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Spatial Analysis of the Sustainable Development Level in Polish Voivodship: Dynamic Approach

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Abstract. The paper discusses the dynamics of spatial diversity of sustainable development in Poland in the voivodship system. The research into the classification differences in time that include one of the thematic areas under four domains: the environmental one and relate to the green economy concept. The environmental domains include climate change, energy, air pollution, sweet water resources, use of lands, bio-diversity and waste management. The Green Economy concept includes: environmental and resource efficiency, natural assets base, the ecological dimension of quality of life, economic opportunities and political reactions, and a socio-economic context. Missing variables will be selected from the group of sustainable development indicators. In the paper the authors applied the method of ranking the voivodships by means of a synthetic measure that took into consideration groups of variables characterising the examined phenomenon. The study covered selected years from the period of the 2004 - 2016. It seemed worthwhile to demonstrate the dynamics of the classification changes. In the future the study results will be compared with the classification based on the Central Statistical Office's indicators that are still being developed in Poland

1. Introduction

There is a growing scientific literature emphasizing that human populations and economic activity are rapidly approaching and even exceeding the limits of key sub-systems and processes of the global environment, which could lead to abrupt phase changes, or “tipping points” in the Earth system [1,2,3, 4]. This literature has identified nine such processes for which we believe it is necessary to define planetary boundaries: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading. The purpose of establishing these planetary boundaries is to demarcate a “safe operating space for humanity”. The safe operating space places an absolute limit on how much economic activity can safely exploit critical global biophysical subsystems or processes [5]. The concept of sustainable development dates back to the turn of 1960s and 1970s, to the beginnings of the philosophy of eco-development understood as such a process of the desired socio-economic growth that does not compromise human environment in a significant and irreversible way, does not lead to the degradation of the biosphere and does not imperil the laws of nature, economy and culture [6]. The notion of sustainable development is broader as it addresses the issues of economic and social progress and the problems of environmental protection as an integrated and interlinked whole. Such a concept of the development of the Earth was first proposed in the international arena by the United Nations Organization in the Report of the World Commission



on Environment and Development in 1987, and it was further discussed at the Earth Summit in Rio de Janeiro in 1992. The sustainable development was defined as a process of changes that seeks to meet the needs of the present without compromising the development opportunities of future generations. This can be achieved through maintaining the right balance among the natural, human and economic capitals [7, 8]. Sustainable development has become a global concern because of problems of environmental pollution, energy consumption and climate change [9]. One of the first attempts in economics to explain sustainable development was the systems approach, which suggests that sustainability can only be achieved by balancing the tradeoffs among the various goals across environmental, economic and social systems [10-15]. Although conceptually appealing and easy to depict visually, this approach has provided little policy guidance on how to assess the tradeoffs among various system goals or how to determine the welfare implications of such choices [16].

The above indicated implication has become a rationale behind this study, the purpose of which is to identify the spatial diversity of the level of sustainable development in Poland in the voivodships. The research into the classification differences in time that include one of the thematic areas under four domains: the environmental one and relate to the green economy concept. The environmental domains include climate change, energy, air pollution, sweet water resources, use of lands, bio-diversity and waste management. The Green Economy concept includes: environmental and resource efficiency, natural assets base, the ecological dimension of quality of life, economic opportunities and political reactions, and a socio-economic context. Missing variables will be selected from the group of sustainable development indicators. In the paper the authors applied the method of ranking the voivodships by means of a synthetic measure that took into consideration groups of variables characterising the examined phenomenon. The study covered selected years from the period of the 2004 - 2016. It seemed worthwhile to demonstrate the dynamics of the classification changes. In the future the study results will be compared with the classification based on the Central Statistical Office's indicators that are still being developed in Poland.

2. Sustainable development as a concept for the development of the World

The sustainable development is regarded as a joint outcome of targeted processes of changes taking place in several dimensions. In scientific research its three aspects are usually investigated: the social, economic and environmental one, but some researchers approach it at a broader angle, e.g. Adamowicz, Dresler [17]. Sustainable development is a process of changes that seeks to meet the needs of the present without compromising the development opportunities of future generations. This can be achieved through integrated efforts to encourage economic growth and environmental protection. Such a definition of sustainable development was popularized thanks to the Report of the World Commission on Environment and Development: *Our Common Future* by G.H. Brundtland [18]. The idea was further discussed at the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, held in Rio de Janeiro in 1992 where an action plan *Agenda 21* was adopted. *Agenda 21* included the means of development and implementation of sustainable development programmes on the local level [7]. Another milestone in striving for sustainable development was the United Nations Millennium Summit in 2002 where the *Millennium Development Goals* were established following the adoption of the UN *Millennium Declaration* [19]. The achievement of those goals was to allow for successfully facing the challenges of the 21st century by 2015. The decisions of the 1992 Summit were rephrased in Johannesburg at the 2002 World Summit on Sustainable Development (WSSD), known as the Earth Summit 2002, and then in Rio de Janeiro in 2012 (Rio+20) where the declaration *The Future We Want* was adopted [20]. The High Level Panel on the Post-2015 Development Agenda announced recommendations for the next global development plan, inviting eminent persons from all over the world to create a new global partnership to eradicate poverty and transform world economies in accordance with the principles of sustainable development. In 2015 the *Millennium Development Goals* were replaced with the *Sustainable Development Goals* included in the *Transforming Our World: 2030 Agenda for Sustainable Development* proclaimed at the Sustainable Development Summit in New York. The *2030 Agenda* contains a collection of 17 Sustainable

Development Goals and 169 targets monitored by means of adequate indicators [21]. The goals and targets are integrated and indivisible and they balance the three dimensions of sustainable development: the economic, social and environmental (Table 1).

Table 1. Sustainable Development Goals (SDGs)

Nb.	Goals
1	No Poverty: End poverty in all its forms everywhere (Economic)
2	Zero Hunger: End hunger, achieve food security and improved nutrition and promote sustainable agriculture (Economic)
3	Good Health and Well Being: Ensure healthy lives and promote well-being for all at all ages (Social)
4	Quality Education: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (Social)
5	Gender Equality: Achieve gender equality and empower all women and girls (Social)
6	Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all (Economic)
7	Affordable and Clean Energy: Ensure access to affordable, reliable, sustainable and modern energy for all (Economic)
8	Good Jobs and Economic Growth: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Economic)
9	Industry, Innovation and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (Economic)
10	Reduced Inequalities: Reduce inequality within and among countries (Social)
11	Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient and sustainable (Environment)
12	Responsible Consumption and Production: Ensure sustainable consumption and production patterns (Environment)
13	Climate Action: Take urgent action to combat climate change and its impacts (Environment)
14	Life Below Water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development (Environment)
15	Life on Land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (Environment)
16	Peace, Justice and Strong Institutions: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels (Social)
17	Partnerships for the Goals: Strengthen the means of implementation and revitalize the global partnership for sustainable development (Social)

Source: [21].

The SDG approach adopted by the UN fits well within the systems approach to sustainable development. First, the 2030 Agenda emphasizes that the SDGs are interlinked, and that ensuring integration across all 17 goals is critical to achieving sustainable development. Second, each of the SDGs can be characterized as a goal primarily attributed either to the economic, environmental or social system [22] (Figure 1).

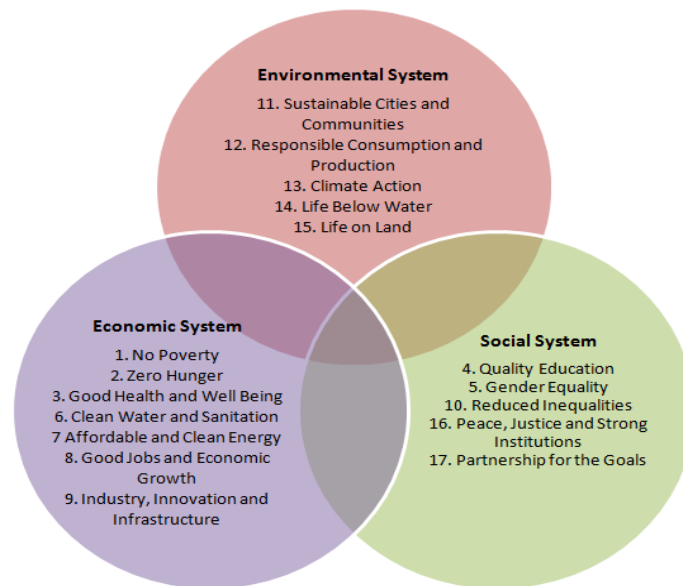


Figure 1. The systems approach to sustainability applied to the 17 SDGs, Source: [22]

Robert F. Kennedy once said that a country's gross domestic product (GDP) measures "everything except that which makes life worthwhile". The metric was developed in the 1930s and 1940s amid the upheaval of the Great Depression and global war. Even before the United Nations began requiring countries to collect data to report national GDP, Simon Kuznets, the metric's chief architect, had warned against equating its growth with well-being. GDP measures mainly market transactions. It ignores social costs, environmental impacts and income inequality. Several alternatives have been devised that attempt to correct some of the problems with GDP. These include Green GDP [23, 24], Genuine Savings [25, 26], the Inclusive Wealth Index [27], the "degrowth accounts" proposed by O'Neill [28], and the Index of Sustainable Economic Welfare [29], also known as the Genuine Progress Indicator (GPI) [30]. The successor to GDP should be a new set of metrics that integrates current knowledge of how ecology, economics, psychology and sociology collectively contribute to establishing and measuring sustainable wellbeing. Against this backdrop, one potential hybrid metric could be a combination of three basic parts, each covering the contributions to sustainable wellbeing from the dimensions of economy, society, and nature [31]. Fig. 2 shows the 17 SDGs and how they contribute to each of the three categories mentioned above. These categories correspond to the three basic goals outlined in the framework of Ecological Economics and the three basic components of sustainability (Figure 2).

What appears a remarkable success of international and EU actions to ensure sustainable development is the acknowledgement of the importance of the environmental dimension for the global growth and for creating decent living standards for present and future generations. The efficient management of natural resources, efficient energy use, guaranteed access to water and sanitation, halting the biodiversity loss, access to ecosystem services, sustainable forestry, sustainable consumption and production patterns (SCPs) and, finally, adaptation to climate change are the core environmental actions to combat poverty and to ensure sustainable development. The above areas have been successfully reflected in the SDGs.

Conducting economic activity in modern conditions is often connected with a negative impact on ecology. Today, economic activity has reached such a scale that it can be considered to be a geological and climate-forming factor which can significantly change living conditions of man. This trend is a serious cause for concern and leads numerous initiatives realized at both the international and the national levels and contributing to the development of green economy. Many countries are developing and implementing special measures of public policies for green economy to level undesirable effects.

Therefore, a consideration of the main challenges in the area of social, economic and environmental development, as well as structure of public policies for green economy is a particular concern [32].

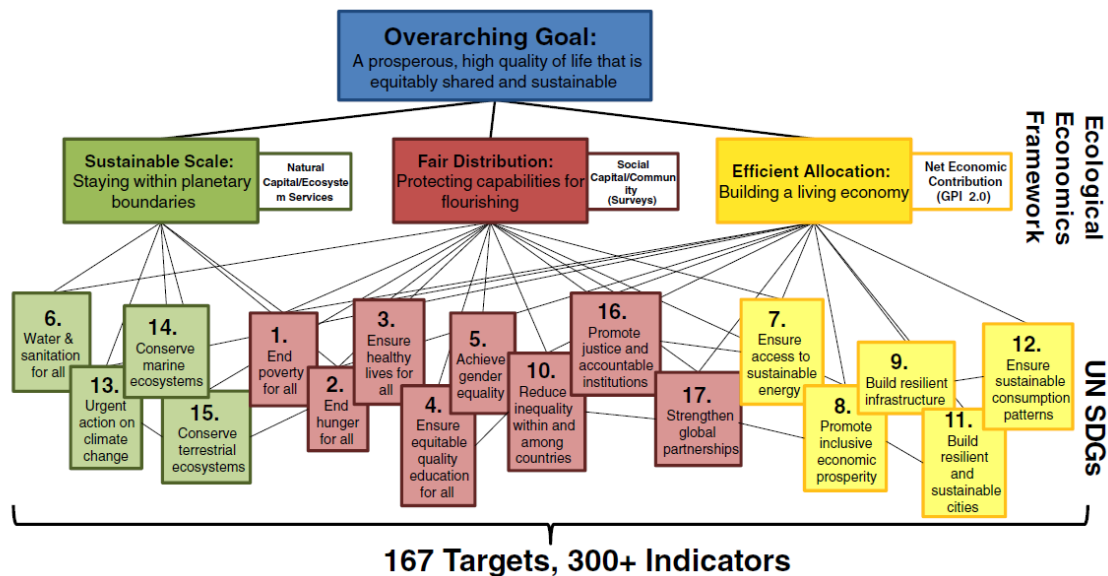


Figure 2. The relationship of the 17 UN Sustainable Development Goals (SDGs) to each other, to the framework of ecological economics, and to the overarching goal of a sustainable, equitable and prosperous system of humans embedded in the rest of nature SDGs, Source: [31]

The issues of sustainable development in the last years is closely related to the green economy concept. In 2008 United Nations Environment Programme UNEP called for an agreement – the Global Green New Deal, recognizing the possibilities and opportunities for overcoming the global economic crisis through the development of green economy sectors. The report *Global Green New Deal. Policy Brief* announced in March 2009 recommended investments in domains of key importance to the environment and, simultaneously, offering the best potential in the process of transformation towards green economy, such as renewable energy, clean technology, energy-efficient buildings, public transport, waste management and recycling, sustainable use of land, water, forests, marine fisheries, and ecotourism [33]. In June 2009 the Organisation for Economic Co-operation and Development (OECD) Ministerial Council made a decision to develop the *Green Growth Strategy* to support green investment and technological innovation thus contributing to economic recovery in the short-term, and helping to build the environmentally friendly infrastructure required for a green economy in the long-term In 2011 OECD proposed a selection of indicators to provide statistical support to monitoring the strategy implementation effects. The proposed indicators complement the Gross Domestic Product (GDP) which, as a fundamental measure of national income, cannot be the only measure of the public well-being and economy greening. The GDP does not take into account the role played by environmental factors. Moreover, the OECD suggested that every country prepare indicators fitting their own socio-economic situation on the basis of its proposal. Polish public statistical institutions have taken on this task and works are under way on preparing the selection of indicators that will serve monitoring the process of the Polish economy greening.

3. Research Method

In order to choose a synthetic development measure the need arises to propose in groups a set of diagnostic variables that best describe the analysed phenomenon. The selection of variables out of the

ones constituting a primary set is conditioned by substantive reasons, expert knowledge as well as by the availability of data.

The first step in the analysis is elimination of variables from the primary set. To this end, one determines basic descriptive statistics and eliminates these variables for which the inequality $V_j \leq 10\%$ is satisfied, where $V_j (j=1, \dots, k)$ denotes the coefficient of variation for the j -th variable. The variables that satisfy the above inequality should be regarded as quasi constant, not providing relevant information about the phenomenon under study and lacking discriminative abilities. Then the representatives of the selected groups are chosen out of the remaining variables that characterise these groups. To achieve this, the parametric method is used [34]. In this method, a starting point is to determine the matrix R of the coefficients of correlation between individual diagnostic variables. The variable classification criterion is a critical value of the correlation coefficient r^* at 0.5.

The diagnostic variables that are similar in terms of the correlation degree create clusters, i.e. such subsets where the minimum similarity between variables is lower than r^* . The clusters consist of one central and several satellite variables that constitute a set of diagnostic variables [35]. The variables should be standardised by transforming destimulants into stimulants. To this end, one can use a simple method of finding the inverse of diagnostic variables of destimulating character. In the next stage of determining a synthetic development measure (SMR) the diagnostic variables are harmonised, i.e. the variables x_{ij} are subjected to standardisation. In the case of destimulants one can use, for example, the formula of variable value standardisation given by:

$$x'_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (1)$$

where:

S_j – standard deviation of j -th variable.

The aggregation of the variable values can be based on formulas with and without ‘development pattern’ and their use is limited by the measurement scale of variables [36, 37]. In the development pattern methods the existence of a model (pattern) object is assumed, in relation to which the taxonomic distances of the remaining objects $q_i = d(x_i, x_0)$ are calculated. These distances allow for ranking the objects from the most developed (the closest to the pattern) to the least developed (the farthest from the pattern). In the market potential studies the maximum value for each variable can be used as the pattern value.

Usually, the distance of a given object from the development pattern (as a synthetic measure value) is measured with the use of Minkowski’s metrics, the special example of which is the Euclidean distance:

$$q_i = \left[\sum_{j=1}^m \frac{1}{m} (x'_{ij} - x_{0j})^2 \right]^{\frac{1}{2}}, \quad \text{for } i = 1, 2, \dots, n \quad (2)$$

where:

x'_{ij} – normalised values of j -th diagnostic variable for i -th object.

The obtained values of the synthetic measure q_i are transformed giving a synthetic development measure q'_i for the i -th object:

$$q'_i = \frac{q_i}{\|Q\|}, \quad \text{for } i = 1, 2, \dots, n \quad (3)$$

where: $\|Q\|$ is a synthetic variable norm.

In practice the formula is transformed by solving $1 - q_i'$, which leads to changed variable preference (in the case of the stimulants the higher the values, the higher the level of the phenomenon under analysis). The norm $\|Q\|$ is usually the maximum value. Eventually, one can rank the tested objects from the best to the weakest in terms of the rural potential by setting the distances of the objects from the development pattern, and then compare the ordering in time.

In the last step of the study the objects may be grouped in k -classes of similar structure where the classification criterion are fixed values of the synthetic variable ($z_i = x'_{ij}$). Clustering of objects for the pattern which is variable in time is conducted basing on the main parameters of the synthetic measure (an arithmetic mean and standard deviation) following the formulas:

$$\begin{aligned} G1: z_i \in \left(\bar{z} + S_z; \max_i \{z_i\} \right), G2: z_i \in \left(\bar{z}; \bar{z} + S_z \right) \\ G3: z_i \in \left(\bar{z} - S_z; \bar{z} \right), G4: z_i \in \left(\min_i \{z_i\}; \bar{z} - S_z \right) \end{aligned} \quad (4)$$

where z_i – the synthetic variable, \bar{z} – the arithmetic mean of the synthetic variable, S_z – the standard deviation of the synthetic variable. This approach permits evaluating the dynamics of changes in clustering individual objects.

3. Results

First, eleven variables were analysed indicated in the group of sustainable development variables describing the environmental governance (table 2). The variables referred to four thematic domains: air pollution (variables X1, X2), electricity (variables X3–X5), fresh water resources (X6) and ecological land (variables X7–X10).

Table 2. Environmental governance variables

	Variable	Unit
X1	Gas pollution from environmentally unfriendly industrial facilities – per capita	t/y
X2	Dust pollution from environmentally unfriendly industrial facilities – per capita	t/y
X3	Share of renewable energy in total electricity production	%
X4	Electricity consumption per PLN 1 million GDP	GWh
X5	Formation of fixed capital used for environment protection purposes related with electricity saving – per capita	PLN
X6	Underground water reserves – increase or loss compared to the previous year	hm ³
X7	Forest cover	%
X8	Rate of restoration and afforestation in total forest cover	%
X9	Rate of agricultural land to total land area	%
X10	Rate of special bird protection areas to total land area	%
X11	Rate of special areas of habitat conservation to total land area	%

Source: own calculations.

According to the adopted research method Authors determined basic descriptive statistics of the analysed variables: the mean, standard deviation and the coefficient of variability. Due to the high variability of variables (over 10%), all eleven of them were left for further analysis. In the next step, their interdependence in subsequent years in the above listed four thematic domains was investigated. As a result the variables marked with high coefficient of variability over 0.5 were eliminated, leaving

six variables (X1, X3, X5, X6, X8, X11). One of them, gas pollution from environmentally unfriendly industrial facilities per capita (X1) was considered as a sustainable development destimulant. The remaining variables were treated as stimulants.

The study covered 16 Polish administrative units (voivodships) (table 3).

Table 3. Marks and location of voivodships in Poland

Mark	Voivodship	Location
W1	łódzkie	central
W2	mazowieckie	central
W3	małopolskie	southern
W4	śląskie	southern
W5	lubelskie	eastern
W6	podkarpackie	eastern
W7	podlaskie	eastern
W8	świętokrzyskie	eastern
W9	lubuskie	nort-western
W10	wielkopolskie	north-western
W11	zachodniopomorskie	north-western
W12	dolnośląskie	south-western
W13	opolskie	south-western
W14	kujawsko-pomorskie	northern
W15	pomorskie	northern
W16	warmińsko-mazurskie	northern

For the set of six variables, separately for each year of the study, synthetic measures were determined (formula 3), according to which the voivodships were ranked from the best to the weakest in terms of the environmental governance level. Next, the voivodships were put in four separate groups G1–G4 following the proposed formula (formula 4). Individual groups and the quantitative structure were analyzed in subsequent years of the study (table 4).

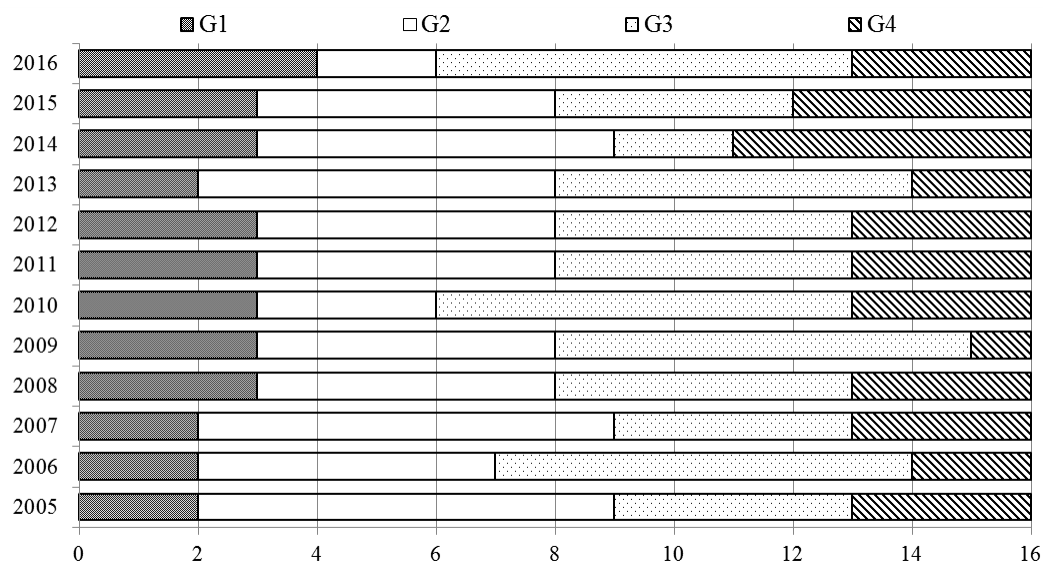
In the first group (G1) of voivodships on the highest development level in terms of the land use governance factors having impact on sustainable development and green economy in every year of the study there were two voivodships: kujawsko-pomorskie (W14) and warmińsko-mazurskie (W16). The latter was moved to G2 only in 2016. Additionally, before 2009 podlaskie (W7) appeared in G1 several times, while lubuskie (W9) joined the group in the last two years. All the voivodships that were included in G1 between 2005 and 2016 are the least industrialized areas in Poland thus offering the best opportunities for the green economy growth.

The voivodships that appeared most often in the last group are lubelskie (W5) and opolskie (W13), and occasionally the świętokrzyskie voivodship (W8). They are not the areas of intensive growth of industry and infrastructure that accompany urban sprawl, but they are underdeveloped in terms of energy management (e.g. renewable energy) or special protection areas. The more voivodships were classified in one group, the more homogeneous the group was with regard to the environmental governance factors. Figure 3 below shows the changes in the number of objects allocated to each group in subsequent years, with the clustering pattern changing in time.

Table 4. Results of voivodship clustering

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
G1	W16	W16	W14	W14	W7	W7	W16	W7	W7	W14	W9	W9
	W14	W14	W16	W7	W14	W14	W14	W16	W16	W16	W16	W14
G2	W7	W11	W9	W16	W16	W16	W7	W14	W6	W6	W14	W7
	W6	W9	W7	W9	W9	W6	W11	W9	W4	W9	W6	W11
	W2	W15	W15	W15	W4	W9	W15	W6	W14	W11	W7	W16
	W11	W7	W11	W12	W6	W11	W6	W15	W9	W10	W12	W6
	W10	W6	W12	W6	W3	W12	W9	W4	W12	W7	W8	W4
	W15	W12	W6	W11	W11	W4	W4	W12	W11	W12	W15	W15
	W9	W1	W4	W2	W12	W15	W3	W3	W3	W4	W4	W10
G3	W12	W10	W3	W3	W15	W8	W10	W11	W15	W8	W10	W12
	W1	W4	W2	W4	W10	W13	W12	W1	W5	W15	W11	W5
	W8	W2	W1	W1	W2	W10	W13	W10	W8	W5	W3	W8
	W3	W3	W5	W10	W1	W3	W2	W13	W1	W1	W13	W2
G4	W13	W8	W8	W8	W8	W5	W5	W5	W10	W3	W5	W13
	W5	W13	W10	W5	W13	W1	W8	W8	W13	W2	W1	W3
	W4	W5	W13	W13	W5	W2	W1	W2	W2	W13	W2	W1

Source: own calculations.

**Figure 3.** Classification dynamics in 2005-2016 - Source: own calculations

It can be seen that the most considerable quantitative changes took place in the two middle groups of voivodships (G2, G3). The first group seemed the most stable in time as it usually consisted of two or three the same voivodships. There were, however, voivodships which, during the 12 years under study, were always in the group of best developed voivodships (kujawsko-pomorskie and warmińsko-mazurskie). Similarly, lubelskie and opolskie never left the fourth group of voivodships on the lowest

level of environmental development. On the other hand, the latter had the best growth potential (i.e. a lot to catch up) measured with their distance to the top voivodship.

4. Conclusions

Efficient management of natural resources, efficient energy use, broad access to fresh water, biodiversity and adaptation to climate change are the principal environmental tasks (environmental governance) in seeking to ensure sustainable development.

Despite almost 15 years that have elapsed since the beginning of the study (2006) the changes in the environmental governance in individual voivodships have not caused considerable changes in their classification. This means that particular attention should be paid to relationships among variables that influence the environmental governance level in the voivodships. The obtained directions of electricity consumption of households with social order indicators are consistent with the desired direction of GUS sustainable development indicators [36]. The increase of electricity consumption is related with increase of water consumption. But the question arises if the change in two factors does not affect the other ones? Hence, the proposal to apply for clustering the multi-dimensional analysis which has proved useful in the analyses of complex phenomena as well as in other research fields [37, 38].

The observed cluster stability is a cause for thought regarding the proposed new selection of variables describing green growth, in which the majority of variables used in this study was also considered important. Further studies will aim at expanding the catalogue of variables until it conveys all the variables in the set proposed in the new concept of green growth as soon as such information set developed for Poland is available in public statistics.

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