The Measurement of Sustainable Development Level in the Aspect of Selection of Indicators and Measurement Methods

Jacek Salamon(✉)

Faculty of Production and Power Engineering, Institute of Agriculture Engineering and Informatics, University of Agriculture in Krakow, Balicka 116b, 30-149 Kraków, Poland
Jacek.Salamon@urk.edu.pl

Abstract. The idea of sustainable development appeared several decades ago and was a response to the growing environmental problems associated with the irrational natural resources management, conducted, in particular, by highly developed countries. Despite many local and international efforts, the list of universal indicators monitoring sustainable development, applicable both to developed and developing areas, has not yet been clearly defined. No specific methods for measuring sustainable development, which would allow for objective determination of the level of sustainability and the direction of its course, have been specified. The paper indicated the possibility of diversifying research results resulting from the adopted method of specification of sustainable development indicators and the applied method of measuring the level of sustainability, which may lead to unreliable results. A set of 71 indicators was employed and the various areas of sustainable development were described synthetically, i.e. the social, economic, environmental and institutional-political domains. The linear ordering of provinces was performed using their taxonomic distance from the reference object. For comparative purposes and determining the direction of development, data from the years 2010 and 2016 were utilized.

Keywords: Sustainable development · Indicators · Methods · Problems

1 Introduction

The notion of sustainable development was originally defined in the UN document 'Our common future' in 1987 as such a development in which the needs of the current generation are satisfied without jeopardising the needs of future generations [5]. The very idea of sustainable development was the response to the growing environmental problems associated with the irrational exploitation of natural resources, a huge burden on the natural environment by pollution and negative effects of industrialization and mechanisation of agricultural production [1].

From the beginning of its development, the notion of sustainable development has been of interest to researchers from numerous areas of science. So far, however, they have been struggling to measure the development in all its spheres, i.e. social, economic and environmental, assuming that sustainable development should include

A. Krakowiak-Bal and M. Vaverkova (Eds.): *Infrastructure and Environment*, pp. 328–336, 2019.
https://doi.org/10.1007/978-3-030-16542-0_41

parallel activities in these three areas, without diminishing the importance of any of them. It has been noted that rich countries, which have achieved a high level of social and economic development, attach great importance to the protection of the natural environment. Poor countries, in turn, behave differently - the need to protect the natural environment is secondary in relation to economic and social needs [1, 9]. Taking the above into account, it can be concluded that countries with different levels of development are in different places in the process of sustainable development [4]. Therefore, the question should be asked about the assumption of the equal importance of all three domains in all circumstances. In addition, the question of identifying a point considered to be one in which development can be treated as sustainable arises. Until now, such a point or object has not been established, and the opinions of researchers are often radically divergent [2, 6].

According to the International Institute for Sustainable Development [3], there are 173 indicators defining the level of sustainable development. These indicators are used in different countries. In Poland, according to the CSO (GUS) study from the year 2015, 101 indicators were distinguished to monitor sustainable development in four domains and 24 areas [10]. The choice of indicators to the national list was determined by the degree of compliance with the definition and significance of the indicator for sustainable development. Phenomena which were special and particularly important for Poland were also taken into account. It should be underscored that for some indicators, it was not determined whether it was a driver, i.e. it promoted sustainable development or an inhibitor. Treating the indicator as a driver or an inhibitor arises then from the subjective assessment of its importance and different interpretation resulting from it.

It was assumed that the increase in the value of the synthetic index indicates a balanced direction of development. In the analyzed period, both changes towards the balancing of development and in the opposite direction were shown. Methodical inaccuracies related to the measurement of sustainability were pointed out. Different methods of classifying areas due to the sustainability of development, presented in the study, lead to ambiguous research results. The ranking of the researched areas varies depending on whether it was determined by adopting the average value of the synthetic sustainable development index or by using the classification-point method.

2 Aim, Material and Method

The aim of the study is to present differences in the assessment of the degree of sustainable development of Polish provinces, depending on the interpretation of individual indicators adopted for research that monitor the development. The aforementioned interpretation concerned, in particular, the fact whether the indicator was treated as a driver or an inhibitor of sustainable development and the problem of treating the indicator as the one which would monitor a specific domain. To compare the data, the research was based on statistical data from the year 2010 and the year 2016.

First, the values of the synthetic indicator of sustainability level were presented in accordance with the classification of indicators adopted by the Central Statistical Office [10]. Then, after a detailed analysis of the indicators, the grouping was modified. For example, the indicator of the number of cars per 1000 inhabitants, treated in social

domain as a driver, was perceived as an inhibitor in the environmental domain. Similarly, the indicator of water consumption in households per capita per year in the social domain was a driver, while in the environmental domain it was an inhibitor. Table 1 presents a detailed breakdown of changes introduced in the classification of sustainable development indicators.

Table 1. Changes introduced in the classification of sustainable development indicators.

Indicator according to CSO classification	Indicator according to modified classification
Social domain: 1. Number of cars per 1000 inhabitants (stimulant)	Environmental domain: 1. Number of cars per 1000 inhabitants (inhibitor)
Social domain: 2. Water consumption in households per capita per year (stimulant)	Environmental domain: 2. Water consumption in households per capita per year (inhibitor)
Social domain: 3. Average meat consumption per capita per month (stimulant)	Environmental domain: 3. Average meat consumption per capita per month (inhibitor)
Social domain: 4. Crimes identified by the police in completed preparatory proceedings per 1000 inhabitants (inhibitor)	Environmental domain: 4. Crimes identified by the police in completed preparatory proceedings per 1000 inhabitants (stimulant)
Economic domain: 1. The length of expressways and motorways per 100 km^2 (stimulant)	Environmental domain: 1. The length of expressways and motorways per 100 km2 (inhibitor)
Economic domain: 2. The average price of a one-way normal ticket for a city bus (stimulant)	Environmental domain: 2. The average price of a one-way normal ticket for a city bus (inhibitor)
Economic domain: 3. Consumption of mineral fertilizers per 1 ha of agricultural land (stimulant)	Environmental domain: 3. Consumption of mineral fertilizers per 1 ha of agricultural land (inhibitor)
Economic domain: 4. Presence of large livestock units per 1 hectare of arable lands (stimulant)	Environmental domain: 4. Presence of large livestock units per 1 hectare of arable lands (inhibitor)
Economic domain: 5. Share of large farms in the total number of farms (stimulant)	Environmental domain: 5. Share of large farms in the total number of farms (inhibitor)
Environmental domain: 1. Share of Natura 2000 areas in total area (stimulant)	Economic domain: 1. Share of Natura 2000 areas in total area (inhibitor)
Environmental domain: 2. The share of legally protected areas in the total area (stimulant)	Economic domain: 2. The share of legally protected areas in the total area (inhibitor)
Environmental domain: 3. Amount of mixed municipal waste collected by households per capita per year (inhibitor)	Economic domain: 3. Amount of mixed municipal waste collected by households per capita per year (stimulant)

The assessment of sustainability level of provinces was carried out employing a synthetic measure, which was the basis for the creation of rankings [7, 8]. The determination of the synthetic measure of development was preceded by the normalization of variables according to the formula:

$$x_{ij}^{'} = \frac{x_{ij} - minx_{ij}}{maxx_{ij} - minx_{ij}} \tag{1}$$

where:

x'_{ij} - the value of the transformed (normalized j-th diagnostic feature of sustainable development in the i-th object (province),
x_{ij} - the actual value of the j-th diagnostic feature of sustainable development in the i-th object,
min_{xj} - the minimum value of the j-th feature of sustainable development,
max_{xj} - the maximum value of the j-th feature of sustainable development.

This transformation resulted in the values of features being in the range [0; 1]. The examined indicators were treated as drivers or inhibitors of sustainable development, whereas the substitution of inhibitors for drivers was made employing the following formula:

$$x_{ij}^{'S} = \frac{1}{x_{ij}^{'D}} \tag{2}$$

where:

$x_{ij}^{'S}$ - sustainable development driver obtained by transforming inhibitors ($x_{ij}^{'D}$) of the development.

The reference object was such an object that was characterized by the highest values of drivers and the lowest values of inhibitors.

The synthetic measure of sustainable development of i-th object (province) was determined using the formula:

$$d_i = 1 - \frac{d_{i0}}{d_0} \tag{3}$$

where:

$$d_{i0} = \left[\sum_{j=1}^{p} \left(y_{ij} - y_{0j}\right)^2\right]^{\frac{1}{2}} \tag{4}$$

is the Euclidean distance of the i-th object from the reference object, while d0 is the distance between the pattern and the antipattern. The antipattern is characterized by the lowest values of drivers and the highest values of inhibitors [7].

The analysis of the level of sustainability was carried out for the years 2010 and 2016.

3 Findings

Table 2 presents the calculated values of the synthetic indicator for all domains (social, economic, environmental and institutional-political), taking into account the classification of the Central Statistical Office. It was assumed that the increase in the value of the synthetic indicator denoted a sustainable direction of development. Based on the data presented in Table 2, it can be stated that in the analysed period the changes both towards sustainable development (an increase in the value of the synthetic index) and in the opposite direction (a decrease in the value of the synthetic index) were evident.

Table 2. The values of the synthetic sustainable development indicator (d_i) of provinces according to domains (dimensions) in the years 2010 and 2016 determined on the basis of the classification of indicators consistent with the Central Statistical Office.

Province	Social domain d_{is}			Economic domain d_{ig}			Environmental domain d_{ie}			Institutional-political domain d_{ip}		
	2010	2016	Change	2010	2016	Change	2010	2016	Change	2010	2016	Change
Dolnośląskie	0.36	0.45	0.09	0.36	0.40	0.04	0.26	0.24	−0.03	0.45	0.53	0.08
Kujawsko-Pomorskie	0.38	0.37	−0.00	0.31	0.32	0.01	0.36	0.35	−0.02	0.35	0.34	−0.01
Lubelskie	0.32	0.36	0.03	0.22	0.24	0.02	0.32	0.32	−0.01	0.25	0.27	0.03
Lubuskie	0.38	0.38	0.00	0.29	0.31	0.02	0.41	0.42	0.01	0.40	0.41	0.01
Łódzkie	0.40	0.40	0.00	0.28	0.34	0.06	0.23	0.21	−0.02	0.38	0.46	0.08
Małopolskie	0.49	0.47	−0.02	0.32	0.34	0.02	0.33	0.28	−0.05	0.26	0.37	0.11
Mazowieckie	0.46	0.46	−0.00	0.40	0.43	0.03	0.25	0.26	0.01	0.27	0.27	0.01
Opolskie	0.44	0.42	−0.01	0.32	0.30	−0.02	0.25	0.27	0.01	0.49	0.52	0.03
Podkarpackie	0.24	0.27	0.03	0.24	0.25	0.00	0.47	0.44	−0.03	0.34	0.35	0.01
Podlaskie	0.39	0.40	0.01	0.20	0.23	0.03	0.46	0.43	−0.03	0.29	0.27	−0.02
Pomorskie	0.50	0.51	0.01	0.44	0.45	0.01	0.33	0.34	0.01	0.36	0.39	0.03
Śląskie	0.44	0.47	0.04	0.36	0.34	−0.01	0.24	0.21	−0.03	0.35	0.36	0.00
Świętokrzyskie	0.26	0.29	0.03	0.24	0.16	−0.08	0.27	0.28	0.01	0.46	0.34	−0.12
Warmińsko-Mazurskie	0.32	0.29	−0.03	0.25	0.17	−0.08	0.48	0.42	−0.07	0.46	0.31	−0.15
Wielkopolskie	0.54	0.53	−0.01	0.39	0.39	0.00	0.35	0.30	−0.05	0.42	0.45	0.03
Zachodnio-Pomorskie	0.34	0.39	0.04	0.31	0.31	−0.01	0.31	0.30	−0.01	0.45	0.41	−0.04

Table 3 presents the calculated values of the synthetic indicator of sustainable development, determined applying modified, against the adopted by the Central Statistical Office classification, classification of sustainability indicators. In this case also, development was denoted both in the sustainable direction and in the opposite one. As a result of alternations in the classification of indicators, there were changes, which involved, inter alia, a change in the direction of sustainable development into the opposite or vice versa.

Table 3. The values of the synthetic indicator of sustainable development (d_i)) of provinces according to the domains (dimensions) in the years 2010 and 2016 determined in line with the modified classification of variables.

Province	Social domain d_{is}			Economic domain d_{ig}			Environmental domain d_{ie}			Institutional-political domain d_{ip}		
	2010	2016	Change	2010	2016	Change	2010	2016	Change	2010	2016	Change
Dolnośląskie	0.35	0.35	−0.01	0.37	0.41	0.04	0.30	0.29	−0.01	0.45	0.53	0.08
Kujawsko-Pomorskie	0.34	0.30	−0.04	0.28	0.29	0.01	0.33	0.34	0.01	0.35	0.34	−0.01
Lubelskie	0.31	0.31	−0.01	0.22	0.27	0.04	0.41	0.39	−0.02	0.25	0.27	0.03
Lubuskie	0.30	0.22	−0.08	0.26	0.28	0.02	0.38	0.39	0.01	0.40	0.41	0.01
Łódzkie	0.35	0.34	−0.02	0.29	0.35	0.06	0.28	0.26	−0.02	0.38	0.46	0.08
Małopolskie	0.49	0.42	−0.07	0.31	0.38	0.07	0.34	0.32	−0.02	0.26	0.37	0.11
Mazowieckie	0.49	0.43	−0.06	0.48	0.53	0.05	0.21	0.24	0.03	0.27	0.27	0.01
Opolskie	0.36	0.32	−0.04	0.33	0.31	−0.02	0.28	0.31	0.03	0.49	0.52	0.03
Podkarpackie	0.25	0.24	−0.01	0.24	0.25	0.00	0.50	0.44	−0.06	0.34	0.35	0.01
Podlaskie	0.36	0.34	−0.03	0.17	0.22	0.05	0.46	0.44	−0.02	0.29	0.27	−0.02
Pomorskie	0.45	0.38	−0.08	0.42	0.45	0.03	0.31	0.34	0.03	0.36	0.39	0.03
Śląskie	0.39	0.38	−0.01	0.40	0.39	−0.01	0.27	0.24	−0.02	0.35	0.36	0.00
Świętokrzyskie	0.22	0.18	−0.04	0.19	0.12	−0.08	0.31	0.35	0.03	0.46	0.34	−0.12
Warmińsko-Mazurskie	0.31	0.21	−0.10	0.19	0.13	−0.07	0.42	0.42	−0.00	0.46	0.31	−0.15
Wielkopolskie	0.42	0.37	−0.07	0.36	0.39	0.03	0.26	0.24	−0.02	0.42	0.45	0.03
Zachodnio-Pomorskie	0.33	0.27	−0.06	0.30	0.31	0.01	0.34	0.35	0.01	0.45	0.41	−0.04

Table 4 presents the ranking of provinces due to the level of sustainable development. The ranking was established on the basis of the mean value of the synthetic indicator from individual domains and by applying the classification and point method.

On the basis of the data included in Tables 2, 3 and 4 a correlation analysis was conducted between the variables describing particular domains in the years 2010 and 2016 employing classification of variables determined by the Central Statistical Office and the modified classification. The values of Pearson's linear correlation coefficients were calculated for the data in Tables 2 and 3 while the Spearman rank correlation coefficient was determined for the data in Table 4. The results of the above analyses are presented in Table 5.

Analysing the data in Table 5. it can be concluded that in the case of the social and economic domains. the changes in the Pearson's linear correlation coefficient are minimal. In the case of the environmental domain, however, there was a significant change in the value of the correlation coefficient. The positive value of the linear correlation coefficient in the case of the variable classification adopted by the Central Statistical Office indicated development in a sustainable direction. The modified classification of indicators, in the case of the environmental domain, indicates the opposite direction of development (negative value of the linear correlation coefficient), i.e. lack of sustainability in development of the natural environment. The analysis of Spearman's rank in none of the domains showed significant differences in the classification of provinces.

Table 4. Ranking of provinces and its changes based on the CSO classification and modified classification (the bottom row) according to individual domains in the years 2010 and 2016.

Province	CSO		Modified		CSO		Modified	
	2010				2016			
	Mean	Points	Mean	Points	Mean	Points	Mean	Points
Dolnośląskie	6	6	3	3	3	3	1	2
Kujawsko-Pomorskie	9	11	13	13	11	11	12	13
Lubelskie	16	16	15	16	15	15	14	14
Lubuskie	5	5	10	10	4	4	10	10
Łódzkie	13	13	12	12	8	8	7	7
Małopolskie	8	7	8	5	6	5	3	3
Mazowieckie	11	8	5	8	7	9	4	8
Opolskie	4	3	4	2	5	6	5	4
Podkarpackie	14	15	11	14	13	12	11	11
Podlaskie	12	12	14	11	12	13	13	12
Pomorskie	2	2	1	1	1	1	2	1
Śląskie	10	10	7	7	10	7	8	6
Świętokrzyskie	15	14	16	15	16	16	16	16
Warmińsko-Mazurskie	3	4	9	9	14	14	15	15
Wielkopolskie	1	1	2	6	2	2	6	5
Zachodniopomorskie	7	9	6	4	9	10	9	9

Table 5. Values of linear correlation of Pearson's and R Spearman's coefficient between the values of the synthetic indicator of the sustainability level and the ranking of provinces in the years 2010 and 2016 in particular domains.

Type of variable classification	Social domain		Economic domain		Environmental domain		Institutional-political domain	
	Pearson	R Spearman	Pearson	R Spearman	Pearson	R Spearman	Pearson	R Spearman
According to CSO	0.936	0.923	0.798	0.882	0.960	0.950	0.648	0.903
Modified	0.924	0.967	0.737	0.806	−0.661	0.871	0.648	0.903

4 Conclusion

Presented research results indicate significant difficulties related to measuring the sustainability of development. These difficulties result from the selection of appropriate variables whose criteria are not unequivocally specified. In addition, arbitrariness, caused by subjective assessments of researchers in qualifying variables to a specific area that monitors a specific domain, is evident. Also, it is not explicitly specified which of the adopted indicators are drivers and which are inhibitors of sustainable development. Maximum, minimal, and in particular optimal values of indicators were not set, which would clearly indicate the fact of sustainability. It should be stated that

the same value of the monitoring indicator in different cases, i.e. in relation to different levels of development (social, economic, environmental, institutional-political) may be a driver or an inhibitor of sustainable development. The determined value of the indicator, depending on the level of socio-economic development, may be optimal, too low or too high.

Particular attention should be paid to the fact that the indicators being a driver of one of the domains are also an inhibitor of another domain. The inclusion of a specific indicator in the monitoring group of a particular domain should be determined, inter alia, by the general level of socio-economic development of a given area.

Different methods of classifying areas due to sustainable development, presented in the study, lead to ambiguous research results. The ranking of the surveyed areas varies depending on whether it was determined using the mean value of the synthetic indicator of sustainable development or using the classification and point method.

The observations presented above denote the necessity of adopting uniform standards referring both to the criteria related to the selection of sustainable development indicators, the unambiguous inclusion of indicators in the group which monitors specific domain, determining the value of optimal indicators which would monitor depending on the level of socio-economic development and the environmental condition of the area. In addition, there is a need to establish uniform methods for measuring sustainability which would clearly and objectively indicate the level of sustainability and the direction of changes.

Acknowledgements. This research was financed by Ministry of Science and Higher Education of the Republic of Poland.

References

1. Borychowski, M., Staniszewski, J., Zagierski, B.: Problemy pomiaru rozwoju zrównoważonego na przykładzie wybranych wskaźników. Roczniki Ekonomiczne Kujawsko-Pomorskiej szkoły Wyższej w Bydgoszczy **9**, 28–43 (2016)
2. Hak, T., Moldan, B.: Sustainability indicators. In: Dahl, A.L. (ed.) A Scientific Assessment. Island Press, Washington DC (2007). SCOPE 67
3. International Institute for Sustainable Development. Compendium. A Global Directory to Indicator Initiatives. https://www.iisd.org/library/compendium-sustainable-development-indicator-initiatives. Accessed 24 July 2018
4. Matuszczak, A.: Zróżnicowanie rozwoju rolnictwa w regionach Unii Europejskiej w aspekcie jego zrównoważenia. PWN, Warszawa (2013)
5. Our Common Future. Report of the World Commission on Environment and Development, United Nations. Oxford University Press, New York (1987)
6. Poveda, C.A., Lipsett, M.G.: Using sustainable development indicators (SDIs) for sustainability assessment of surface mining operations in the oil sands projects: applicability, usefulness and cost. WIT Trans. Ecol. Environ. **176**, 55 (2013)
7. Salamon, J.: Comparative analysis of sustainable development of provinces. Infrastruct. Ecol. Rural Areas **IV**(3), 1833–1842 (2017)

8. Walesiak, M.: Uogólniona miara odległości w statystycznej analizie wielowymiarowej. Wydawnictwo Akademii Ekonomicznej, Wrocław (2006)
9. Wheaton, E., Kulshreshtha, S.: Agriculture and climate change: implications for environmental sustainability indicators. WIT Trans. Ecol. Environ. Ecosyst. Sustain. Dev. **175**, 99–110 (2013)
10. Wskaźniki zrównoważonego rozwoju Polski 2015. GUS. Urząd Statystyczny Katowice, Katowice (2015). http://stat.gov.pl/obszary-tematyczne/inne-opracowania/inne-opracowania-zbiorcze/wskazniki-zrownowazonego-rozwoju-polski-2015.5.2.html. Accessed 16 June 2018