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SPATIAL DIVERSITY OF PODLASIE RURAL COMMUNES FOR ENVIRONMENTAL CONDITIONS AND AGRICULTURAL LAND USE

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Summary

This study presents spatial diversity of environmental and economical conditions of 105 communes in Podlasie province. The eight variables which are indicators of environmental and economic conditions were used for the evaluation of regional differentiation. Multivariate statistical methods i.e. principal component analysis (PCA) and hierarchical cluster analysis (Ward's method) were used for classification of communes into 4 distinct clusters. Among the studied variables percentage of light soils and index of natural condition quality for agriculture were most strongly correlated with PC1, they had the biggest contribution in total spatial variation among the communes.

Key words and phrases: multivariate methods, Podlasie province, rural communes diversity, statistical classification

Classification AMS 2000: 62P12, 62P20

1. Introduction

Environmental conditions are very important for development of rural areas. Environmental constraints can cause limits to agricultural production and worsen development of wide areas. In EU countries such areas are very often supported by special subsidies destined to Less Favoured Areas (LFAs). One of the main causes is low quality of soils as well as other environmental factors such as rainfall shortage or slopes. Very often it is connected with worse development of infrastructure and market (van Keulen, 2006).

Since accession of Poland to the EU in year 2004, some parts of all rural areas are treated as less-favoured areas (LFA). Such a status allows these subregions to receive special support. It gives a chance for equal development with other areas, which have better environmental conditions.

Wide diversity of the rural areas occurs on the farm level and regional levels in less-favoured areas (LFAs). To quantify spatial patterns of rural landscape, many environmental, agricultural, and socio-economic variables characterizing quality of soil and it's agricultural productivity, land use (agricultural activity), and social conditions in LFAs, have been used (Griffith et al., 2000; Ciołkosz, 2003; Cifaldi et al., 2004; Ruben and Pender, 2004; van Keulen 2006). The knowledge of the spatial variation of these variables is necessary for future policy for sustainable rural development in these areas (Ruben and Pender, 2004).

Podlasie province is one of the most important regions which needs special policy in Poland (Kostrzewska et al., 2006; Roszkowska et al., 2006). Almost all rural communes are treated as LFAs in this province. It means that environmental and social conditions for agriculture are much worse than in other parts of Poland.

The aim of the paper was to assess the diversity among 105 rural communes across Podlasie province (102 communes have been recognized as LFAs) for 8 environmental and economical indicators (variables) recorded in 2002 (GUS, 2003).

2. Material and methods

The following 8 variables were used for multivariate analyses: percentage of natural high quality area (X_1), percentage of light soils (X_2), percentage of pastures and meadows (X_3), percentage of forests and forest land (X_4), index of natural condition quality for agriculture (X_5), average farm area in hectares (X_6),

index of agricultural production intensity (X_7), and income per 1 hectare (X_8) were collected in an agricultural survey (GUS 2003). Variables 1 to 5 characterize environmental condition whereas variables 6 to 8 are characteristics of economic conditions. The index of natural condition quality for agriculture (X_5) is a complex measure of agricultural land quality and depends mainly on soil quality, topographic features, and climatic conditions (Bud-Gusaim, 2005). The index of agricultural production intensity (X_7) was calculated on the base of four following variables: livestock density; share of expenses for fertilizers and pesticides; percentage of maize in arable area, and percentage of industrial crops in arable area (Herzog et al., 2006). The index of agricultural production intensity (L) is a sum of standardized values of these four variables according to the following formulae (Herzog et al., 2006):

$$L = \sum_{i=1}^{4} \frac{X_i - X_{i\,\min}}{X_{i\,\max} - X_{i\,\min}} \tag{2.1}$$

where: X_i is the *i*-th variable contributing to the intensity index L, $X_{i\,min}$ and $X_{i\,max}$ are the minimum and maximum values of the *i*-th variable, respectively.

Principal component analysis (PCA) was performed for all these variables after standardization to identify a core set of variables that are major, key-attributes contributing to the overall spatial diversity of the province (Filipiak and Wilkos, 1998; Griffith et al., 2000; Kobrich et al., 2003; Maseda et al., 2004). The hierarchical cluster analysis (Ward's method) was used to classify similar rural communes (Ward, 1963; Filipiak and Wilkos, 1998; Młodak, 2006). This method is different from others cluster analysis methods because it uses an analysis of variance approach to evaluate the distances between clusters. It is commonly used in regional taxonomy (Momen et al., 1995; Griffith et al., 2000; Kobrich et al., 2003; Maseda et al., 2004; Zabbini et al. 2007). Analyses were done using Statistica 7.1 statistical software (Dobosz, 2004).

3. Results and discussion

On the basis of results showed in Table 1, we can conclude that the highest coefficients of variation (CV=107%), among examined variables, were found for percentage of natural high quality area (X_1) – (Table 1). It proves very large variation among communes for the variable: some of them are totally covered by such areas, and some of them lack such areas. Quite large variability

(CV=65%) was observed for percentage of forests and forest land (X_4). The smallest variability (CV=15%) was observed for index of natural condition quality for agriculture (X_5).

Table 1. Means, maximum and minimum values, standard deviations (SD) and coefficients of variation (CV) for examined variables and their correlation coefficients with the first three principle components (PC1, PC2, PC3)

	PC1	PC2	PC3	mean	min	max	SD	CV
X_1	0.74	0.03	0.35	28.3	0.0	100	30.2	107%
X_2	0.85	0.30	-0.13	49.0	14.9	95.2	16.6	34%
X_3	0.39	0.67	0.38	35.3	15.9	79.8	10.3	29%
X_4	0.69	-0.41	0.44	27.1	6.6	87.7	17.5	65%
X_5	-0.87	-0.33	0.21	54.5	36.2	76.1	8.1	15%
X_6	-0.44	0.73	-0.12	10.6	2.1	17.8	3.6	34%
X_7	-0.73	0.17	0.49	0.37	0.019	0.751	0.13	36%
X_8	-0.66	0.17	0.17	1730.2	464	5251	766.8	44%

Variables strongly correlated with the first principal component contributed mostly to the overall variation of the communes studied. Contribution of variables correlated with the second principal component to the total commune variability was much smaller. In our research the first and the second PC explained 65.5% of the whole spatial variation in the 8 variables (Fig. 1). The first principal component had the largest share in the total variability, explaining 47.9% of it. The variables strongly positively correlated with the first principle component (PC1) are X_1, X_2, X_4 and variables negatively correlated with PC1 are X_5, X_7, X_8. The second principal component (PC2) explained less total variability (17.6 %). PC2 was strongly correlated positively with variables X_3 and X_6. Then, PC1 identifies the most important pattern (gradient) of the LFA variation. PC2 revealed the second major pattern of the spatial variation, identified as the average farm area and percentage of grasslands.

Ward method of cluster analysis used in our research enabled to divide the 105 rural communes into four homogenous groups (clusters) with respect to agriculture and socio-economic variables (Fig. 2). Groups consist of 10 to 43 communes.

Patterns of their similarities and dissimilarities are visualized on the PC plot (Fig. 1). On the basis of *F* statistic values in Table 2, we can say that these groups were most differentiated with respect to the following variables: index of natural condition quality for agriculture (X_5), percentage of forests and forest

land (X_4), percentage of light soils (X_2), and percentage of natural high quality area (X_1). These variables were strongly correlated with the first principal component (PC1). The indicators which were less varied between clusters include percentage of pastures and meadows (X_3) and average farm area (X_6) – these variables are strongly correlated with the second component (PC2).

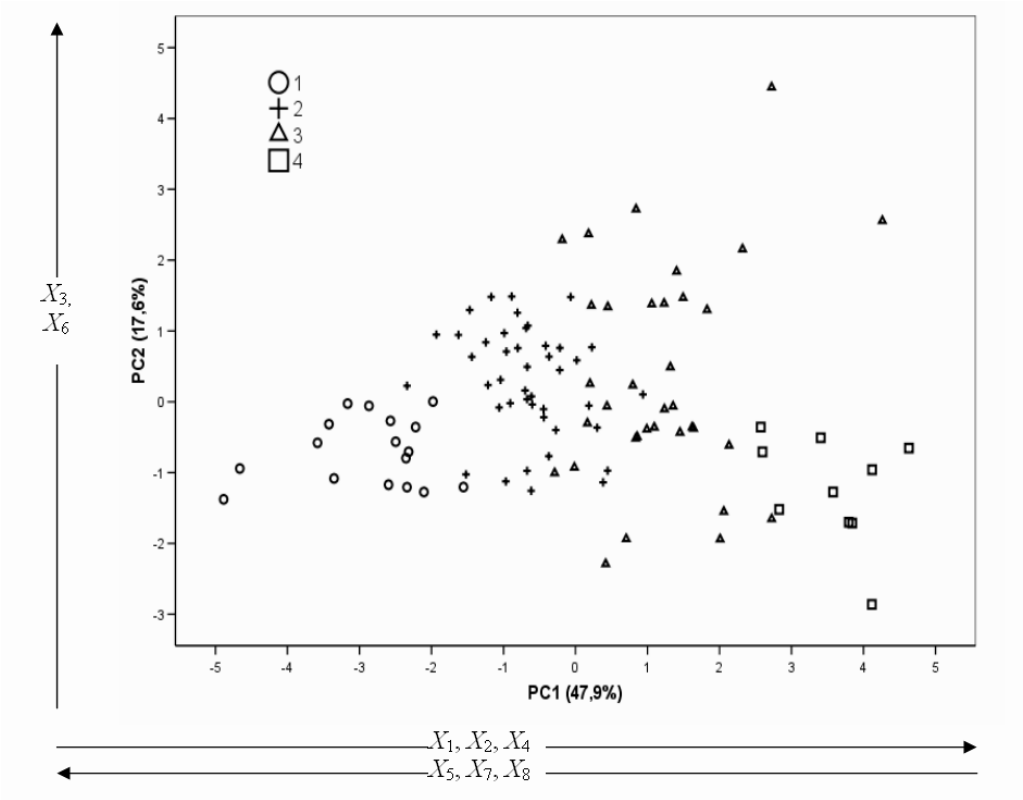

Fig. 1. Plot of the first and the second PC scores for the 105 rural communes in Podlasie province

The results obtained indicate distinct spatial variability among the rural communes in Podlasie province. On the basis of the spatial distribution in different groups of communes we can see that the diversity among them is mostly present in East-West direction and relatively small in North-South direction. The smallest values of PC1 are for communes which are nearer to eastern border of Poland (fig. 2).

Multivariate grouping of spatially distributed objects by cluster analysis very often reveals similarity between neighbouring objects and, simultaneously, differences between objects which are in larger distance (Caravelli, 2000; Ceccato, 2002). In our case the divided groups included very often neighbouring communes.

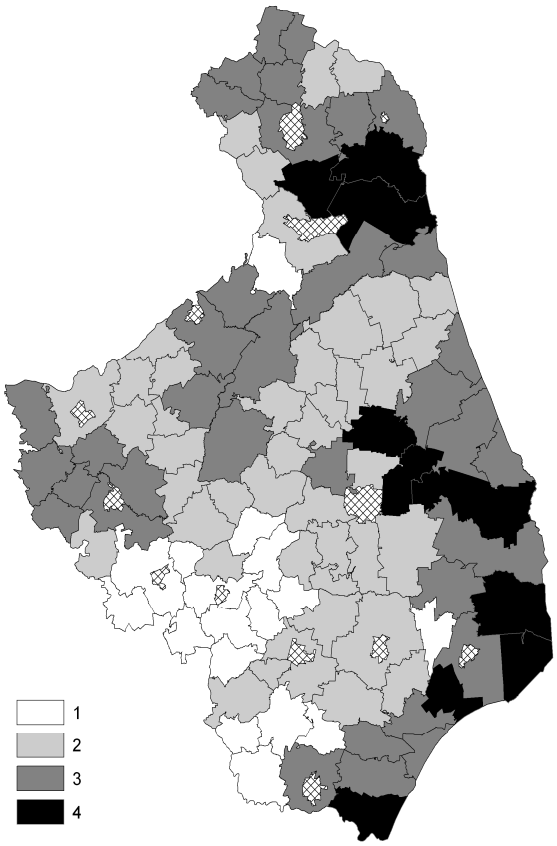

Fig. 2. Map of Podlasie province with different groups of rural communes

Values of variables: percentage of natural high quality area (X_1), percentage of light soils (X_2), and percentage of forests and forest land (X_4) which were positively correlated with PC1 were bigger for communes which are nearer to eastern border of Podlasie province. These communes have the worst environmental condition for agricultural production. These communes belong to group 4 which is marked in black color on the map. There are following communes: Białowieża, Czarna Białostocka, Dubicze Cerkiewne, Giby, Gródek, Mielnik, Narewka, Nowinka, Płaska and Supraśl. This group had much smaller average

farm area than other three groups of communes as well as smaller average income per one ha. It means that not only environmental conditions are unfavorable, but also economic indicators are the results of the natural conditions.

Table 2. Means, standard deviation of examined variables for clusters of communes and *F* statistic values from the analysis of variance in which the factor levels were clusters

variables	No of cluster				all communes	*F* statistic
	1	2	3	4		
	mean (standard deviation)					
X_1	5.42 (12.36)	11.86 (15.92)	46.09 (27.57)	75.84 (14.83)	28.32 (30.24)	44.6**
X_2	25.8 (5.1)	44.9 (9.3)	59.6 (12.9)	69 (10.8)	49 (16.6)	55.6**
X_3	26.1 (4.3)	36.2 (6.2)	37.9 (13.9)	37.5 (8.6)	35.3 (10.3)	6.5**
X_4	19.8 (8.6)	18.9 (7.5)	28.6 (12)	69.8 (12.3)	27.1 (17.5)	76.0**
X_5	67.8 (3.71)	55.7 (4.05)	49.1 (4.8)	45.8 (5.08)	54.5 (8.09)	85.5**
X_6	11.55 (2.04)	11.45 (3.47)	10.52 (3.51)	5.56 (1.96)	10.59 (3.57)	9.8**
X_7	2579 (558)	1893 (763)	1352 (422)	910 (252)	1730 (767)	23.5**
X_8	0.536 (0.109)	0.376 (0.121)	0.324 (0.078)	0.24 (0.118)	0.371 (0.133)	21.2**
No of communes	17	43	35	10	105	

**- at 0.01 significance level

The most favoured environmental conditions for agricultural production were for the first group of communes. The communes are in white color on the map. These communes in average had very small percentage of natural high quality area (X_1) and relatively small percentage of light soils (X_2). Most of the communes from this group are situated in South-West part of Podlasie province.

Negative correlation between such variables as value of income per 1 ha (X_8) and coefficient of agricultural production intensity (X_7) with PC1 means that very often the environmental conditions are correlated with economic indicators of agricultural production. Value of average income which is probably the most important indicator of agricultural production intensity was much higher for communes with better natural conditions (for group 1) than for other groups (especially from group 4).

Among the variables studied these which are characteristics of quality of soil discriminate to a high degree the communes in Podlasie province. The soil quality is one of the most important factors which should be taken into consideration in planning future agricultural policy in EU (Tóth et al., 2007). Bad quality of soil can cause marginalization of agricultural areas (Mander et al. 2005).

Other economical indices are connected with natural soil conditions which are important for intensive agricultural production. The most unfavourable environmental conditions for agriculture are in the east part of Podlasie and this part needs very careful regional policy. This part is not only important as a region which needs special economical support, but also it is important because of its natural (e.g. Białowieża Forest) and historical heritage (diversity of culture).

Applying various multivariate statistical methods allows to point out these characteristics of LFAs which are very important in planning future activities for support of these areas.

Another aim, except of distinguishing these important variables, is to indicate groups of subregions which are similar according to many variables (Ceccato and Persson, 2002)

Cluster analysis can be a useful tool indicating the objects with similar economic activities in geographical space. Collocation of similar communes in the area of Podlasie province according to studied variables shows connection between geographical location and socio-economical conditions. Connections or lack of connections between subregions is very important factor which enables or limits sustainable development of LFAs (Oskam et al., 2004).

4. Conclusions

The analyses conducted revealed very strong influence of natural conditions on intensity of agricultural production. Soil quality was the main factor connected with other environmental and economical indices of agriculture in Podlasie. Better soil quality causes possibilities to intensive crops cultivation and, as a result, it is very important factor which is strongly connected with income per unit area. Such connections should be taken into consideration in the future agricultural policy because natural constrains such as bad soil quality can limit sustainable development of the region. Spatial distribution of communes with worse environmental and economical conditions for agricultural production in Podlasie province evidenced that such communes are mainly located in the eastern part of the province.

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ZMIENNOŚĆ PRZESTRZENNA GMIN WOJEWÓDZTWA PODLASKIEGO POD WZGLĘDEM WARUNKÓW ŚRODOWISKOWYCH I ROLNICZEGO UŻYTKOWANIA TERENU

Streszczenie

Zaprezentowano zróżnicowanie przestrzenne warunków środowiskowych i ekonomicznych 105 gmin województwa podlaskiego. Osiem zmiennych, które są wskaźnikami warunków środowiskowych i ekonomicznych zostało wykorzystanych do oceny zróżnicowania regionalnego. Wielowymiarowe metody statystyczne tj. analiza składowych głównych (PCA) i hierarchiczna analiza skupień (metoda Warda) zostały wykorzystane do wydzielenia 4 odrębnych grup gmin. Spośród badanych zmiennych, udział gleb lekkich i wskaźnik waloryzacji rolniczej przestrzeni produkcyjnej były najsilniej skorelowane z pierwszą składowa główną (PC1), tak więc te zmienne najsilniej wpływały na całkowitą zmienność wśród gmin.

Słowa kluczowe: metody wielowymiarowe, województwo podlaskie, zmienność gmin wiejskich, klasyfikacja statystyczna

Klasyfikacja AMS 2000: 62P12, 62P20