on the level of environmental governance in the studied area was also analysed. For this purpose, Principal Component Analysis (PCA) was applied, which is a tool for exploratory data analysis which enables the reduction in many variables by transforming them into mutually orthogonal, new independent variables. A theoretical model has been developed to describe the structure of relationships between the tested attributes [Statistics… 2011]. The number of main components was identified on the basis of Kaiser's criterion, according to which for further analyses the components corresponding to own values greater than 1 were taken into account. The interpretation of the components was made on the basis of the analysis of factorial loads, which expressed the contribution of a given sub-indicator of environmental governance to the individual components of the main components.

On the basis of the sub-indicators of environmental governance, an analysis of the similarity of districts of the examined region was also made, due to the spatial variability of these indicators. For this purpose cluster analysis was used, which is also a tool for exploratory data analysis and consists in classifying objects into the most internally homogeneous classes possible [Panek 2009]. Grouping by the k-means method was applied, as a result of which *k*-clusters of districts differing from one another by sub-indicators of environmental governance were formed to the greatest extent possible and which do not constitute sub-clusters of other clusters. One of the metrics, namely the Euclidean distance [Kolenda 2006], was used as the coefficient of similarity of the analysed areas.

4. Results

4.1. Differentiation in level of environmental governance in the south-west region of Poland

Statistical analysis of the sub-indicators of environmental governance in terms of their diagnostic properties showed that these indicators were characterised by different degrees of differentiation (Table 2). The following indicators were characterised by greater differentiation: carbon dioxide emissions (X1), expenditure on air and climate protection (X2), dust pollution emissions (X4), reduction in gaseous pollutants (X5), legally protected areas (X8), green areas (X9), onsite waste water treatment systems (X12) and illegal landfill sites (X13). For these indicators, the coefficient of variation was much higher than the coefficient of variation for the other indicators, and the values of these indicators were more scattered around the average value (Table 2).

Table 2. Descriptive characteristics of partial indicators of environmental governance

Indicators	Min.	Max.	Range	Average	Standard deviation	Coefficient of variation
X1 Emission of carbon dioxide	0.20	9368.62	9368.42	1160.83	2351.12	202.54
X2 Expenditure on air protection	0.02	40.77	40.75	3.51	7.33	208.88
X3 Electricity consumption	613.8	1052.00	438.20	745.78	84.36	11.31
X4 Emission of dust pollutants	0.00	1.26	1.26	0.19	0.31	157.13
X5 Reduction of gaseous pollutants	0.10	98.80	98.70	27.18	30.94	113.83
X6 Reduction of dust pollutants	16.70	100.00	83.30	87.55	21.21	24.23
X7 Forest cover	4.10	59.10	55.00	26.47	12.98	49.03
X8 Legally protected areas	0.15	70.51	70.36	18.69	17.61	94.21
X9 Green areas	0.10	5.10	5.00	0.58	1.14	195.46
X10 Municipal waste	113.7	291.10	177.40	191.02	36.82	19.28
X11 Treated wastewater	46.23	100.00	53.77	97.01	10.92	11.26
X12 Domestic sewage treatment plants	1.79	174.15	172.36	46.34	37.54	81.01
X13 Illegal landfill sites	0.00	24155.00	24155.00	2844.17	4625.06	162.62

Source: own work on the basis of the GIS Environmental Governance Database.

Analysis of the correlation between environmental governance indicators showed that some indicators were highly correlated at the materiality level of $p \leq 0.05$. The indicator of gaseous pollutant emissions was highly correlated (0.99) with, inter alia, the indicator of carbon dioxide emissions. Indicators such as the number of illegal landfill sites and the area of illegal landfill sites were also significantly correlated (0.85). For further analysis, the indicator of gaseous pollutant emissions and the number of illegal landfill sites were not taken into account.

The south-west region of Poland is spatially diversified in terms of a synthetic indicator of environmental governance (Figure 5). High synthetic environmental governance index (Class I), characterised by districts that constitute 25.08% (7364 km^2 [2843.5 mi^2]) of the analysed region, i.e.: Wałbrzyski, Milicki, Kłodzki, Górowski and Jelenia Góra (Lower Silesia Province) as well as Strzelecki, Oleski, and Opolski (Opolskie Province). The high value of the synthetic environmental governance indicator in those areas was affected by low carbon dioxide and dust emission, a significant share in treated municipal and industrial wastewater as well as a small area of illegal landfill sites and low electricity consumption. In order to protect the climate, it is necessary to further reduce the emission of greenhouse gases because by 2020 in Poland the level of reduction is expected to increase to 40% [Czarski (ed.) 2011].

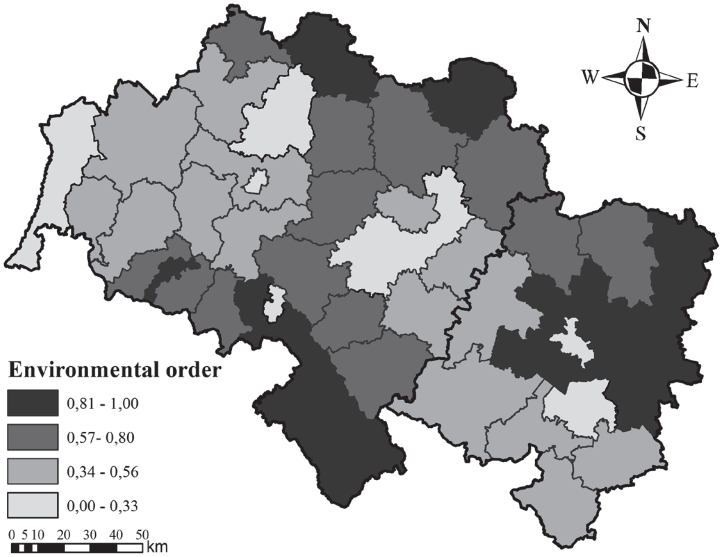

Figure 5. Spatial diversity of the synthetic indicator of environmental governance

Source: own work on the basis of the GIS Environmental Governance Database.

The average synthetic indicator of environmental governance (Class II) is characterised by districts which constitute 27.46% (8062 km^2 [3113 mi^2]) of the analysed region. On the other hand, the accumulation of unfavourable environmental governance phenomena occurs in the following districts: Zgorzelecki, Wrocławski, Lubiński, as well as in Legnica and Wałbrzych (Lower Silesia Province); Krapkowicki and Opole (Opolskie Province), which constitutes 13.53% (3973 km^2 [1534 mi^2]) of the analysed area (Figure 5).

4.2. Determinants of the level of environmental governance in the south-west region of Poland

The Principal Component Analysis (PCA) showed that the level of environmental governance in the districts located in the south-west region of Poland differentiated the indicators related to the first five main components, which corresponded to own values greater than 1. These components explained 70.20% of the total volatility of the analysed indicators (Table 3, Figure 6).

The analysis of the values of factorial loads shows that the level of environmental governance in the south-west region of Poland was most strongly determined by the indicators related to climate change, i.e. carbon dioxide emissions (X1) and

Table 3. Factor loads, eigenvalues, variance percentage and cumulative variance percentage of obtained components for indicators of environmental governance

Indicators	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
X1 Emission of carbon dioxide	**–0.76**	0.24	0.23	–0.19	–0.27
X2 Expenditures on air protection	**0.54**	–0.20	0.11	–0.23	0.08
X3 Electricity consumption	–0.15	–0.36	0.15	**–0.46**	–0.38
X4 Emission of dust pollutants	**–0.82**	0.17	0.24	0.03	–0.05
X5 Reduction of gaseous pollutants	0.37	**–0.66**	0.37	0.01	0.29
X6 Reduction of dust pollutants	0.43	**0.55**	–0.44	0.22	–0.01
X7 Forest cover	–0.40	–0.37	**–0.63**	0.03	0.31
X8 Legally protected areas	–0.45	**–0.52**	0.12	0.34	0.16
X9 Green areas	**0.85**	–0.15	0.11	–0.25	0.07
X10 Municipal waste	**–0.65**	–0.44	–0.13	0.18	–0.12
X11 Treated wastewater	0.31	0.27	0.49	**0.58**	–0.14
X12 Domestic sewage treatment plants	–0.33	0.26	0.31	0.04	**0.66**
X13 Illegal landfill sites	–0.35	0.47	0.08	**–0.48**	0.38
Eigenvalues	3.72	1.98	1.25	1.13	1.05
Explained part of variability of accessions [%]	28.59	15.21	9.64	8.68	8.08
Cumulative part of variability [%]	28.59	43.80	53.44	62.13	70.20

Source: own work on the basis of the GIS Environmental Governance Database.

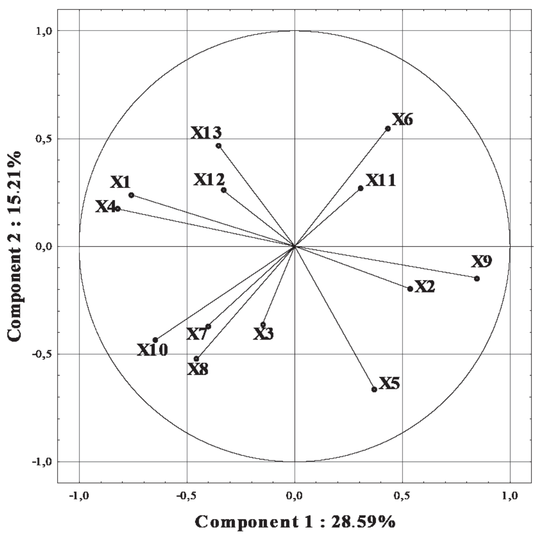

Figure 6. Plot of the scatter in space of the first and second principal component of environmental governance indicators

Source: own work on the basis of the GIS Environmental Governance Database.

expenditure on air and climate protection (X2), dust pollution emissions (X4) and green areas (X9). These indicators were characterised by factorial loads for the first main component and explained 28.59% of the variance (Table 3, Figure 6). The growing demand for energy and the associated emissions of gases responsible for global warming force us to take all legal, technological and investment measures aimed at reducing the amount of energy consumed, and also greenhouse gas emissions [Roszkowska, Karwowska 2014].

On the other hand, indicators concerning air protection, i.e. the reduction in gaseous pollutants (X5) and the reduction in dust pollutants (X6) had high factorial loads for the second component, which can be interpreted as a component of the influence of the amount of retained or neutralised pollutants in plants and factories of high environmental impact on the level of environmental governance. A high share of urbanised and industrial areas has an impact on the natural environment. The types of technological processes carried out and the care taken by industrial plants to install equipment to reduce emitted pollutants [Czarski (ed.) 2011] have a large impact on the state of air purity.

The third component was interpreted as a component of the impact of the forest area (X7) on the level of environmental governance. Maintenance of natural values is very important for ecological and economic reasons and serves to maintain a rich biodiversity [Dobrzański, Dobrzańska 2010].

However the level of environmental governance in the analysed area was slightly affected by factorial loads of the fourth and fifth component, which can be interpreted as a component of the impact of treated municipal and industrial wastewater (X11) and a component of the impact of onsite waste water treatment systems (X12) on the level of environmental governance, respectively. These indicators show the extent to which the generated wastewater is discharged into the environment in compliance with the regulations, and are taken into account in the assessment of the progress in improving water quality in accordance with the Water Framework Directive [Czarski (ed.) 2011].

4.3. Spatial variability of environmental governance components in the south-west region of Poland

The GIS Environmental Governance database, developed for the purpose of this study, also enabled the typology of the districts of the south-west region of Poland in the aspect of their sustainable environmental governance to be developed. The recognition of the specification of each of the four types of areas separated in the taxonomic classification was performed on the basis of the analysis of the values of the average values of synthetic sub-indicators for each cluster (Figure 7) and in relation to the ranges of sub-indicators of environmental governance in real units (Table 4). The results of the clusters analysis are also presented in the form of a typological model, which presents spatial variability and arrangements that are created by factors conditioning the sustainable development of the areas adopted for research (Figure 8).

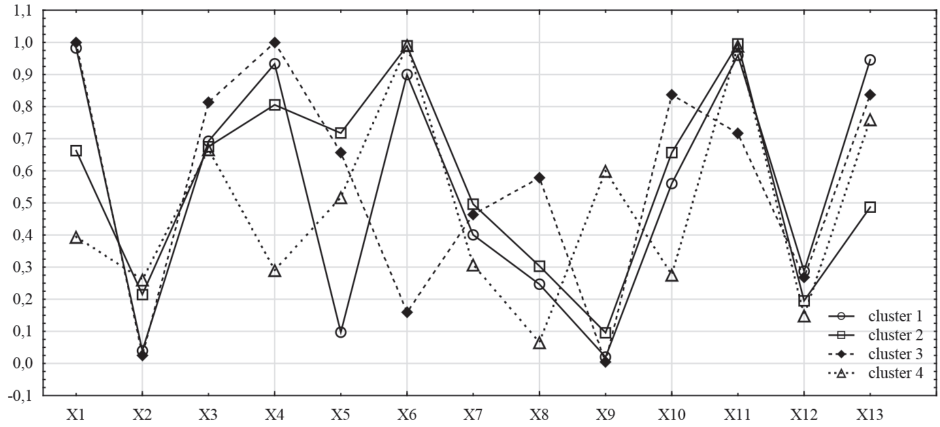

Figure 7. Diagram of average synthetic partial indicators of environmental governance

Source: own work on the basis of the GIS Environmental Governance Database.

Table 4. Ranges of partial indicators in area types

Cluster 1			Cluster 2		Cluster 3		Cluster 4	
min.		max.	min.	max.	min.	max.	min.	max.
Climate change								
X1	0.20	471.34	0.48	34.51	270.82	7868.95	3279.72	9368.62
Energy								
X2	0.02	13.07	0.48	2.00	0.05	40.77	0.12	18.87
Air protection								
X3	646.70	1052.00	613.80	783.50	646.20	912.60	672.00	842.80
X4	0.01	0.52	0.00	0.01	0.03	0.58	0.66	1.26
X5	0.10	60.00	40.00	80.00	52.40	98.30	18.90	98.80
X6	61.70	100.00	16.70	50.00	95.60	100.00	96.90	100.00
Land use								
X7	6.40	59.10	15.60	40.50	21.80	44.40	4.10	48.20
Biodiversity								
X8	0.15	46.19	12.02	70.51	2.80	56.83	0.15	16.93
X9	0.10	0.50	0.10	0.20	0.10	1.60	0.20	5.10
Waste management								
X10	135.00	265.50	113.70	193.10	155.00	207.40	203.60	291.10
X11	46.23	100.00	52.82	100.00	99.53	100.00	97.09	100.00
X12	4.63	174.15	17.20	72.36	12.44	59.26	1.79	61.62
X13	0.00	5883.0	28.00	12976.0	284.00	24155.0	924.00	10588.0

Source: own work on the basis of the GIS Environmental Governance Database.

The most favourable conditions of environmental governance in the aspect of sustainable development are present in the type 3 area (Figure 7, Table 4), to which the following districts were qualified: Legnicki, Lwówecki, Milicki and Górowski (Figure 8). These districts are characterised by, among others, low emission of carbon dioxide and dust pollution, low consumption of electricity, high share of forest areas and legally protected areas, and low expenditures of communes on air and climate protection per capita. The type 4 area is the district of Zgorzelec and the cities of Opole, Legnica, Wałbrzych and Wrocław. They are characterised by high carbon dioxide and dust pollution emission, high electricity consumption, low share of legally protected areas and a large amount of mixed municipal waste from households.

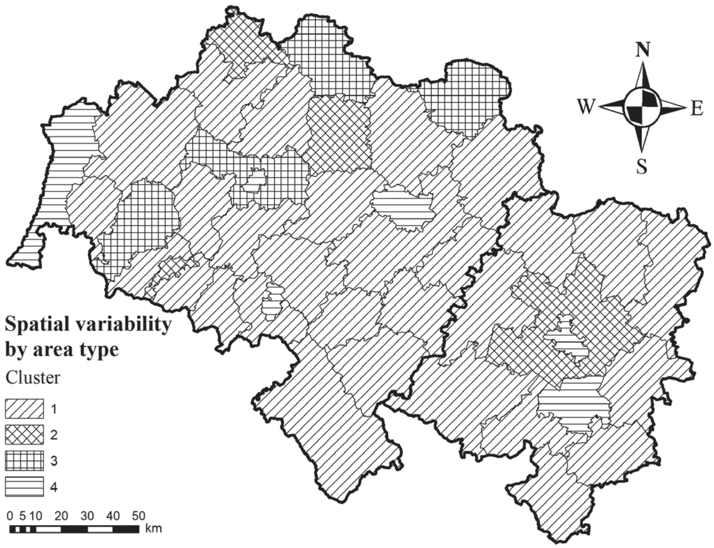

Figure 8. Spatial distribution of districts by area type

Source: own work on the basis of the GIS Environmental Governance Database.

The type 1 area is the largest coherent sub-area, constituting about 72% of the analysed region (Figure 8). This area is characterised by low carbon dioxide and dust pollutants' emissions, the lowest proportion of gaseous pollutants retained or neutralised in industrial plants and factories of high environmental impact on the level of environmental governance, a high proportion of treated municipal and industrial wastewater, the highest number of onsite waste water treatment systems and the lowest proportion of illegal landfill sites.

5. Conclusions

The analysis of the environmental governance of districts located in the south-west region of Poland in terms of their sustainable development, based on sub-indicators, enabled the development of a synthetic measure of development and a comprehensive assessment of the level of the studied phenomenon.

The organisation of many data describing environmental governance in the GIS database and the application of exploratory data analysis methods enabled the analysis of spatial diversity of environmental components and the classification of districts according to the synthetic indicator of the level of environmental governance. The high level of the synthetic indicator of environmental governance is represented only by eight districts, which constitute about 25% of the analysed region. The level of this governance was most strongly determined by indicators related to climate change and biodiversity.

The concept of sustainable development assumes a balance between the sub--indicators. The typology of four sub-areas reflects the local variation in the level of the sub-indicators of environmental governance in the analysed area. The research carried out in this way made it possible to identify both favourable and unfavourable phenomena occurring in the analysed area within the scope of their sustainable environmental governance. The developed cartographic models are a visualisation of not only the state of the studied phenomenon, but also the local structures that create sub-indicators. Both areas, homogeneous in terms of the analysed indicators and characterised by different conditions, require a different scope and direction of activities within local policy and financial support.

The research shows that the presented methodological solutions may be applied not only in the area of environmental governance analysis, but also in other areas of sustainable development such as social and economic governance. The solutions proposed in this work are a useful tool for analysing the complexity of the problems in the implementation of the concept of sustainable development. They enable obtaining new, comprehensive information from the set of the conducted observations, which is necessary at the stage of modelling both its potential and the barriers conditioning sustainable development, taking into account the specificity of the conditions and the resources of a given area.

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