SPATIAL ANALYSIS OF CROP DIVERSITY IN HUNGARY BEFORE AND AFTER INTRODUCTION OF GREENING

Márta Gaál[1], András Molnár[2]

[1] Research Institute of Agricultural Economics, National Agricultural Research and Innovation Centre, Budapest, Hungary

[2] Takarek Group, Budapest, Hungary

gaal.marta@aki.naik.hu, andras.molnar.aki@gmail.com

ABSTRACT

Due to the introduction of greening measures during the latest reform of the Common Agricultural Policy (CAP), the assessment of crop diversity has increasingly been a focus of interest. Better understanding of the factors that may influence the outcomes of diversity calculation could help the further evaluation of the regulations. This study investigates the spatial pattern of crop diversity in different scales and the changes over time in Hungary. Regional differences in crop diversity can be demonstrated at all scales examined, but the patterns are not exactly the same. Some increase in diversity can be revealed after the introduction of greening, but there are no further increasing tendencies.

Keywords*:* crop diversity, Shannon index, spatial resolution, agricultural policy

1. INTRODUCTION

Many authors have studied the advantages of diversifying agriculture crops and the negative effects of having a monoculture system. A farm growing only few crops is very sensitive to be affected by the emergence of a pathogen, pest invasion, and weather damages, or economic and market risks as well. Crop diversity can be realized across time by crop rotation, while diversifying the portfolio of cultivated crops maintains diversity in space (Weigel et al., 2018). Diversity has a positive and significant effect on crop production, especially when rainfall is low (Donfouet et al., 2017), and can potentially contribute to offer ecological services (Montelone et al., 2018). On the other hand, the negative effects of the monoculture on soil quality and on ecological conditions are also well known. However, excessive diversification could lead to adverse fragmentation of resource capacities, which may prevent the development of an optimum production level and size.

The Common Agricultural Policy (CAP) also puts emphasis on efficient agro-environmental actions for sustainable development. The 2013 CAP reform introduced a payment for a compulsory set of ‘greening measures’, one of which is crop diversification. According to this, farms having 10 to 30 hectares have to grow at least two crops, with the main crop representing a maximum of 75% of the arable area. Farms over 30 hectares are required to have at least three crops, the main crop covering at most 75% of the land and the two main crops together at most 95% (EU, 2013). Based on the European Commission (EC, 2017) report 75% of arable land in the EU was affected by this measure in 2016, while more than 90% in Hungary.

Agriculture is a traditionally important sector in the Hungarian economy, as the country has favorable soil and climatic conditions for several crops. However, the combined area of wheat and maize, accounts for about 45% of the arable land. The present study aims to compare crop diversity in Hungary before and after introduction of greening, and to explore whether the regulation had a significant impact on the cropping pattern. The effect of the spatial resolution of the analysis was also examined.

2. METHODOLOGY

2.1 Database

The Hungarian Agricultural Land Parcel Identification System (Hungarian acronym: MePAR), which is mandatory for the administration of agricultural subsidies, is based on physical blocks (more than 300,000). The size of the blocks varies on a relatively wide range, while the average size of the eligible area is around 25 hectares. A physical block may contain several agricultural parcels. When farmers submit subsidy claims they indicate their parcels and crops within the blocks, but the country-wide parcels' geometry is available only for the Hungarian Paying Agency.

In a former study (Gaál et al., 2018) crop diversity at species-level was analyzed based on the administrative data of 2010-2014. For data protection reasons the agency transformed the parcels' data to a 1x1 km (100 hectares) grid, therefore the obtained database contained for each grid the crop codes and the area by crops. The total number of the grid cells was 94,293.

Recent calculations were based on the same administrative database for 2014-2018, but attribute data (block id, crop code and area) were obtained at parcel level, which allowed the calculations at block level. Additionally, the blocks could also be aggregated at higher administration levels, from which the settlements (LAU 2) were applied. There were 3,154 settlements with an average size of almost 3,000 hectares.

2.2 Methods

Many diversity indices for calculating richness and evenness are frequently applied in ecology and landscape metrics, like the Shannon diversity index (SDI), the Simpson diversity index, and the Berger-Parker index. The Shannon diversity index has been applied as an indicator of cropland diversity in several studies (e.g. Aguilar et al., 2015; Donfouet et al., 2017; Montelone et al., 2018; Weigel et al., 2018). SDI can be calculated according to the following equation:

$$SDI = -\sum_{i=1}^{N} p_i * lnp_i$$

where N is the number of land cover types and p_i corresponds to the proportional abundance of the i^{th} type. The index can vary between 0 to infinity in theory; a low value represents low diversity while a high value evidences high diversity. Calculations were done block and settlement levels, and each crop code was counted as separate crop type.

Optimized hot spot analysis was implemented to detect spatial clustering of Shannon diversity values. This tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots) using the Getis-Ord Gi* statistic.

Additionally, statistical analyses were carried out to test the significant differences among the diversity values. Due to the non-normal distribution, Kruskal-Wallis and Mann-Whitney test were applied to reveal the overall differences among the years. Pearson's chi-squared statistics and Kendall's tau-b were also applied to check the differences in data distribution.

Basic calculations were done in a PostgreSQL database. Spatial clustering (optimized hot spot) and the representation were carried out with ArcGIS Desktop software.

3. RESULTS

3.1 Crop diversity at different scales

Considering the whole country, the total number of crop types varied between 314 and 400 per year. In a greater area there is a higher probability to cultivate more crops, therefore the crop diversity values depend on the size of the units examined. At block level the maximum number of the crop types was 27, with an average value of 2.5. Using the 1x1 km grid, the maximum number of crop types was 33, while the average was 6. The settlements cover much greater area, therefore at this level the maximum value was 133, while the average 23. Settlement level analysis of course hides diversity at lower levels of aggregation, especially the occurrence of the zero diversity values (only one crop) has reduced. Therefore, greater level of aggregation (blocks –> 1x1 km grid –> settlements) indicated a shift to the higher diversity values. However, adjusting the symbol categories to the given data, some clear regional patterns can be observed at any scale (Figure 1).

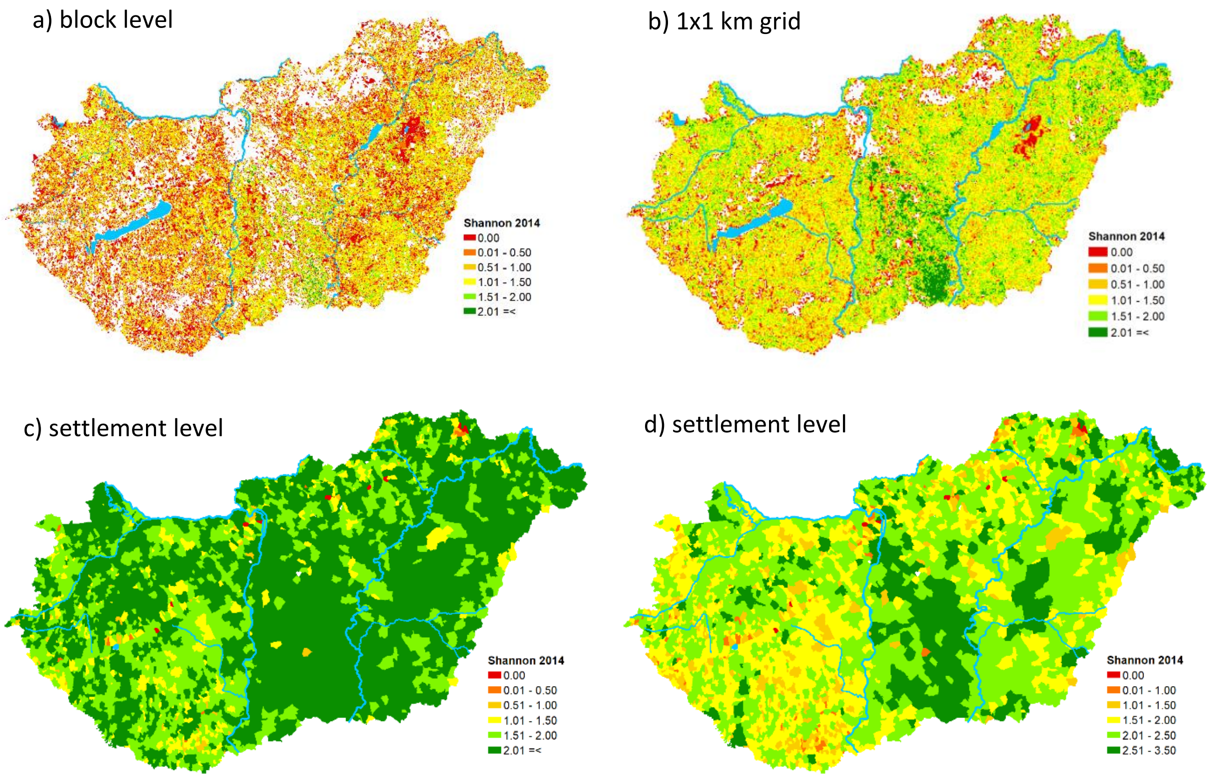

Figure 1. Scale dependency of crop diversity results
(a, b, and c with the same categories, d adjusted to the settlement level result)

3.3 Changes over time

The Shannon diversity index was calculated for each year from 2014 to 2018, for the physical blocks and for the settlements, as well. National average diversity values were calculated in two ways. First, as simple averages of the values obtained for the blocks/settlements, and secondly due to the different sizes of crop area in the blocks/settlements, area based weighted averages were also calculated (Table 1).

Except from the unweighted averages for blocks, there was an overall increase in crop diversity from 2014 to 2016, and until 2018 it remained almost stable. Based on the statistical analysis this increase proved to be significant for unweighted values at settlement level and weighted averages at block level. For weighted values at settlement level the significant difference between 2014 and 2015 could be kept only at 90% probability (p=0.075). The unweighted and weighted averages for the blocks show opposite tendencies over the years. Probably due to the increasing number of blocks (from 217,274 to 257,622 in total), and consequently the increasing number of the smaller blocks with one crop type (SDI = 0). In 2014, 87,736 blocks were found with mono-cropping, were the main crop types were permanent grassland (15,329 blocks, 17.5%), maize (14,856, 16.9%), and wheat (11,435, 13.0%). In 2018, 114,405 blocks were covered only by one crop type, which is about 30% more. The number of the blocks with wheat had a slight increase (plus 1,222 blocks), while the blocks with maize had decreased (with 1,018 less). The main changes are related to permanent grasslands, as the number of the blocks became more than twice (34,863), while the total grassland area has not changed. So, these were only administrative changes, which refer to the more precise delineation of grassland areas according to the maintenance of permanent grassland measure.

Table 1. Statistics of the Shannon diversity on national level

Calculation		2014	2015	2016	2017	2018	Chi-square	*p*- value
Blocks	average	0.53	0.54	0.51	0.50	0.49		
	median	0.51 *a*	0.51 *b*	0.44 *c*	0.40 *d*	0.38 *e*	1351.6	0.0001
Blocks, weighted	average	0.72	0.77	0.77	0.76	0.76		
	median	0.69 *a*	0.78 *b*	0.78 *c*	0.77 *d*	0.77 *e*	2088.6	0.0001
Settlements	average	1.96	2.04	2.06	2.04	2.03		
	median	1.98 *a*	2.07 *b*	2.09 *b*	2.08 *b*	2.08 *b*	106.2	0.0001
Settlements, weighted	average	2.13	2.21	2.23	2.20	2.20		
	median	2.16	2.24	2.25	2.22	2.22	4.054	0.3988

* different letters indicate the statistically different years

In addition to averages, the distribution of the diversity values is also important. The distributions were analyzed according to the categories presented in Figure 1a for block level and for settlement level Figure 1d. At both level significant correlations (p=0.000) were found between the categories and the years. In the case of settlements (Table 2) zero diversity values were hardly found and had a decreasing tendency. The remaining two settlements had only permanent grasslands. A decreasing tendency can be observed in the diversity category of 1.01-1.5, while a continuous increase in the category of 2.01-2.05, both in the number of settlements and the percentage of area affected.

Table 2. Distribution of the Shannon diversity values on settlement level

SDI categories	2014		2015		2016		2017		2018	
	count	area	count	area	count	area	count	area	count	area
0	9	0.0%	10	0.0%	6	0.0%	7	0.0%	2	0.0%
0.01-1.00	58	0.4%	51	0.2%	56	0.2%	66	0.3%	70	0.3%
1.01-1.50	346	5.6%	220	3.0%	215	2.9%	215	2.9%	217	2.9%
1.51-2.00	1199	29.5%	1065	23.3%	1004	21.9%	1018	23.5%	1042	23.9%
2.01-2.50	1252	47.8%	1449	51.7%	1486	52.9%	1479	52.9%	1488	55.1%
2.51-3.50	281	16.8%	355	21.9%	383	22.0%	365	20.4%	330	17.8%

At block level a weak negative correlation (Kendall's tau-b = -0.0269) can be observed between the diversity categories and the years examined, which can be a consequence of the increasing number of blocks.

3.2 Spatial distribution

Optimized hot spot analysis was implemented to identify statistically significant spatial clusters of high (hot spots) and low diversity values (cold spots). Hungarian geographical meso-regions were also used to understand the patterns. Due to the temporal variability, the patterns were slightly different over the years. Figure 2 shows the year 2018 as an example.

At block level, high diversity areas were found at Körös-Maros interfluve (1.13), in Hajdúság (1.11), Bácska Plain (1.3), and at the Small Plain (2.1), which are high-quality arable land with many crops. Additionally, the farm structure – more parcels in the blocks – can contribute to the high diversity between the Danube and Tisza (1.1-1.2), and at the Upper-Tisza region (1.6). Low diversity is typical for unfavorable soil conditions, and for the hilly-mountainous parts of the country.

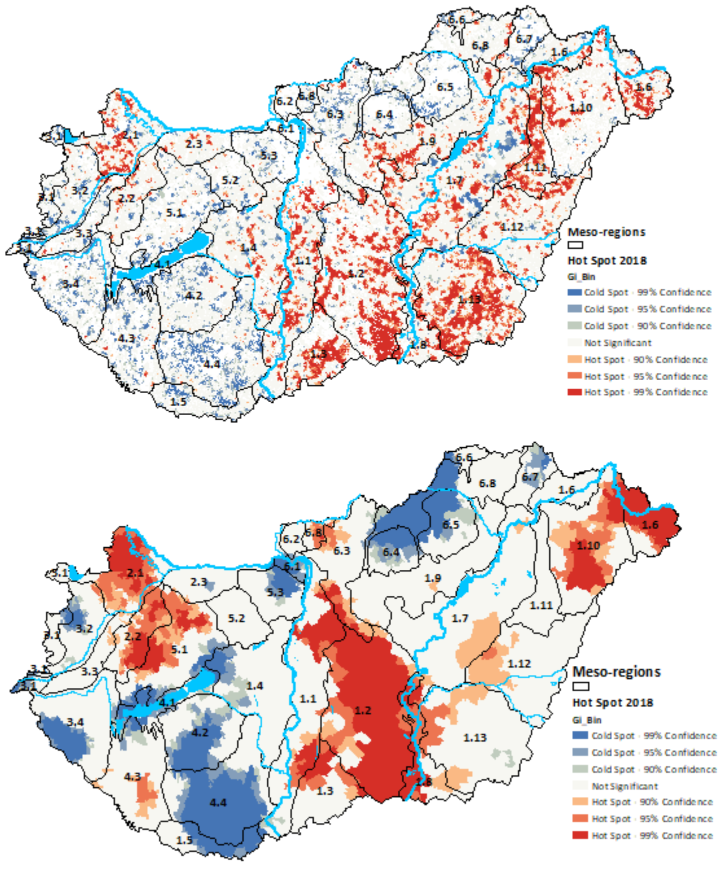

Figure 2. Crop diversity hot spot analysis results
(red areas are significant clusters of high diversity, while blue areas are clusters of low values)

Similar patterns can be recognized also at settlement level, e.g. the high diversity areas at meso-regions 1.2, 1.6, and 2.1. However, due to the aggregation, hot spot areas can appear at settlement level, when the blocks have few crops, but all together several crops are grown at the given area, e.g. in Nyírség (1.10). In contrast, high diversity at block level does not imply high diversity at settlement level. This may be typical to areas with greater blocks, like at Körös-Maros interfluve (1.13).

Cold spot areas were found in the Balaton area (4.1), Mecsek Mountains and Tolna hills (4.4), and Mátra and Bükk Mountains (6.4-6.5), which are typical wine regions.

4. Discussion

Instead of the clear trends, diversity values showed both spatial and temporal variabilities over the years. The interpretation of the changes in diversity has difficulties, as the calculated results depend on several factors. Spatial diversity pattern could be partly explained by topographic, climatic, and soil factors, but farm structure has also an important effect. At the same time, the choice of the spatial unit is crucial during the analysis. However, some low/high-diversity areas can be identified at all scales examined. The diversity values were significantly higher in 2015 than in 2014, which might indicate the effectiveness of the introduction of greening. However, this increase was observed only at 65% of the settlements, and there are no settlements where the increase in diversity would be continuous since then.

In the presented results all crop types were counted as separate for the diversification measure, however, some of them like species of *Brassicaceae*, *Solanaceae*, and *Cucurbitaceae* should be aggregated according to the regulations. Therefore, the calculated diversity values could be an overestimate in some cases.

An analysis based on FADN data of ten countries (EC, 2017) showed that the crop diversification measure has resulted in an increase in the diversity of cultivated crops over 0.8% of the arable area. Compared to this, the obtained results indicate more favorable changes in Hungary.

5. Conclusions

Crop diversity has an important role in sustainable agro-ecosystems. Due to the changes in the physical block system, a higher aggregation level should be used for further monitoring. 1x1 km grid can provide an effective aggregation level, but parcels' geometry is needed for the calculation, which is not publicly available. Settlements level can also provide adequate information of the spatial differences and the changes over time.

References

Aguilar, J., Gramig, G.G., Hendrickson, J.R., Archer, D.W., Forcella, F., Liebig, M.A. (2015) 'Crop species diversity changes in the United States: 1978–2012', PLoS ONE 10(8): e0136580. https://doi.org/10.1371/journal.pone.0136580

Donfouet, H.P.P., Barczak, A., Détang-Dessendre, C., Maigné, C. (2017) 'Crop Production and Crop Diversity in France: A Spatial Analysis', Ecological Economics 134 pp. 29-39. http://dx.doi.org/10.1016/j.ecolecon.2016.11.016

EC (2017) 'Evaluation study of the payment for agricultural practices beneficial for the climate and the environment', https://ec.europa.eu/agriculture/sites/agriculture/files/fullrep_en.pdf

EU (2013) 'Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013', https://eur-lex.europa.eu/eli/reg/2013/1307/oj

Gaál, M., Blanco Mojica, L.F., Zubor-Nemes, A. (2018) 'Spatio-temporal analysis of crop diversity in Hungary', Proceedings of 60th Georgikon Scientific Conference, Keszthely. pp. 105-110.

Monteleone, M., Cammerini, A.R.B., Libutti, A. (2018) 'Agricultural "greening" and cropland diversification trends: Potential contribution of agroenergy crops in Capitanata (South Italy)', Land Use Policy 70: 591-600. http://dx.doi.org/10.1016/j.landusepol.2017.10.038

Weigel, R., Koellner, T., Poppenborg, P., Bogner, C. (2018) 'Crop diversity and stability of revenue on farms in Central Europe: An analysis of big data from a comprehensive agricultural census in Bavaria', PLoS ONE 13(11): e0207454. https://doi.org/10.1371/journal.pone.0207454