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ANALYSES OF AGRI-ENVIRONMENTAL INDICATORS AT REGIONAL LEVEL IN THE SLOVAK REPUBLIC

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Abstract

This paper focuses on evaluation of agri-environmental indicators at regional level in the Slovak republic. Parts of the territory that have characteristics in terms of agro-ecological landscape infrastructure, generating various public goods and externalities, have been identified. For following public goods: landscape formation, biodiversity, quality and availability of water resources, soil quality, air quality, climate stability and flood prevention, we have identified and quantified indicators that reflect the benefits provided by different types of landscape space, agricultural land or farming practices. The analysis showed a strong polarization based on the natural conditions that determine the production conditions.

Key words: *agriculture, agri-environmental indicators, public goods, externalities*

INTRODUCTION

Multifunctionality and, within it, the production and non-production benefits of the agri-resort are also an important issue in terms of the announced focus of the future EU CAP on a "greener" direction of farming, as well as in terms of public interest [2]. The concept of "public goods and externalities" (PGEs) responds to the needs of the European Commission related to the design and evaluation of public policies and specific programmes needed to stimulate or reduce the "environmental spillovers" produced by the agricultural sector within the EU [6].
According to [7] "some public goods within agriculture, e.g. the maintenance of ecosystems, are considered positive externalities, i.e. they are side-effects of the production of agricultural commodities. If ecosystem maintenance were carried out for this specific purpose, e.g. as a contract between farmers and conservationists, it would still be a public good - biodiversity conservation - not an external benefit resulting from production carried out for another purpose".
Increasing food production without further damaging biodiversity is a key challenge for contemporary societies [9]. In their study, the authors assess the trade-offs between agricultural production and two key agri-environmental indicators under four contrasting scenarios for Europe in 2040. The scenarios present different storylines involving assumptions about macroeconomic drivers (e.g. population growth and GDP growth rates), demand for food and livestock products, as well as policy decisions on trade liberalisation/protectionism, biodiversity conservation, land-use planning regulations and subsidies to farmers through the European Union's Common Agricultural Policy.
"Humanity is placing a heavy burden on agricultural landscapes, demanding sufficient food production, more ecosystem services and the preservation of biodiversity" [8]. [3] found that areas with an increase in multifunctionality are also becoming more biologically and agriculturally diverse, without large losses in overall food production. This suggests the potential for complementarities between the objectives of food production, multiple ecosystem services, and biological and agricultural diversity in agricultural landscapes. Multifunctional agroecosystems are the result of complex adaptive interactions between humans and nature, with key trade-offs between food production and other ecosystem services [1].

MATERIALS AND METHODS

The aim of the paper is to analyse agri-environmental indicators at regional level in the Slovak republic. In designing the methodology, we drew on the evaluation framework of the JRC scientific and technical research report "Feasibility Study on the Valuation of Public Goods and Externalities in EU Agriculture" [7].

The first step was to identify the regions. Regions refer to coherent parts of the territory that are characteristic in terms of agro-ecological landscape infrastructure, generating various public goods and externalities (PGEs). For this purpose, regions were identified based on landscape and farming system variables that were assumed to be related to one or more PGEs and for quantifying which we had district-level data. Regions were identified based on variables that were not used as PGE indicators. This was necessary so that we could test associations between different PGEs and different regions. Unification of the underlying data was done by standardizing the data. Two variants of Cluster Analysis (CA) were used to identify regions. First, in the "classical" cluster analysis, we used hierarchical procedures as the exploratory clustering solution, and the resulting solution was performed by a non-hierarchical procedure. Second, we performed Principal Component Analysis (PCA) to reduce the number of variables and then performed cluster analysis (with the methodological choices described above) using only the first few principal components. By using PCA, we avoided that including too many variables representing a group of (correlated) variables would result in a solution that gives too much weight to that group.

The next step was to identify indicators that are characteristic of selected public goods and externalities provided by each type of landscape space or farming practice. Based also on the results of research works [11, 12] the following indicators were identified for selected PGEs - landscape formation, biodiversity, quality and availability of water resources, soil quality, air quality, climate stability and flood prevention. The indicators are listed in Table 1.

The final step was to associate PGE indicators with regions, which we analysed by comparing the mean values of PGE indicators for each region and factor analysis (FA) of the district-level data, using PGE indicators as variables and regions coded as binary code variables.

RESULTS AND DISCUSSIONS

Identification of regions

The regionalisation of Slovakia was carried out on the basis of indicators that have an affinity to the landscape dimension and partly also to the intensity of agriculture. The segmentation of districts into regions has been confirmed by several models (using cluster analysis and principal component analysis) and is quite unambiguous (Map 1).

It confirms the basic idea of dividing the districts of Slovakia into four different parts - districts of southern and south-western Slovakia with predominance of production areas, then the area of central and northern Slovakia with less favourable production and climatic conditions, the rest of Slovakia as a transitional area (due to the nature of Slovakia, areas with natural and other specific constraints prevail here as well), and distinct urban agglomerations.

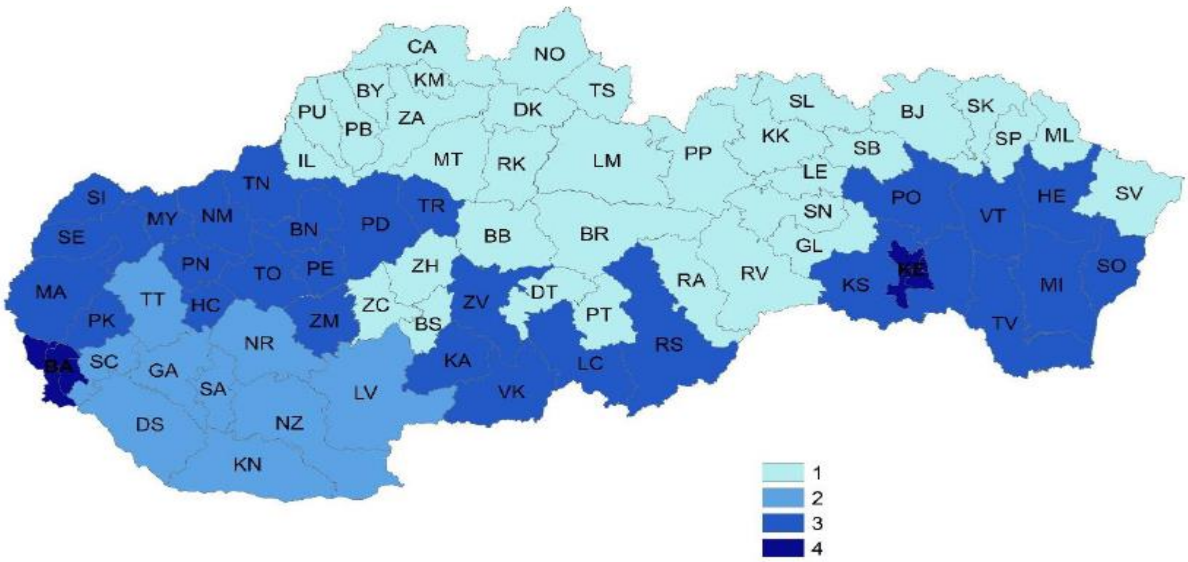
Indicators of public goods and agricultural externalities

Because of breadth of the set of indicators that characterize the selected public goods and externalities, we present only a fragment - indicators that relate to landscape and soil quality.

Landscaping

In recent years, several clearly defined indicators have been used to assess the diversity of the landscape mosaic, which allow to evaluate its changes in time and space and also to compare trends in the development of landscape structure in different regions.

Landscape space indicators can be classified into two main categories - composition and configuration, which encompass different aspects of the landscape mosaic [4]



Map 1. Identification of the regions
Map legend: Districts included in the cluster 1, 2, 3, 4
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics.

Landscape composition refers to the presence of different land cover types and their representation in each category. Indicators of landscape composition are not spatially explicit. That is, they measure what is present and in what relative quantities or proportions, without any spatial allocation of it to refer to where on earth it may be. Metrics (indicators) of landscape composition are very important descriptors, especially because the relative abundance of landscape cover types limits the potential value of spatially explicit indicators [10]. Landscape configuration refers to the geographic distribution of the landscape mosaic, while composition refers to the variety and extent of individual land cover types. The Shannon diversity index (SHDI) is a typical example of an indicator from the category of landscape composition and is often used in landscape ecology studies to describe landscape diversity.

The Shannon index quantifies landscape diversity using two components - the number of individual classes (compositional component) and the evenness of class distribution (structural component). The SHDI is the sum of the products - the area of the individual land cover classes and their natural logarithm. Its value increases if the number of different classes increases and/or the proportional representation of classes is more balanced. The maximum SHDI value for a particular number of classes is reached if all classes have the same area in the area under consideration. The different size of individual sites is reflected in the value of the Shannon index: the smaller the differences in the size of the sites, the higher the SHDI value [5].

In the calculations of the SHDI of the landscape cover of the Slovak Republic, the following classes formed the compositional component of the index: arable land, permanent grassland, vineyards, hops, orchards, gardens, forest land, water areas, built-up area and courtyard, other non-agricultural area.

The SHDI values of the landscape cover of the Slovak Republic in individual districts ranged from 0.81 (Gelnica district) to 1.79 (Bratislava IV district). The highest SHDI values of the SR land cover were recorded in the urban districts of Bratislava and Košice, also in the districts of Michalovce, Sobrance, Trebišov, Prešov, Myjava, Nové Mesto nad Váhom and Pezinok (SHDI values above 1.5). The lowest values were recorded in districts where one compositional component is significantly dominant (SHDI values less than

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1), in the case of dominance of arable land - Šaľa district, in the case of dominance of forest land - Gelnica and Brezno districts (Fig. 1).

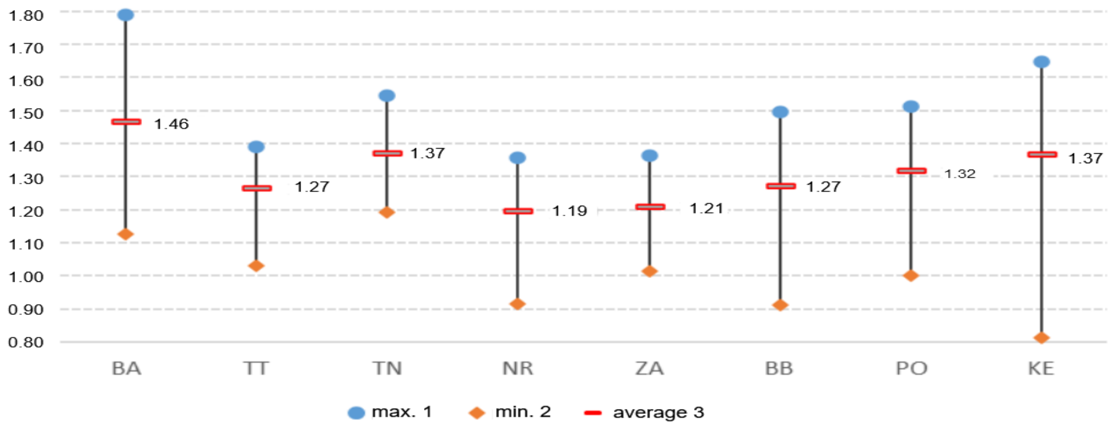


Fig. 1. SHDI of landscape cover of the Slovak Republic by regions
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Notes: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region

In the case of the Shannon index of agricultural land cover diversity, the composition consisted of the following classes of crops grown on arable land (cereals, maize, legumes, root crops, oilseeds, and fodder crops), permanent grassland, vineyards, orchards, vegetables and other areas. The highest average SHDI values of agricultural land cover were calculated for the Bratislava, Trnava, Nitra and Trenčín regions. The districts with the highest SHDI values of agricultural landscape include Pezinok, Veľký Krtíš, Nové Mesto nad Váhom, Rimavská Sobota and Bánovce nad Bebravou. The districts with the lowest SHDI values of agricultural landscape are Čadca, Medzilaborce and Gelnica, where one compositional component of the index (permanent grassland) accounts for more than 90% of the structure of agricultural landscape cover (Fig. 2).

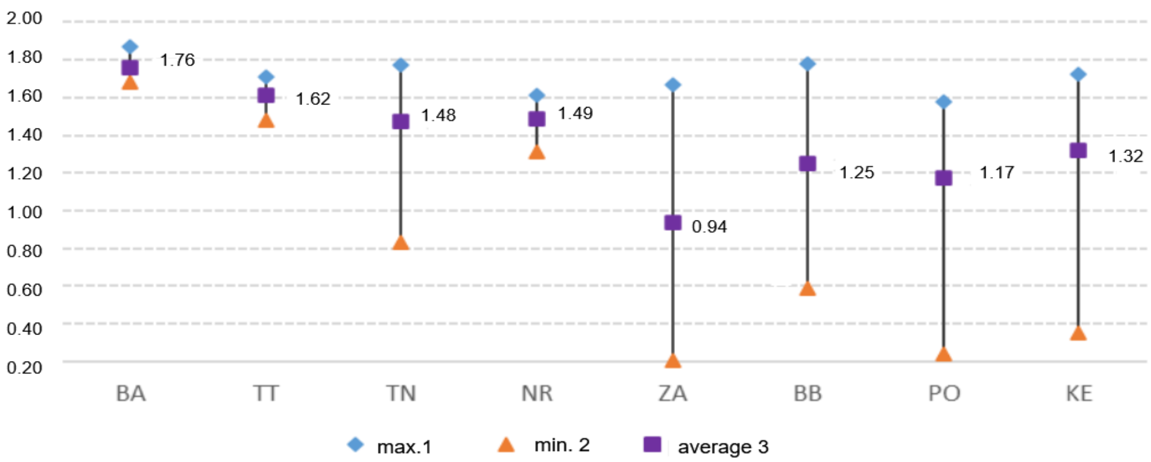


Fig. 2. SHDI of agricultural landscape of the Slovak Republic by regions
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics.
Notes: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region

The Shannon Equal Distribution Index (SHEI) expresses the diversity of the landscape cover of the Slovak Republic, values range from 0 to 1. The value of the index is close to 1 if the land cover types have almost the same proportional representation or if a high abundance of the landscape types under consideration is present. Low values mean that one type of landscape cover dominates within the assessed landscape area (Fig. 3).

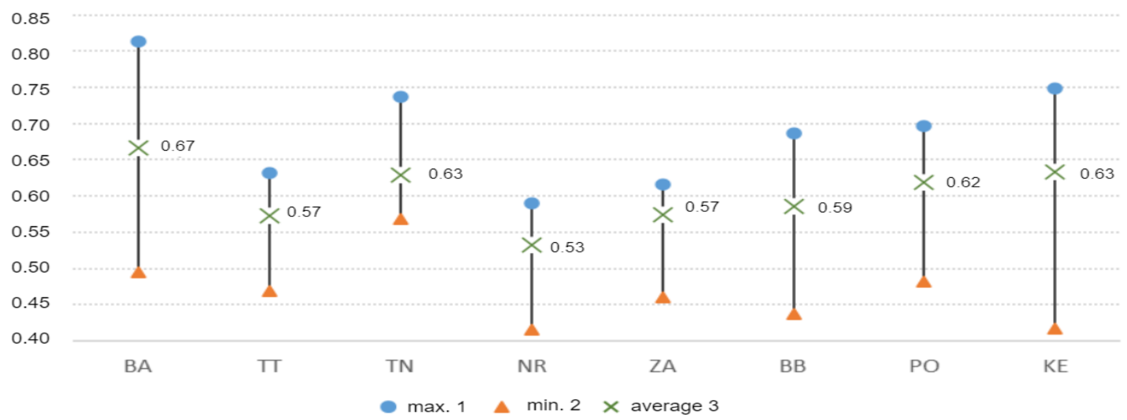
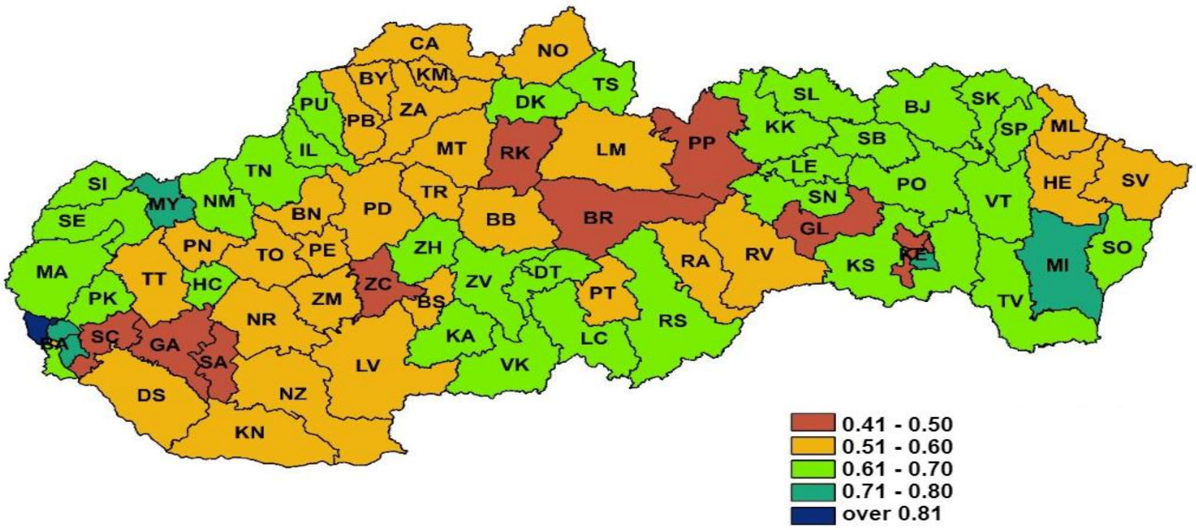


Fig. 3. SHEI (Shannon Equitability Index) land cover values of the Slovak Republic by regions
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics.
Notes: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region

Low values of the index were recorded in districts with dominance of arable land in the total landscape cover of the district (Senec, Galanta, Šaľa) and districts with dominance of forest land (Gelnica, Brezno, Poprad, Ružomberok). According to the index values, some urban districts of Bratislava and Košice show a high diversity of land cover types, as do the districts of Michalovce and Myjava (Map 2).



Map 2. SHEI values of land cover of the Slovak Republic by districts
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Map legend: Shannon equitability index of land cover of the Slovak Republic

The interpretation of resulting values of the index of uniform distribution of agricultural landscapes is similar to the index of uniform distribution of the entire landscape cover of the Slovak Republic, values range from 0 to 1. The different types of agricultural land cover consisted of selected classes of crops grown on arable land, permanent grassland, vineyards, orchards, vegetables and other areas. Districts with high value of the index of uniform distribution of agricultural landscape (above 0.7) are situated mainly in the Bratislava, Trnava and border districts of the Trenčín Region and the southern districts of the Banská Bystrica region (Fig. 4, Map 3).

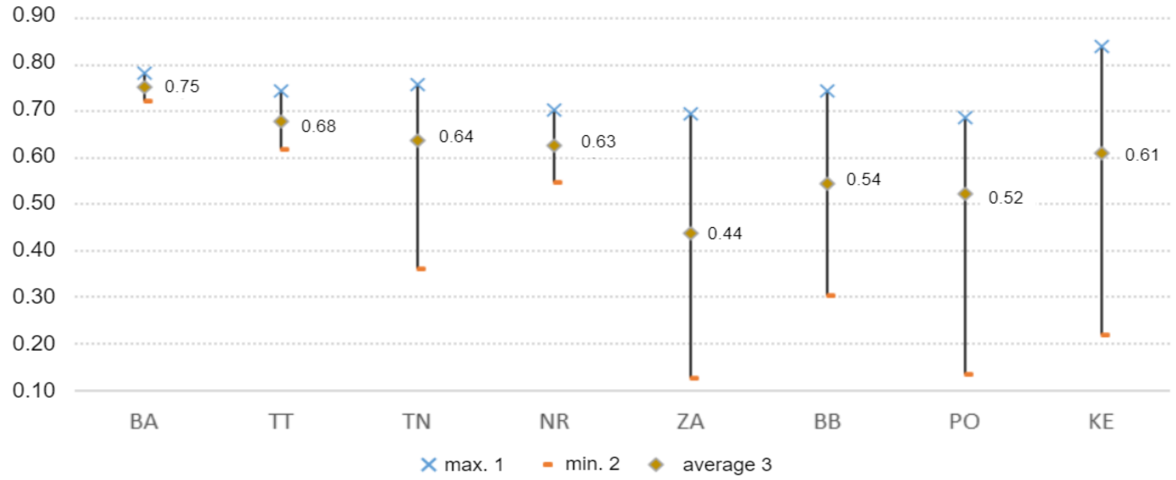
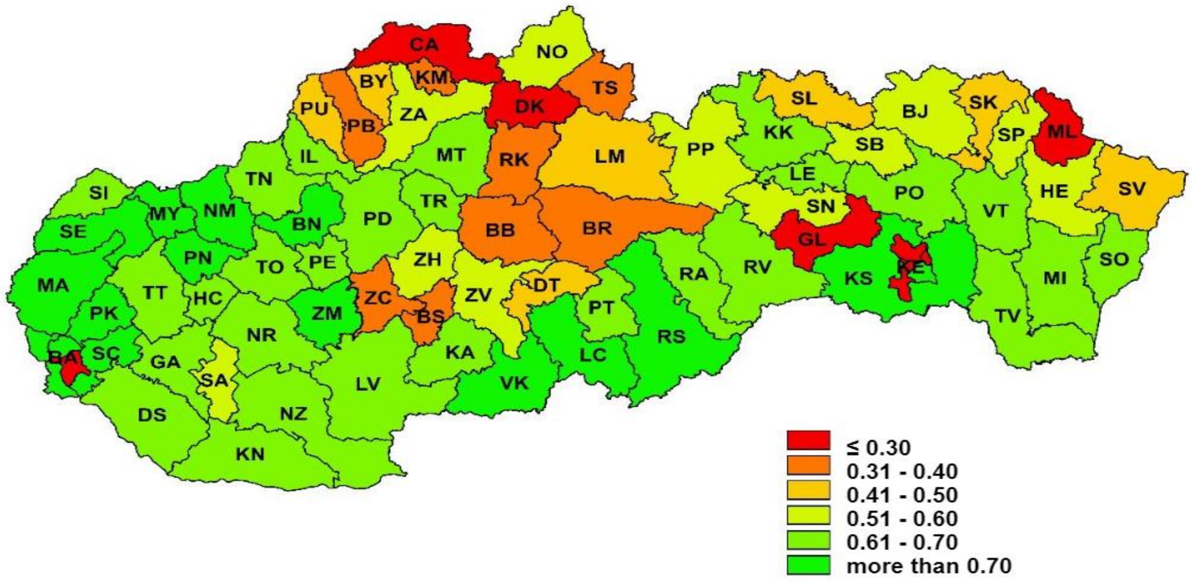


Fig. 4. SHEI values of the agricultural landscape by regions
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Notes: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region



Map 3. SHEI values of agricultural landscape of the Slovak Republic by districts
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Map legend: Shannon equitability index of agricultural landscape of the Slovak Republic

The Naturalness Index (NI) values reflect the natural value of heterogeneous ecosystems and in 2019 the NI values ranged from 15 (Bratislava I district) to 83 (Banská Štiavnica district).

As the value of the index increases, the self-healing capacity of the ecosystem increases and thus its intrinsic value increases.

The districts with the highest NI values were located mainly in the Žilina region (Fig 5, Map 4).

The urban districts of Bratislava and Košice had the lowest NI values, as well as districts with a high concentration of intensive agricultural production (Senec and Galanta districts).

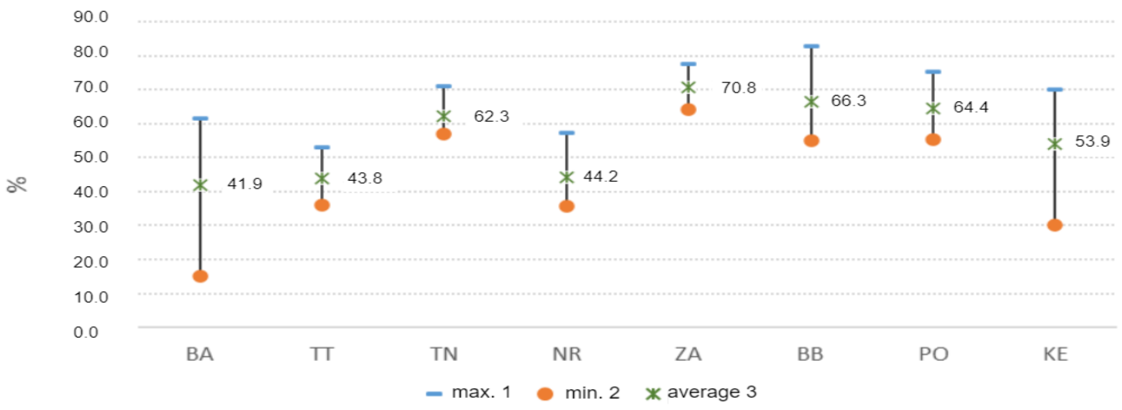
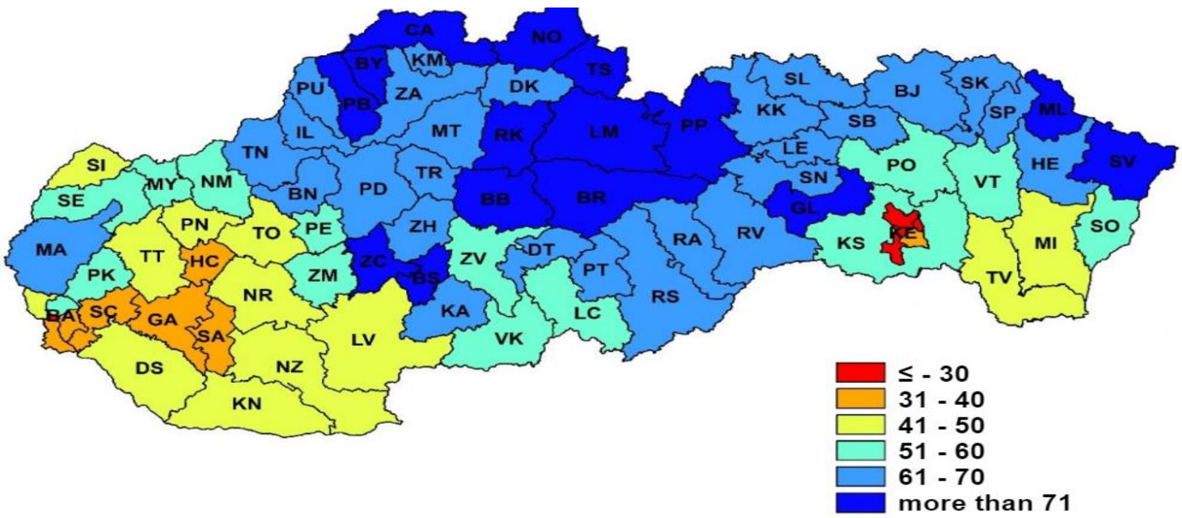


Fig. 5. Naturalness Index by regions
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Notes: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region



Map 4. Values of Naturalness Index by districts
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Map legend: Naturalness Index

Soil quality

The methodology for calculating potential water erosion represents the theoretical loss of soil mass conditioned by relatively stable erosion factors - rainfall erodibility (R-factor), soil erodibility (K-factor), slope length and slope gradient (ZS-factor). The highest average values of potential water erosion were recorded in the districts of the Žilina Region, where the values reached the level of extremely high erosion, especially in the districts of Bytča, Čadca, Dolný Kubín, Kysucké Nové Mesto, Ružomberok and Žilina. Extremely high values were also found in the districts of Gelnica and Žarnovica. The Figure 6 presents maximum, minimum and average values of potential water erosion by regions. Current erosion expresses the intensity of water erosion occurring in specific conditions, taking into account the influence of dynamic erosion factors, namely vegetation cover (C-factor) and human land management (P-factor).

The soil conservation efficiency of the vegetation cover is expressed by the C-factor, which is dependent on the density, structure and duration of the vegetation cover.

The P-factor is an expression of the effectiveness of anti-erosion measures, i.e. the method of agrotechnics or the effectiveness of technical measures to prevent surface outflow. It was necessary to simplify the expression of these factors at the district level.

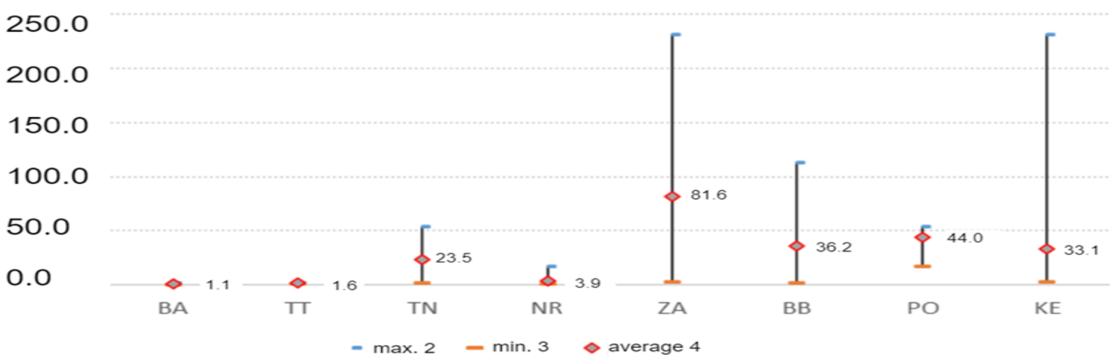


Fig. 6. Potential water erosion by regions, in tonnes per ha of utilised agricultural area
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Note*: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region, 7/
Note**: degree of potential water erosion (according to the Research Institute of Agricultural and Food Economics): 1. ≤ 1.0 slight; 2. 1.1-10.0 low; 3. 11.0-30.0 medium; 4. 31.0-60.0 high; 5. 61.0-100.0 very high; ≥ 100.0 extremely high

The C-factor has a different value for each crop. When calculating the value of the C-factor at the district level, we based on the data on harvested areas (Statistical Office of the Slovak republic) of individual cultivated crops on usable agricultural land. The P-factor was not taken into account in the calculations, as data on soil erosion control measures are not recorded. Resulting values of actual erosion at the district level were calculated as the product of potential erosion and the C-factor.

The lowest average values of current water erosion (degree of slight erosion) were found in the districts of Bratislava and Trnava regions. The highest (in the middle stage of current water erosion) were found in the districts of Žilina and Prešov regions, especially in the districts of Ružomberok, Bytča, Žilina, Prešov, Vranov nad Topľou. Values at the medium level of current water erosion were also recorded in the districts of Myjava, Trenčín, Revúca, Žarnovica and Rožňava (Fig. 7).

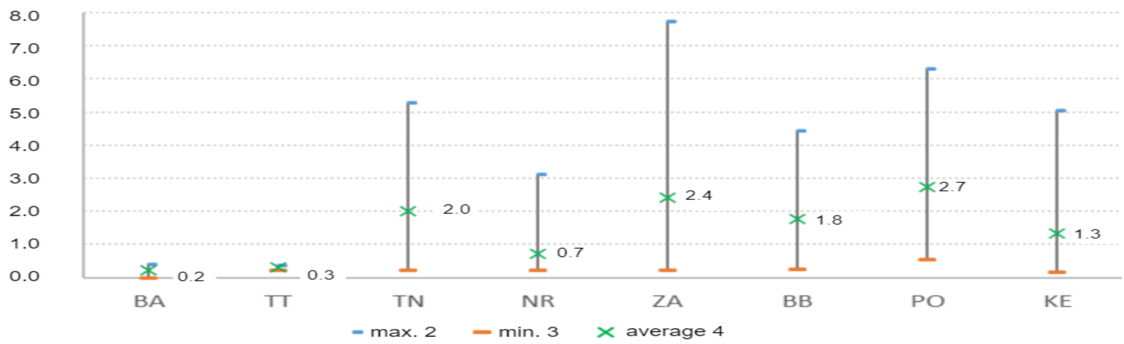


Fig. 7. Actual water erosion by regions, in tonnes per ha of utilised agricultural area
Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Note*: BA – Bratislava Region, TT – Trnava Region, TN – Trenčín Region, NR – Nitra Region, ZA – Žilina Region, BB – Banská Bystrica Region, PO – Prešov Region, KE – Košice Region, 7/
Note**: degree of actual water erosion (according to the Research Institute of Agricultural and Food Economics): 1. ≤ 1.0 slight; 2. 1.1-4.0 low; 3. 4.0-8.0 medium; 4. 8.1-13.0 high; 5. ≥ 13.1 very high

Relationships between PGEs and the regions

The association of PGE indicators to regions by comparing the mean values of PGE indicators for each region is documented in Table 1.

Table 1. Comparison of mean values of PGaE (public goods and externalities) indicators for regions

	Maintenance of the agricultural landscape		
Region	**Shannon diversity index of land cover of the Slovak Republic**	**Shannon diversity index of agricultural landscape**	**Shannon equitability index of land cover of the Slovak Republic**
1	1.22 (1.24)	1.01 (1.06)	0.58 (0.59)
2	1.14 (1.16)	1.52 (1.52)	0.52 (0.53)
3	1.41 (1.41)	1.62 (1.64)	0.64 (0.64)
4	1.51 (1.55)	1.51 (1.68)	0.7 (0.71)
	Maintenance of the agricultural landscape		**Biodiversity**
Region	**Shannon equitability index of agricultural landscape**	**Naturalness index**	**% share of protected areas on the district's total area**
1	0.46 (0.48)	69.02 (69.02)	35.61 (34.86)
2	0.63 (0.64)	39.64 (40.27)	6.73 (6.42)
3	0.69 (0.7)	56.44 (57.84)	18.32 (17.02)
4	0.7 (0.73)	39.65 (35.56)	14.44 (13.16)
	Biodiversity		**Quality and availability of water resources**
Region	**% share of NATURA sites from utilised agricultural land area**	**% share of organic farming from utilised agricultural land area**	**Precipitation total in mm per year**
1	3.2E-02 (0)	18.74 (15.01)	866.96 (864.74)
2	2.07E-02 (0)	1.05 (0.93)	593.72 (594.22)
3	2.1E-02 (0)	7.32 (2.38)	703.55 (698.11)
4	0.16 (0)	9.7 (2.47)	671.25 (651)
	Quality and availability of water resources		
Region	**% share of land with irrigation system from the district's total area**	**% share of irrigated land from the district's total area**	**% share of area with applied fertilizers from the district's total area**
1	7E-03 (0)	1.66E-03 (0)	16.48 (15.94)
2	8.29 (7.63)	3.02 (1.14)	65.77 (67.49)
3	1.17 (8.78E-02)	0.27 (8.37E-03)	33.5 (33.86)
4	0.17 (0)	0.17 (0)	93.23* (13.22)
	Quality and availability of water resources	**Soil quality**	
Region	**Amount of nitrogen applied (in kg) per ha of utilised agricultural area**	**Potential water erosion (in tonnes per ha of UAA per year)**	**Actual water erosion (in tonnes per ha of UAA per year)**
1	89.02 (82.61)	63.72 (53.67)	2.43 (2.16)
2	197.2 (198.45)	1.62 (1.66)	0.33 (0.33)
3	138.89 (142.07)	13.08 (2.32)	1.44 (0.38)
4	1258.84* (26.28)	3.11 (1.66)	0.26 (0.27)
	Air quality		**Climate stability**
Region	**NH3 emissions from animal production in kg/ha UAA**	**NH3 emissions from agricultural land in kg/ha UAA**	**% of organic carbon in soils**
1	6.84 (6.24)	1.04 (0.9)	1.82 (1.82)
2	6.96 (6.37)	5.82 (5.73)	1.97 (1.97)
3	9.57 (7)	3.54 (3.65)	1.82 (1.79)
4	3.04 (3.03)	51.58* (1.03)	1.7 (1.86)
	Climate stability		**Flood prevention**
Region	**Amount of nitrous oxide emissions from animal production in Gg N2O per ha of utilised agricultural land per year**	**Amount of nitrous oxide emissions from agricultural land in Gg N2O per ha of utilised agricultural land per year**	**Retention capacity of land in m3/ha of agricultural land**
1	2.1E-07 (2.07E-07)	1.76E-06 (1.63E-06)	928.2 (931.04)
2	1.43E-07 (1.31E-07)	3.76E-06 (3.79E-06)	1020.72 (1013.85)
3	1.94E-07 (1.83E-07)	2.68E-06 (2.74E-06)	1010.72 (1041.37)
4	4.46E-08 (8.94E-10)	2.38E-05 (4.96E-07)	789.61 (886.25)

Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics
Note: the values in the table are expressed as the arithmetic mean, in brackets the median. Region 4 (large urban agglomerations) is specific, for some indicators we have recorded extreme values (designation *), which may be related to discrepancies between the location of the company's official headquarters and the land management site.

Region 4 (large urban agglomerations) are specific. For some indicators we recorded extreme values, this may be due to a different location of the business as opposed to the location of record (company headquarters). We decided to exclude Region 4 from further examination on the basis of these facts and the low intensity of agricultural production (Košice district is not included in Region 4).

Table 2 presents scores of PGaE indicators and regions in each factor (after rotation).

Table 2. Scores of PGaE indicators and regions in each factor (after rotation)

	Factor 1	Factor 2	Factor 3	Factor 4
Shannon diversity index of agricultural landscape	**-0.881774**	0.036445	0.050656	0.060133
Shannon equitability index of land cover	**-0.529318**	-0.008019	**-0.424567**	0.151283
Shannon equitability index of agricultural landscape	**-0.891778**	0.140677	0.001123	0.082979
Naturalness index	**0.669963**	-0.016925	**-0.633639**	0.074742
% share of protected areas on the district's total area	**0.411495**	-0.051220	**-0.288867**	**0.270618**
/% share of NATURA sites from utilised agricultural land area	-0.105995	-0.060561	-0.062422	**0.624431**
/% share of organic farming from utilised agricultural land area	**0.414073**	-0.095481	-0.171614	0.103000
Precipitation total in mm per year	**0.745454**	0.059864	**-0.498832**	0.028118
% share of land with irrigation system from the district's total area	**-0.208486**	-0.015017	**0.793898**	0.005089
% share of area with applied fertilizers from the district's total area	-0.167299	**0.970715**	0.117173	-0.037666
Potential water erosion (in tonnes per ha of UAA per year)	**0.741421**	-0.076617	-0.178886	-0.045871
Actual water erosion (in tonnes per ha of UAA per year)	**0.376107**	-0.070461	**-0.298645**	-0.089788
NH3 emissions from animal production in kg/ha UAA	-0.065008	-0.093124	-0.057747	-0.189030
NH3 emissions from agricultural land in kg/ha UAA	-0.071840	**0.994892**	-0.046536	0.020438
% of organic carbon in soils	**-0.217745**	-0.040160	**0.553151**	**0.541841**
Amount of nitrous oxide emissions from agricultural land in Gg N2O per ha of utilised agricultural land per year	-0.068949	**0.993414**	-0.047955	0.034087
Retention capacity of land in m3/ha of agricultural land	-0.116684	0.046275	0.120875	**-0.729554**
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Region 1	**0.829258**	-0.081288	-0.241382	0.194457
Region 2	-0.096753	0.025713	**0.899826**	-0.045366
Region 3	**-0.647923**	-0.141783	-0.321674	**-0.377852**

Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics.

The associations between PGaE indicators and regions are weaker but in many cases substantial, so we used a lower threshold to identify stronger (modulus of scores no lower than 0.3) and weaker (modulus of scores between 0.2 and 0.3) associations.

CONCLUSIONS

The association of PGaE indicators to regions through factor analysis of district-level data, using PGaE indicators as variables and regions coded as binary code variables, demonstrated the following:

Areas of Region 1 (areas of predominantly higher elevation) are strongly positively associated with the natural state index, the percentage of protected area acreage of total district acreage, the percentage of organic farming of usable farmland acreage, rainfall, and both potential and actual water erosion; we did not observe weaker positive associations. Region 1 districts are strongly negatively associated with the Shannon index of agricultural landscape diversity, the Shannon index of even distribution of all land cover (similarly, the Shannon index of diversity of all land cover is highly correlated with it), and the Shannon index of even distribution of agricultural landscapes; they are more weakly negatively associated with the percentage of irrigable land out of the total county acreage and the percentage of organic carbon in the soil.

Areas of Region 2 (areas with good production conditions) are strongly positively associated with the percentage of irrigable land out of total district area and the percentage of soil organic carbon; we did not observe weaker positive associations. Areas of Region 2 are strongly negatively associated with the Shannon index of even distribution of all land cover (and similarly with the Shannon index of diversity of all land cover, which is highly correlated with it), then with the index of natural state of the landscape, rainfall; more weakly negatively associated with the percentage of acreage of protected areas in the total area of the district, and water erosion current. Factor 2 was characterized by a high association of indicators associated with high values of nitrogen inputs per hectare of usable agricultural land (this indicator was not directly included in the modelling due to singularities in the matrices, but is highly correlated with, e.g., the percentage of acreage with fertilizer applied out of the total acreage of the district that was included). Because Factor 2 was specified in this way, this was not taken into account in Factor 3, which is the priority for consideration for Region 2. Simply put, nitrogen inputs in production areas need to be given high consideration in the design of measures. This is also evident from the identification, quantification and localisation of the PGaE related to the nitrogen issue itself.

Areas of Region 3 (transition areas between Region 1 and 2) are not clearly associated with PGaE indicators.

The analysis showed a strong polarization based on the natural conditions that determine the production conditions. An interesting finding is the mostly strong associations of PGaE indicators for polarized areas in terms of agroecological structures. Another interesting finding is the “dispersion“ of the studied associations in the “transition“ region.

These findings were also valid for different combinations of input variables as well as for optional numbers of factors (while keeping the limit of still admissible characteristics of the models). This implies the validity of proposals for targeted measures to potentiate the positive and reduce the negative impacts of activities within the agricultural sector.

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