CBCS
http://agrobiol.sggw.waw.pl/cbcs

Communications in Biometry and Crop Science
Vol. 3, No. 2, 2008, pp. 72–79

International Journal of the Faculty of Agriculture and Biology,
Warsaw University of Life Sciences, Poland

REGULAR ARTICLE

Crop diversity at the gmina level and its causes in the Podlasie district of Poland

Dariusz Gozdowski[1*], Barbara Roszkowska-Mądra[2], Wiesław Mądry[1]

[1] Department of Experimental Design and Bioinformatics, Warsaw University of Life Sciences, Poland.
[2] Division of Business Management, University of Białystok, Poland.
* Corresponding author: Dariusz Gozdowski, E-mail: dariusz_gozdowski@sggw.pl

CITATION: Gozdowski, D., Roszkowska-Mądra, B., Mądry, W. (2008). Crop diversity at the gmina level and its causes in the Podlasie district of Poland. *Communications in Biometry and Crop Science* 3 (2), 72–79.

Received: 28 April 2008, Accepted: 15 September 2008, Published online: 14 October 2008

ABSTRACT
Crop diversity is an important feature from agricultural and ecological points of view, because it secures preservation of natural biodiversity (flora and fauna species) and reduces negative effects of agricultural production. It is especially important in regions with valuable natural conditions such as the Podlasie district (northeast region of Poland). This study presents a distribution of crop diversity in the Podlasie district's gminas[1] and attempts to probe into its possible causes. Crop diversity was evaluated based on Shannon's index and assessed on the share of the main crops. The data applied were obtained in the National Agricultural Census of Poland in 2002. Relationships between Shannon's index and several characteristics of socio-economic and environmental conditions were estimated using multiple linear regression. The results obtained demonstrated that crop diversity depended mainly on share of light soils; the bigger share caused lower crop diversity. Livestock density was another factor influencing crop diversity; the effect of cattle density was positive while that of pig density is negative. The results of this study identify factors that can be taken into consideration in planning a future policy for sustainable development of the district; these factors are share of light soils and livestock density.
Key Words: *Shannon's index; spatial variability; sustainable development.*

INTRODUCTION

Spatial diversity of crops is an important issue in many ecological, agricultural and economic surveys. The spatial scale of such surveys is varied and ranges from one field

[1] Gmina – the smallest administrative unit in Poland. It has a similar meaning as Gemeinde in Germany or township in the U.S.

through one farm and village up to a regional or even continental scale (Duelli, 1997; Meng et al., 1998; Cromwell and Oosterhout, 2000).

High crop diversity is favorable for ecological sustainability. Intensification of agricultural production leads to the reduction of a number of crop species grown in a region. In Poland, like in other European countries, intensification of agricultural production and livestock feed demands has caused the simplification of crop production and increased the share of cereals, especially high-yielding species such as wheat, barley and maize (Chloupek et al., 2004). Other crops are more and more marginalized, and eventually they can even disappear from production. This would be unfavorable from miscellaneous points of view, the most important ones being ecology, sustainable agriculture, agricultural tradition, and biological diversity. Crop diversity reduces the negative impact of agricultural production on the environment (Cutforth et al., 2001).

Crop diversity is determined by many factors which can be divided into two groups, namely natural (environmental) and socio-economic. Natural conditions such as climate and soil fertility limit cultivation of many crops, while socio-economic factors such as needs of market force farmers to grow selected crops (Benin et al., 2004). Identification of reasons influencing crop diversity is important to create an appropriate socio-economic future policy that could allow for conservation of or even an increase in biodiversity in rural areas.

Crop diversity is estimated using a variety of methods based on various criteria, such as number and share of cultivars, species or groups of crops (Meul et al., 2005). To present the diversity quantitatively, quite often numeral indexes are used. They allow for synthetic evaluation of diversity and comparison of the diversity between different areas. Of many such indexes, the most common is Shannon’s index; it takes into account a number of species or cultivars as well as their share in a geographic area of study.

Crop diversity is often reported in terms of the so-called autocorrelation, which measures whether regions situated next to each other have similar crop diversity. If this is the case, which is quite often the situation, there is positive spatial autocorrelation between the regions. Otherwise, that is to say, when no such pattern is observed for spatial distribution of crop diversity, autocorrelation does not exist (Beck et al., 2006; Rana et al., 2007).

The aim of this study is to evaluate crop diversity in the gminas of the Podlasie district located in northeast Poland as well as discuss its possible causes. Owing to many environmental and economical constrains, most areas of this region are treated as LFA (Less Favoured Areas) according to the European Union law. Hence, proper policy is needed for sustainable development and conservation of crop diversity in the region.

MATERIALS AND METHODS

The data applied were obtained in the National Agricultural Census of Poland in 2002, which covered the whole population of farmers. The census was conducted by the Central Statistical Office (GUS 2003). We chose the Podlasie district as a region of interest because it is has many valuable natural areas, e.g. Białowieża National Park. For this reason, sustainable agricultural is especially important for preserving biodiversity in the district. A basic unit used in the analyses was a gmina, a local administrative unit; each of 105 rural and mixed (urban-rural) gminas in the Podlasie district covers an area from 70 to 430 square kilometers. Agricultural production is the main activity of people living in both kinds of gminas (rural and mixed), thus we decided to consider all gminas in the analyses.

For the analyses, mean values of agricultural production characteristics for all 105 rural gminas were used. Shannon’s index (Y_1) was assessed based on the share of the following crops or groups of crops in the arable area:

- wheat and barley (intensive cereal species) (Y_2)
- rye, oat and triticale (extensive cereal species) (Y_3)

- maize (Y_4)
- potatoes (Y_5)
- industrial crops, mainly sugar beets (Y_6)
- other crops (Y_7)

Shannon's index (H) was calculated according to the following formula (Gering et al., 2003; Meul et al., 2005):

$$H = -\sum_{i=1}^{s} p_i \, ln(p_i) \ , \qquad [1]$$

where s is a number of crops or groups of crops and p_i is the share of a particular crop/group of crops; p_i's, the sum of which equals 1, are expressed as a value between 0 and 1 .The higher the value of Shannon's index, the higher the crop diversity in the area (the maximal H value is obtained when the share of all crops is the same).

To evaluate the spatial distribution of crop diversity, we used Moran's global coefficient of spatial autocorrelation (I_G) (Moran, 1948). For each gmina Morans's local correlation coefficient (I_L) was determined to detect outliers (i.e., those gminas which have crop diversity noticeably different from their neighbors). The spatial autocorrelation coefficients were calculated using ArcGIS 9.1 software (Mitchell, 2005).

Relationships between Shannon's index (Y_1) and the following characteristics of socio-economic and environmental conditions were estimated:

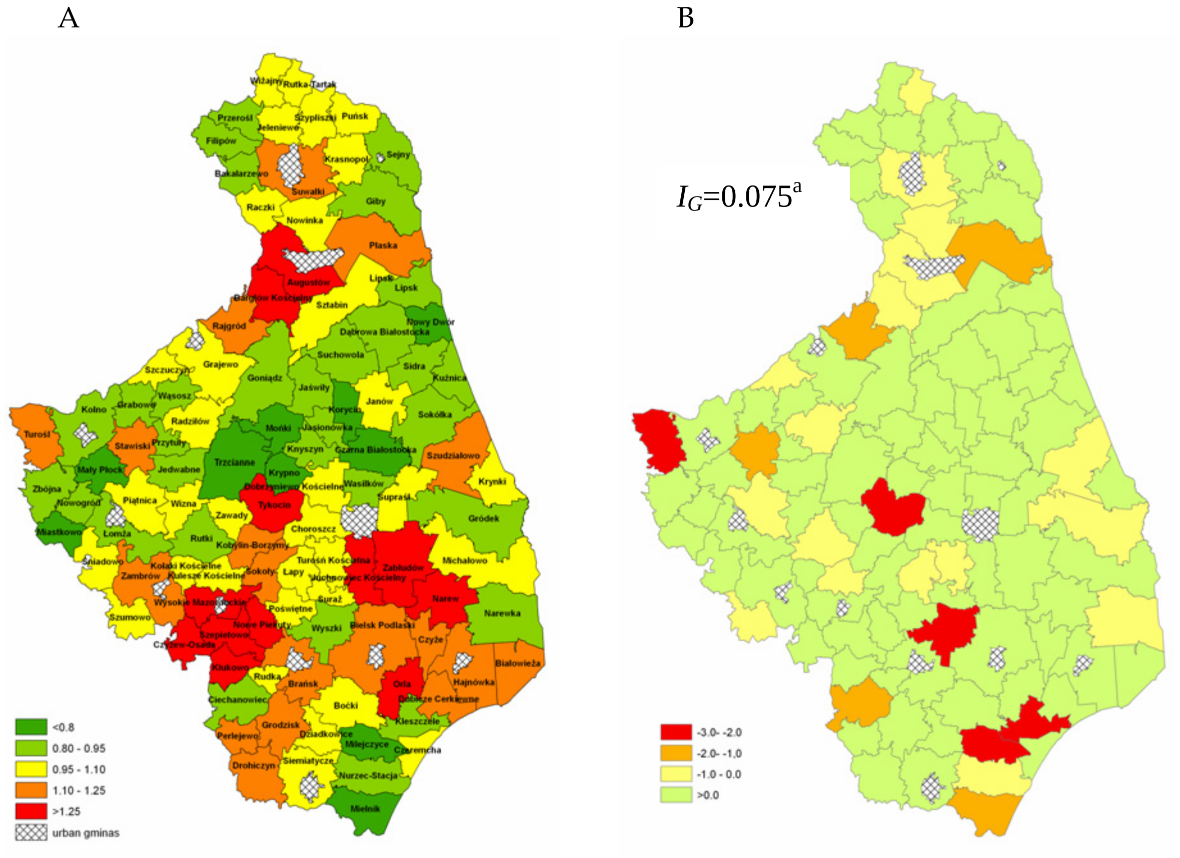
X_1 – share of area with special natural conditions (%)
X_2 – share of light soils (%)
X_3 – share of pastures (%)
X_4 – share of farmers without professional agricultural education (%)
X_5 – cattle density (units per 100 hectares)
X_6 – pig density (units per 100 hectares)
X_7 – share of fallowed land (%)

These variables were chosen from more than 50 variables for three reasons: first, they were rather weakly correlated. Second, they carried most important information about many agricultural production aspects in Poland, and third, they may have a significant effect on Shannon's index. The influence of these 8 variables on Shannon's index was estimated using multiple linear regression. Before the analysis, the variables were standardized to facilitate the comparison of partial regression coefficients. The best-fitted multiple regression model was found by all-possible-regressions with the maximal R^2-adjusted value using REG procedure of SAS 9.1 (ADJRSQ option); the null hypothesis for an i^{th} independent variables, that is H_0: β_i=0, was tested at the 0.05 probability level.

RESULTS

The largest share in arable areas had extensive cereals species, i.e., rye, oat and triticale; their average share over all gminas was 67.8%. The likely reason of so large a share is a predominance of light soils in the Podlasie district and low soil demands of these crops (Kostrzewska et al., 2006). Standard deviation for share of extensive cereals was the highest, which means that absolute differences between shares of this group of crops for gminas were higher than those for the other crops.

Because of different units, the coefficient of variation (CV) better represents the variability of variables which characterize agricultural production than the standard deviation does. The highest variability (CV) was observed for share of area with special natural conditions (X_1) and share of fallows (X_7), whereas there was a relatively small variability for share of farmers without professional agricultural education (X_4). The values of Shannon's index for gminas of the Podlasie district (figure 1A) indicate differences between gminas in crop diversity. The gminas with a low value of Shannon's index had a predominance of extensive cereals.



[a] – value of Moran's global spatial autocorrelation for Shannon's index

Figure 1. Maps of the Podlasie district presenting (A) values of Shannon's index and (B) standardized values of Moran's local spatial autocorrelation coefficient for Shannon's index.

Relatively high values of Shannon's index were observed in the gminas situated in southern and northern parts of the district (around Augustów gmina). Significant ($p \leq 0.01$), though small, positive global autocorrelation (I_G=0.075) was observed, indicating that crop diversity was similar for neighboring gminas. Based on local Moran's statistics (I_L), outlier gminas were identified. These gminas had small values of Moran's autocorrelation coefficient (figure 1B), which means that crop diversity for these gminas was much higher (e.g., Turośl and Tykocin) or much smaller (e.g., Wyszki, Kleszczele and Milejczyce) than for the neighboring gminas.

The correlations among shares of crops and groups of crops (Table 2) indicate moderate negative correlations between the share of intensive cereals (Y_2) and the share of extensive cereals (Y_3), as well as between the share of industrial crops (Y_6) and the share of extensive cereals (Y_3), with the respective correlation coefficients –0.76 and –0.65. These correlations could result from soil quality: in gminas with better soils, the share of crops with higher soil demands (e.g., wheat, barley and sugar beet) was greater than in gminas with worse soils; simultaneously, the former gminas had a smaller share of crops with lower soil demands (e.g., rye and oat).

Standardized multiple regression analysis, applied to estimate the influence of shares of crops or groups of crops on Shannon's index, indicates the strongest effect of share of extensive cereals for the index (Table 3).

Table 1. Means and variability parameters of Shannon's index (Y_1), shares of particular crops or groups of crops (Y_2-Y_7), and characteristics of agricultural production (X_1-X_{10}) for gminas of the Podlasie district.

Variable	Mean	Standard deviation	CV (%)	Min.	Max.
Shannon's index (Y_1)	1.02	0.18	17.7	0.54	1.52
Share of particular crops or groups of crops in arable area (%)					
Wheat and barley (Y_2)	11.8	7.1	59.7	2.4	37.3
Rye, oat and triticale (Y_3)	67.8	9.0	13.2	40.1	86.9
Maize (Y_4)	3.6	2.8	76.5	0.0	14.9
Potatoes (Y_5)	9.5	3.8	40.4	3.3	20.4
Industrial crops, mainly sugar beets (Y_6)	1.3	1.9	145.1	0.0	9.0
Other crops (Y_7)	6.1	4.6	76.4	0.8	35.3
Characteristics of agricultural production					
Share of area with special natural conditions (%) (X_1)	28.3	30.2	106.8	0.0	100.0
Share of light soils (%) (X_2)	49.0	16.6	33.9	14.9	95.2
Share of pastures (%) (X_3)	35.3	10.3	29.1	15.9	79.8
Share of farmers without professional agricultural education (%) (X_4)	37.1	7.1	19.2	22.7	60.8
Cattle density (units per 100 hectares) (X_5)	60.1	27.1	45.0	4.4	130.7
Pig density (units per 100 hectares) (X_6)	79.3	51.8	65.3	5.5	275.9
Share of fallowed land (%) (X_7)	15.0	15.4	102.4	0.9	71.2

Table 2. Correlation matrix for shares of crops and groups of crops (Y_2 – Y_7).

	Wheat and barley (Y_2)	Rye, oat and triticale (Y_3)	Maize (Y_4)	Potatoes (Y_5)	Industrial crops (Y_6)
Rye, oat and triticale (Y_3)	–0.76	1.00			
Maize (Y_4)	0.08	–0.37	1.00		
Potatoes (Y_5)	–0.40	0.17	–0.27	1.00	
Industrial crops (Y_6)	0.56	–0.65	0.34	–0.29	1.00
Other crops (Y_7)	0.00	–0.44	0.08	–0.26	0.04

Table 3. Standardized partial regression coefficients (b_i) for share of crops and groups of crops influencing Shannon's index, and coefficient of determination (R^2).

Independent variable	b_i	P-value
Wheat and barley (Y_2)	–0.18	0.001
Rye, oat and triticale (Y_3)	–0.91	<0.001
Maize (Y_4)	0.12	<0.001
Potatoes (Y_5)	–0.06	0.056
Industrial crops (Y_6)	0.17	<0.001
R^2	93.59	<0.001[a]

[a] P-value for the regression model

The negative coefficient of regression (–0.91) indicates that the increase in share of extensive cereals (i.e., rye, oat and triticale) was the main cause that decreases crop diversity. Other shares of crops and groups of crops had smaller effects on crop diversity. A positive effect on Shannon's index had share of maize (Y_4) and share of industrial crops (Y_6) (values of regression coefficients respectively equal to 0.12 and 0.17).

Correlation coefficients for variables that characterize the agricultural production in the Podlasie district's gminas are presented in Table 4. Since the variables that were strongly correlated were not considered in the analysis, only weak or moderate correlations between these variables occurred.

Table 4. Correlation matrix for characteristics of agricultural production in gminas of the Podlasie district.

	Shannon's index (Y_1)	X_1	X_2	X_3	X_4	X_5	X_6
Share of area with special natural conditions (%) (X_1)	–0.05	1.00					
Share of light soils (%) (X_2)	–0.45	0.50	1.00				
Share of pastures (%) (X_3)	–0.16	0.30	0.42	1.00			
Share of farmers without professional agricultural education (%) (X_4)	–0.01	–0.09	0.21	0.01	1.00		
Cattle density (units per 100 hectares) (X_5)	0.21	–0.37	–0.43	0.03	–0.15	1.00	
Pig density (units per 100 hectares) (X_6)	–0.24	–0.25	–0.28	–0.33	–0.17	0.40	1.00
Share of fallowed land (%) (X_7)	–0.01	0.50	0.49	0.14	–0.05	–0.69	–0.43

Table 5. Partial regression coefficients (bi) between standardized values of variables which are characteristics of agricultural production in the Podlasie district and Shannon's index

	b_i	P-value
Share of area with special natural conditions (%) (X_1)	0.21	0.025
Share of light soils (%) (X_2)	–0.60	<0.001
Share of pastures (%) (X_3)	–0.18	0.048
Share of farmers without professional agricultural education (%) (X_4)	0.16	0.049
Cattle density (units per 100 hectares) (X_5)	0.48	<0.001
Pig density (units per 100 hectares) (X_6)	–0.43	<0.001
Share of fallowed land (%) (X_7)	0.37	0.017
R^2 ($R^2_{adj.}$) %	50.28 (46.13)	<0.000[a]

[a] P-value for the regression model

The determination coefficient for the model of Shannon's index by seven selected independent variables characterizing the agricultural production in the Podlasie district's gminas equaled 50.28%. The share of light soils (X_2) had the greatest effect on Shannon's index but the effect was negative (Table 5), indicating that the higher the share of light soil, the smaller the crop diversity. Pig density (X_6) also had quite a strong negative effect, a likely reason of which was high share of cereals, the main feed crop for pigs. Cattle density (X_5) had the strongest positive effect on Shannon's index. The effects of the other variables, namely share of area with special natural conditions (X_1), share of farmers without professional agricultural education (X_4), and share of fallows (X_7), were much smaller.

DISCUSSION AND CONCLUSIONS

From the analysis it can be concluded that crop diversity in the Podlasie district is influenced by environmental conditions, especially soil quality. A high share of light soils has a negative effect on diversity, though not too strong. This is probably due to the positive effect of share of light soils on share of extensive cereals (i.e., rye, oat and triticale). An opposite situation occurs for a small share of light soils and high share of better soils, for which situation high crop diversity can be expected. Livestock density is another factor significantly influencing crop diversity. Depending on an animal species, the influence was positive or negative, being positive for cattle density and negative for pig density. Livestock density (both cattle and pig) greatly depends on people's activity, so the future livestock density in these gminas can be controlled, hence, indirectly maintaining or even increasing crop diversity.

The overall effect of the independent variables considered on Shannon's index is not too strong, since almost 50% of total variability of the index was explained by unknown factors reflected by the residual term. For the moment it is difficult to claim which factors that were not considered in the model affected the crop diversity.

Increasing biodiversity of agricultural areas and high crop diversity is positive from an ecological point of view; however, intensification of agricultural production is inevitably connected with limiting the diversity (Cutforth et al., 2001). Because economical and ecological points of view are very often contradictory, without an appropriate policy to support sustainable development it is impossible to conserve crop diversity (that is, keep high share and number of species and cultivars in a region) (Benin et al., 2004; Rana et al., 2007). It is important to trace changes of crop diversity in the region in time, because downward tendency of the diversity should be stopped by appropriate agricultural policy (e.g., subsidies for adaptation of sustainable cropping systems).

REFERENCES

Beck, J., Kitching, I., Linsenmair, E. (2006). Determinants of regional species richness: an empirical analysis of the number of hawkmoth species (Lepidoptera: Sphingidae) on the Malesian archipe, *Journal of Biogeography*, 33, 694–706.

Benin, S., Smale, M., Pender, J., Gebremedhin, B., Ehui, S. (2004). The economic determinants of cereal crop diversity on farms in the Ethiopian highlands. *Agricultural Economics* 31, 197–208.

Chloupek, O., Hrstkovaa, P., Schweigert, P. (2004) Yield and its stability, crop diversity, adaptability and response to climate change, weather and fertilisation over 75 years in the Czech Republic in comparison to some European countries. *Field Crops Research*, 85, 167–190.

Cromwell, E., Oosterhout, S. (2000). On-farm conservation of crop diversity: policy and institutional lessons from Zimbabwe. In: Brush, S. (Ed.). *Genes in the Field: On-Farm Conservation of Crop Diversity*. IDRC, Ottawa, Canada, 217–238.

Cutforth, L., Francis, C., Lynne, G., Mortensen, D., Eskridge, K. (2001) Factors affecting farmers' crop diversity decisions: An integrated approach. *American Journal of Alternative Agriculture*, 16, 168–176.

Duelli, P. (1997). Biodiversity evaluation in agricultural landscapes: An approach at two different scales. *Agriculture, Ecosystems & Environment*, 62, 81–91.

Gering, J., Crist, T., Veech, J. (2003). Additive Partitioning of Species Diversity across Multiple Spatial Scales: Implications for Regional Conservation of Biodiversity. *Conservation Biology*. 17, 488–499.

GUS (2003). *Report of Results of the 2002 Census of Agriculture*. Central Statistical Office, Warsaw (in Polish).

Kostrzewska, M.K., Jastrzębska, M., Wanic, M., Nowicki, J. (2006). Valuation of natural conditions and land development in Podlaskie province using different classification methods. *Fragmenta Agronomica*, 90, 54–71 (in Polish).

Meng, E., Smale, M., Bellon, M., Grimanelli, D. (1998). Definition and measurement of crop diversity for economic analysis. In: Smale, M. (Ed.). *Farmers, Gene Banks and Crop Breeding: Economic Analyses of Diversity in Wheat, Maize, and Rice*. Kluwer Academic Publishers, 19–31.

Meul, M., Nevens, F., Reheul, D. (2005). Genetic diversity of agricultural crops in Flanders over the last five decades, *Agronomy for Sustainable Development* 25, 491–495.

Mitchell, A. (2005). *The ESRI guide to GIS analysis. Vol.2 Spatial measurements and statistics.* ESRI Press, Redlands, California.

Moran, P. (1948). The interpretation of statistical maps. *Journal of the Royal Statistical Society: Series B* 10, 243–251.

Rana, R., Garforth, C., Sthapit, B., Jarvis, D. (2007). Influence of socio-economic and cultural factors in rice varietal diversity management on-farm in Nepal. *Agriculture and Human Values.* 24, 461–472.