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CLUSTER ANALYSIS IN ASSESSMENT OF ORGANIC FARMS SUSTAINABILITY. PART II RESULTS OF RESEARCH

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ABSTRACT

A modern model of agriculture is based on three orders - organic, social and economic. An attempt was made in this paper to apply cluster analysis for assessment of economic and organic sustainability of organic farms. Factors that statistically influenced a decision on which farms should be recognised as sustainable were indicated. Analyses allow the following conclusion: 1) in organic farming, animal production including cattle breeding and rearing must be based on a high acreage of permanent grasslands; 2) neither the performed production processes nor the level of their automation rate or the level of organic balance do not decide on the production effectiveness, but factors of the surrounding including social factors.

Introduction, aim and scope of the paper

The first part of the paper (Sporysz et al., 2019) characterizes the problem and describes methodology of research and statistical analysis. In the second part, the authors focus on the research results and discussion. The scope of the study covered events from 50 organic farms located within the area of four voivodeships of southern Poland: Małopolskie, Podkarpackie, Śląskie and Świętokrzyskie Voivodeship. The basic studies included events from 2 years (2011, 2012) and were carried out as a part of the development project of the National Centre for Research and Development titled "Innovative impact of technique and technology and IT support of management on the production efficiency in organic farms NO. 12 016510". This project was carried out at the Faculty of Production Engineering and Power Energy in Krakow. Reports by farm owners submitted to institutions that supervise organic farms and registers of economic events carried out by farmers for the purpose of realization of the research project were used for data collection. Since the reports are submitted to several supervising units, including certificating units and agencies supervised by the Minister of Agriculture and Rural Development, a significant discrepancy of records was reported. For the purpose of verification of reasons for these discrepancies and due to the endurance of the project, in some of the farms, studies were supplemented to the end of 2015. All data were verified and on this basis results that influenced random events were removed.

The main aim of the paper was to verify the usefulness of cluster analysis for assessment of organic farms sustainability, i.e. whether the clusters obtained as a result of cluster modelling group farms well with regard to sustainability and then which features decide on the usefulness to a given cluster. More details may be found in the first part of the paper.

Methodology of work

Assessment of organic farms sustainability with the use of the clustering method was carried out in two stages. The first one, is arbitrary selection of variables that influence the sustainability (organic and economic based on the survey article by Lampridi et al., 2019) namely their scaling and determination of clusters and their centres. The second one was a verification of how the dependent variable shaped (a sustainability rate) and which features had a main impact on the object (farm) assignment to a given cluster.

As it was shown in the first part of the paper, the number of clusters was in both cases determined to be 3 (organic and economic sustainability). The area of agricultural land (GL) (ha), participation of arable land in the entire farm area (AL) (%AL), analogous participation of permanent grasslands (PGL) (%AL), orchards and plantations (%AL), percentage participation of grains, root and forage crops in arable lands (% AL), and the amount of the introduced elements (respectively nitrogen, potassium, phosphorus and organic elements) were arbitrary accepted as dependent variables. In case of economic sustainability this was: farm area (AL) (ha), replacement value of machines (PLN·ha^{-1}), replacement value of buildings (PLN·ha^{-1}), livestock (LSU·100 ha^{-1}), input of live labour (man-hour·ha^{-1}), gross final production (PLN·ha^{-1}) and production costs (PLN·ha^{-1}).

Since, particular independent variables had considerably different ranges of values, they were scaled to the range of (0.1) according to the formula

$$\widetilde{x_i} = \frac{-x_{min}}{x_{max} - x_{min}}$$

where:

$\widetilde{x_i}$ stands for a new value (scaled) of the i-th observation of the variable x while x_{max} x_{max} respectively the lowest and the highest value of the original variable.

For the purposes of visualization, the PCA analysis was used, which based on the scaled variables data reduced their number to two components (arbitrary accepted). Both in the PCA and cluster analysis Euclidian metrics was used.

Results of research

Organic sustainability

Figure 1 presents division of clusters on account of two main components (they were formed based on variables which characterise the investigated farms (area of agricultural land

and the structure of their use) and the introduced nutritive elements and organic substances). Contrary, table 1 shows centres of clusters which will be used for description of farms.

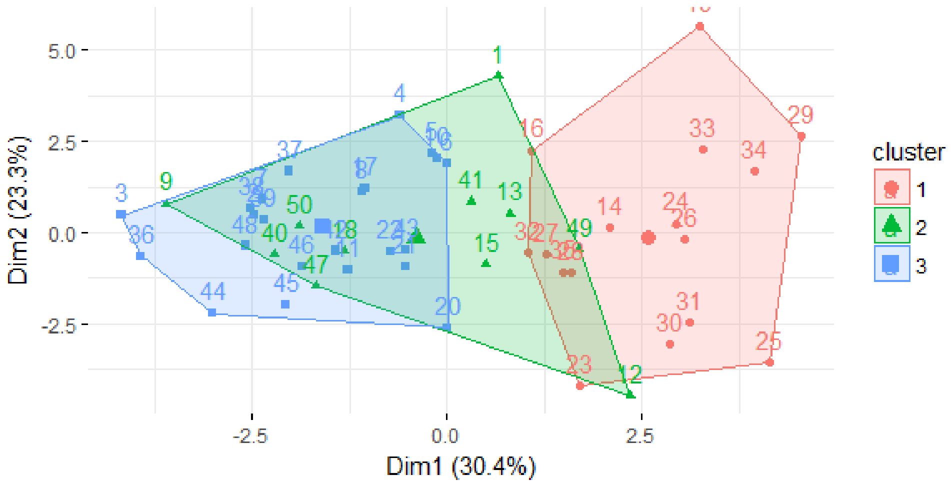

Figure 1. Graphical illustration of clusters based on two base components

Table 1.
Characteristics of centres of clusters for organic sustainability

Variable		No of cluster		
		1	2	3
1	Agricultural land (ha)	23.57	9.31	6.62
2	Arable land (%AL)	30.95	87.57	53.98
3	Permanent grasslands (%AL)	68.77	3.54	29.4
4	Grains (%AL)	32.63	44.94	56.03
5	Root (%AL)	6.36	10.84	9.73
6	Fodder (%AL)	60.54	32.32	12.15
7	Meadows (%PGL)	79.71	1.21	98.59
8	Orchards and plantations (%AL)	0.28	8.89	16.62
9	Grazing lands (%PGL)	20.29	16.97	1.41
10	Introduced N	56.98	34.65	29
11	Introduced P	36.55	24.08	20.39
12	Introduced K	78.14	54.53	46.72
13	Introduced OM	0.51	0.48	0.34

The basic question was whether the so defined clusters also present a variability with regard to the organic sustainability. Analyses were limited to the research on the balance of nitrogen and organic substance (phosphorus and potassium behave similarly to nitrogen). Table 2a presents mean values and medians of nitrogen sustainability for each of three formed clusters. It is significant that discrepancy between the mean value and median in some cases may suggest the lack of a regular character of distribution or a uniform character of the variance. Shapiro-Wilk and Lavene's tests that were carried out appropriately did not allow rejection of the hypothesis of the regular nature of the distribution with the uniformness of variation at 5% significance level.

Table 2.
Values of mean and median for a) nitrogen balance b) balance of the organic substance for each cluster

a)

Balance N		
No of cluster	Mean	Median
1	-95.84	-83.89
2	-77.12	-72.91
3	-56.00	-50.69

b)

Balance SO		
No of cluster	Mean	Median
1	0.84	0.85
2	0.45	0.70
3	0.10	0.05

The first cluster had the highest deficiency of nitrogen (95.84 kg·ha^{-1}). The objects belonging to the second cluster also had a deficiency of this element; however, it was at the lowest level (77.12 kg·ha^{-1}). The lowest deficiency of the nitrogen balance amounting to 56.00 kg·ha^{-1} was characteristic for the group of farms belonging to the third cluster and that one was accepted as the best balanced with regard to this component. In order to find a statistically significant variability of the investigated farms on account of nitrogen balance, analysis of variance was applied (StatSoft Inc., 2013). The farms of cluster 3 significantly differed from others. While, no significant differences in the farm balance with nitrogen for objects from cluster 1 and 2 were shown (table 3).

Table 3.
Analysis of variance for nitrogen balance

	Duncan test; variable Balance N(Sheet 1) Uniform groups, alfa = ,05000 Error: MS group = 1729,8, df = 47,000			
Subclass no	Class	Balance N Average	1	2
1	1	-95,83940	****	
2	2	-77,11820	****	
3	3	-55,99650		****

Table 2 b shows values of means and median of the organic substance balance for each group of farms belonging to the remaining three clusters. In this case, the best balance of organic substance (0.45 t·ha^{-1}) was in case of farms from cluster 2 since it is the closest to the referential value (0.5 t·ha^{-1}). Cluster 1 had the highest balance of OM (0.85 t·ha^{-1}) while cluster 3 had balance at the lowest level and it was only 0.10 t·ha^{-1}. An answer to an analogous question concerning significance of differences between farms assigned to particular clusters due to the OM balance was presented in table 4. In this case each cluster differed significantly from the remaining ones.

Table 4.
Analysis of variance for organic substance balance

	Duncan test; variable Balance OM(Sheet 1) Uniform groups, alfa = ,05000 Error: MS group = 0,15777, df = 47,000				
Subclass no	Class	Balance OM Average	1	2	3
3	3	0,09739	****		
2	2	0,45182		****	
1	1	0,84375			****

Another step was to determine features which characterize the best farms both on account of the nitrogen and organic substance balance. Table 5 presents a percentage participation of particular variables in a particular element. The highest impact on the leading components was in case of variables which were responsible for the size of the introduced mineral elements (N P and K) and OM, agricultural land area, percentage participation of arable land, permanent grasslands and orchards and plantations in agricultural lands, percentage participation of fodder crops in arable land.

Table 5.
Participation of particular variables in elements

Variables		Component 1	Component 2
1	Agricultural land (ha)	3.01	17.40
2	Arable land (%AL)	0.12	22.22
3	Permanent grasslands (%AL)	3.93	22.54
4	Grains (%AL)	0.87	5.90
5	Root (%AL)	0.54	0.80
6	Fodder (%AL)	9.04	6.64
7	Meadows (%PGL)	0.01	3.25
8	Orchards and plantations (%AL)	6.93	0.30
9	Grazing lands (%PGL)	0.57	4.96
10	Introduced N	20.84	1.74
11	Introduced P	21.47	1.88
12	Introduced K	22.02	1.90
13	Introduced OM	10.63	10.47

It may be concluded that objects belonging to the third cluster assumed as the most favourable on account of the nitrogen balance had the lowest acreage of agricultural land, which was at the average 6.62 ha. Farms that have the biggest area of agricultural land belonged to the first cluster which had the biggest deficiency of the nitrogen balance. It must be noticed that participation of arable lands in farms from cluster 3 constituted over a half (ca. 54%) of the entire area of agricultural land and ca. 30% of permanent grasslands. Compared to the remaining clusters these were values close to average. A considerable increase of arable land participation (cluster 2) and their reduction (cluster 1) was a negative situation. Also farms from cluster 3 had the biggest area of orchards and plantations which constituted 16.62% of agricultural land. On account of use of arable land in farms belonging to that group, grains prevailed which constituted ca. 56% of AL – the highest amount from all the investigated groups. The lowest index was in case of fodder plants (12.15% AL) and root crops (9.73% AL). In case of permanent grasslands meadows prevailed that constituted 99% of PGL while grazing lands only 1%. Taking into consideration mineral elements N, P and K in farms belonging to cluster 3, we see that these were the lowest values occurring in all groups of farms and were respectively N – 29.00 $kg \cdot ha^{-1}$, P – 20.39 $kg \cdot ha^{-1}$ and K – 46.72 $kg \cdot ha^{-1}$. In case of the introduced organic substance it was also the lowest value and it was 0.34 $t \cdot ha^{-1}$. And the introduced mineral elements and OM decided the most on the location of a farm in particular clusters.

The group of objects belonging to cluster 2 (assumed as the most favourable on account of the organic substance balance), was characterized with a small agricultural land area which on average was ca. 10 ha. The most sustainable farms had a high acreage of arable land which was as much as 87.57% AL, while they were characterised with the lowest participation of permanent grasslands – 3.54%AL. Participation of particular crops in arable lands had average values. Grains (44.94% AL), fodder crops (32.32% AL) while the lowest participation of root crops (10.48% AL) had the highest participation. Area of orchards and plantations also assumed medium values and constituted 8.89% AL. In case of the area of permanent grasslands the most favourable were those farms, which had acreage of grazing lands which constituted ca. 17% PGL and a considerably smaller area of meadows which constituted only 1.21 % PGL. The number of the introduced mineral elements N, P and K was at the average level and was respectively: 34.65, 24.08 and 54.53 $kg \cdot ha^{-1}$. The number of the introduced organic substance was at the level of 0.48 $t \cdot ha^{-1}$.

Farms from the first cluster characterised with an excessively high balance of organic matter (0.84 $t \cdot ha^{-1}$), mainly had a great area of agricultural land and a high participation of permanent grasslands (ca. 69% AL). The highest participation in arable lands was in case of fodder plants which had 60% of AL while the lowest was participation of grains (32.63% AL) and root crops (6.36% AL). Farms from this group practically did not have orchards and plantations but had the highest participation of grazing lands in permanent grasslands (20.29% PGL). Doses of the introduced mineral elements N, P and K were the highest from all the investigated clusters and were at the level from 36.55 to 78.14 $kg \cdot ha^{-1}$. In case of the introduced organic substance it was also the highest value and it was 0.51 $t \cdot ha^{-1}$.

Based on the characteristics of cluster centres, one may notice a great similarity between cluster 2 and 3. According to the analyses, farms belonging to those clusters proved to be the best balanced with regard to respectively organic matter and nitrogen. While, in each case of analysis of the organic balance, cluster 1 was the worst.

Economic sustainability

Figure 2 presents division of clusters in the investigated farms on account of economic sustainability.

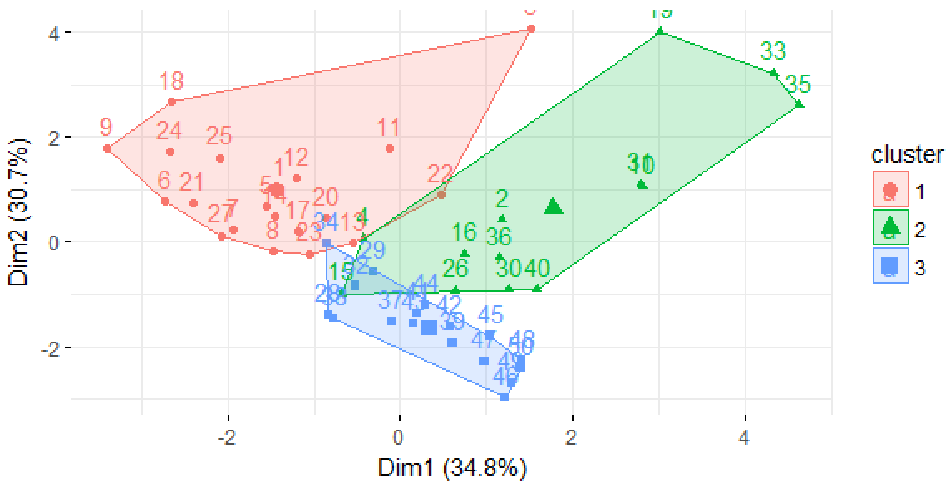

Figure 2. Graphical illustration of clusters based on two base components

Table 6 presents characteristics of cluster centres. For each cluster, an average value and median of income per fully employed person was determined (table. 7).

Table 6.
Characteristics of cluster centres for economic sustainability

	Variable	No of cluster 1	2	3
1	Area AL (ha)	5.19	9.03	24.16
2	Replacement value of machines (PLN·ha^{-1})	48962.75	30714.54	22319.76
3	Replacement value of buildings (PLN·ha^{-1})	38592	26936.77	11405.18
4	Livestock (LSU·100 ha^{-1})	62.91	3.01	73.13
5	Input of live labour (man-hour·ha^{-1})	431.3	175.77	177.18
6	Gross final production (PLN·ha^{-1})	9762.6	11473.15	6195.53
7	Production costs (PLN·ha^{-1})	6655.75	3637.77	3843.59

Table 7.
Values of average and median of income per fully employed person for each of clusters

	Income per fully employed person	
No of cluster	Mean	Median
1	14360.70	7792.527
2	78114.64	63161.29
3	25092.90	27183.26

The first cluster covers farms with the lowest annual income per a fully employed person – on average slightly above 14.3 K PLN. The second cluster with the highest average income at the level of ca. 78 K PLN per annum. On the other hand, the third cluster is an average cluster with the mean of 25 K PLN. The second cluster was recognised as the most economically balanced.

To investigate variability of the investigated farms on account of economic sustainability, analysis of variance was used (table 8). Farms classified to cluster 2 that indicates the highest income per a fully employed person significantly differed from the remaining ones. While, no significant differences in income of objects from cluster 1 and 3 were proved.

Table 8.
Analysis of variance for economic sustainability

	Duncan test; variable Income per FEP(Sheet 1) Uniform groups, alfa = ,05000 Error: MS group = 1084E6, df = 47,000			
Subclass no	Class	Income per FEP	1	2
1	1	14360,66	****	
3	3	25092,90	****	
2	2	78114,64		****

Based on the data set in table 9 it was concluded that the highest impact on allocation of farms to particular clusters had production costs, agricultural land area, livestock and live labour input. To a smallest degree, the impact was also in case of the replacement value of machines and buildings.

Table 8.
Participation of particular variables in elements

Variables		Component 1	Component 2
1	Area AL (ha)	20.38	12.44
2	Replacement value of machines (PLN·ha^{-1})	14.51	9.91
3	Replacement value of buildings (PLN·ha^{-1})	14.22	14.46
4	Livestock (LSU· 100 ha^{-1})	1.83	45.70
5	Input of live labour (man-hour ha^{-1})	17.99	0.00
6	Final gross production (PLN·ha^{-1})	4.56	8.63
7	Production costs (PLN·ha^{-1})	26.51	8.87

As it was mentioned above, table 6 presents characteristics of centres of the formed clusters referred to variables on account of which the economic sustainability was investigated. Farms belonging to the second cluster (with the highest average value of income per a fully employed person) had an average area of agricultural land, which was ca. 9 ha. The replacement value of machines was at the level of above 30 K PLN·ha^{-1}, while the replacement value of buildings was ca. 27 K PLN·ha^{-1}. It is worth noticing that farms that well economically balanced had a very low livestock which was only 3.01 LSU·(100 ha)$^{-1}$. In case of work inputs also in this group they were the lowest and on average they were ca. 176 man-hour·ha^{-1}. Analysis of the gross final production, makes us notice that in the investigated group of farms it was the highest and was at the level of 11.5 K PLN·ha^{-1} while the production costs were there the lowest and were only 3.6 K PLN·ha^{-1}.

Farms belonging to the cluster with objects with the lowest income per a fully employed person prove that they had the lowest area of agricultural land (5.19 ha). The replacement value of machines and buildings was in this group at the highest level and it was respectively 49 and 38.5 K PLN·ha^{-1}. They also had a high livestock of 62.91 LSU·(100 ha)$^{-1}$ and the highest labour inputs as high as 430 man-hour·ha^{-1}. The gross final production assumed the average value and was almost 10 K PLN·ha^{-1}, while the production costs were considerably higher than the remaining groups - on average above 6.5 K PLN·ha^{-1}.

Conclusion

Based on the characteristics of centres of clusters for organic sustainability, one may notice that the most balanced farms with regard to NPK belong to cluster 3 and with regard to OM, they belong to cluster 2.

On account of nitrogen balance, the objects belonging to cluster 3 had the lowest acreage of agricultural lands (average 6.62 ha), a similar participation of arable land (54% of AL area) and permanent grasslands (30% of AL), the highest participation of the orchards and plantations area (16.62% AL), predominance of grains in the sowing structure (ca. 56% of AL), the lowest rate of participation of fodder crops (12.15% AL) and root crops (9.73% AL), the lowest introduced doses of NPK among all groups of farms (N – 29.00 kg·ha^{-1}, P – 20.39 kg·ha^{-1} and K – 46.72 kg·ha^{-1}) and the lowest introduced dose of OM (0.34 t·ha^{-1}).

On account of the balance of organic matter, objects from cluster 2 had a small area of agricultural land (average ca. 10 ha), a high acreage of arable land (as much as 87.57% of AL), the lowest participation of permanent grasslands (3.54% of AL), the average participation of particular crops in arable lands (grains covered the biggest area – 44.49% of AL and fodder plants – 32.32% of AL, while the lowest participation was in case of root crops - 10.84% of AL), average participation of the acreage of orchards and plantations (8.89% AL), average level of the introduced mineral elements NPK (respectively 34.65; 24.08 and 54.53 kg·ha^{-1}) and the amount of the introduced organic matter at the level of 0.48 t·ha^{-1}.

In cluster 2, a higher participation of root and fodder plants influenced a better balance of organic substance but at the same time a worse balance of mineral elements NPK. Thus, in organic farming, an activity consisting in animal production, including cattle breeding and rearing must be based on a high acreage of permanent grasslands. They constitute the best fodder base for animals, of which excrement are used for organic fertilization of field crops. This was confirmed by Szeląg-Sikora and Kowalski (2012) - organic farms from Małoplska region which breed farm animals were bigger than the others and had a very low livestock. According to Sokołowicz, Topczewska (2016), this situation may result from a great labour consumption of breeding and a small number of processors.

The highest impact on classification of farms to particular clusters (economic sustainability) had production costs, agricultural land area, livestock, and live labour input. To a smallest degree, the impact was also in case of the replacement value of machines and buildings.

Cluster 2 with the highest average value of income per a fully employed person had an average are of agricultural land (ca. 9 ha), a replacement value of machines of ca. 30 K PLN·ha^{-1}, a replacement value of buildings of ca. 27 K PLN·ha^{-1}, very low livestock (only 3.01 LSU·100 ha^{-1}), low work inputs (average only 176 man-hour·ha^{-1}), the highest final gross production (ca. 11.5 176 K PLN·ha^{-1}), and the lowest production costs (only 3.6 K PLN·ha^{-1}

Cluster 1 with the lowest average value of income per a fully employed person had the lowest area of agricultural land (only 5.19 ha), a high replacement value of machines and buildings (respectively 49 and 38.5 K PLN·ha^{-1}), high livestock (62.91 LSU·(100 ha)$^{-1}$), the highest inputs of work amounting to 430 man-hour·ha^{-1}, the average gross final production (almost 10 K PLN·ha^{-1}) and considerably higher production costs than the remaining groups – on average above 6.5 K PLN·ha^{-1}.

A low impact of the replacement value of the machinery park on classification of farms is a result of a small impact of the production trend. Based on this, one may conclude that the production effectiveness is not influenced by the production processes and the level of their automation rate or the level of organic sustainability but factors of the surrounding including social factors. It manifests through the fact that the level of subsidies and a possibility of the sale of products on the local market, regardless the price for these products, decide on the income of organic farms. It is confirmed by the research by Wrzaszcz (2017) who concludes that Organic farms reduce their distance with regard to profitability of a product referred to average farms as a result of absorption of funds from governmental programs. Moreover, Krupa et al., (2016) claims that in organic farms the production profitability and amount of income is influenced by main subsidies.

Therefore, an ensured level of subsidies, at the limited sale of products on the local market causes that there is no interest in other markets, but production is limited even to the level that ensures only own needs. Such actions are not favourable for the development perspective of organic production. Thus, it is necessary to integrate producers and recipients, who will search for new sale markets for sold organic products - a suitably high price will be possible to obtain.

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WYKORZYSTANIE ANALIZY SKUPIEŃ W OCENIE ZRÓWNOWAŻENIA GOSPODARSTW EKOLOGICZNYCH. CZĘŚĆ II. WYNIKI BADAŃ

Streszczenie. Nowoczesny model rolnictwa, to model oparty na trzech ładach – ekologicznym, społecznym i ekonomicznym. W pracy podjęto próbę wykorzystania analizy klastrów do oceny zrównoważenia ekonomicznego i ekologicznego gospodarstw ekologicznych. Wskazano czynniki, które statystycznie wpływały na decyzję o tym, które gospodarstwo należy uznać za dobrze zrównoważone, a które nie. Analizy pozwalają na stwierdzenie: 1) w rolnictwie ekologicznym prowadzenie działalności w zakresie produkcji zwierzęcej, w tym głównie chów i hodowla bydła, musi być oparte o wysoki areał trwałych użytków zielonych; 2) o efektywności produkcji nie decydują realizowane procesy produkcyjne i poziom ich umaszynowienia, czy też poziom zbilansowania ekologicznego, a czynniki otoczenia, w tym czynniki społeczne.

Słowa kluczowe: analiza klastrów, gospodarstwo zrównoważone, gospodarstwo ekologiczne