THESIS OF DOCTORAL (PhD) DISSERTATION

GÁBOR VALKÓ

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SZENT ISTVÁN UNIVERSITY
DOCTORAL SCHOOL OF MANAGEMENT AND BUSINESS ADMINISTRATION

DEVELOPMENT OF THE INDICATOR SYSTEM OF SUSTAINABLE AGRICULTURE WITH THE APPLICATION OF COMPOSITE INDICATORS

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1. A PRELIMINARIES OF THE WORK AND OBJECTIVES

1.1. The importance and timeliness of the topic

In the last decade, the concept of sustainable development became inevitable when economic, social and environmental processes are assessed. In the evaluation of agricultural production – in addition to the previous approach focusing on quantity and quality of the product – the impact of agriculture on the environment, on rural population, and on the quality of life in rural areas is more and more in the forefront that is collectively described by the concept of sustainable agriculture.

Agricultural production is a nature-related activity, and has a significant impact on the state of the environment, but also is an integral part of rural life. On the one hand it has a remarkable influence on rural areas and on the other hand it is dependent on them in many aspects. The Earth's growing population will require a huge amount of surplus production of food; so the increase of utilised agricultural area and / or the increase of production efficiency are inevitable if consumption patterns remain unchanged. Therefore, the efficiency and the economic dimension of sustainability for agriculture – similarly to the energy sector – are more emphasised within the topic of sustainability compared to other economic sectors.

A reliable indicator system describing sustainability becomes a more and more pronounced requirement of decision-makers. Besides, there is also an intensified expectation among the population to gain information on the social and economic processes in terms of sustainability. Many organizations and scientific institutions have developed indicators and indicator systems that attempt to measure the performance of agriculture in terms of sustainability. However, they are not fully adapted to the Hungarian and European Union agriculture, and most of them do not allow temporal or spatial comparisons.

There is a need for an indicator system that describes agricultural production of the EU Member States in terms of sustainability and that is also capable of the evaluation of certain sustainability areas and that presents results that are easy to communicate. This type of indicator system has not yet been developed for the EU. In my opinion, compiling an indicator system for the EU Member Countries on the sustainability of agriculture that is based on statistical data and that can serve as a basis for producing composite indicators describing sustainability domains is crucial. The composite indicator is a tool for the assessment of the agricultural sustainability of each Member States and the EU as a whole and the results are easy to communicate. The indicator system should be capable of comparing sustainability performance of individual countries and also of monitoring the development over time.

1.2. Objectives of the paper and hypotheses of the research

Objectives

The first goal of the thesis (C_1) was to systematise and present the conceptual system of sustainable development and sustainable agriculture by studying the scientific literature. My priority aim was the determination of the definition of sustainable agriculture, which is essential for developing the theoretical framework of the system. In addition, I reviewed and structured the indicator systems for sustainable development and the indicator systems of sustainable agriculture.

The next goal of the research was to develop a system of indicators on sustainable agriculture for the EU Member Countries that is based on statistical data (C_2). The third objective of the research was the collection of statistical data that are essential for the production of indicators and carrying out data checks (C_3).

The research resulted in a weight system (C_4), which allows the calculation of composite indicators based on data of the indicator system. To this end, questionnaires were filled by national and international experts in order to make an objective assessment of the importance of sustainability in each area. In the survey, the experts could comment on the indicator system, so they also carried out an assessment of it.

I set a goal of compiling the Sustainable Agricultural Index evaluating the sustainability of agricultural production for the 28 Member Countries of the EU (C_5). In addition to the general assessment, spatial and temporal comparisons were used to analyse the performance achieved by the individual Member States and the EU as a whole in the main areas of agricultural sustainability. During the evaluation, the performance of Hungary was analysed separately regarding the domains of the Sustainable Agricultural Index.

In the research I also aimed at separating groups of countries based on the Sustainable Agricultural Index and its components (C_6). Besides, the composite indices were analysed with respect to territoriality, both in terms of spatial relationships and regional share of changes (C_7).

The hypotheses formulated during the research and the methods of proof are shown in Table 1, while the research process is illustrated in Figure 1.

Table 1: The hypotheses formulated during the research and the methods of proof

	Hypothesis	Method of proof
H_1	The assessments of national experts are not considerably different from the opinion of international experts on the importance of indicators of sustainable agriculture.	Primary expert survey
H_2	A significant proportion of experts make no difference in the evaluation of the four domains of sustainable agriculture.	Primary expert survey
H_3	European agriculture is moving in the direction of sustainability in the period under review.	Analysis of composite indicators
H_4	The sustainability performance of Hungarian agriculture does not differ greatly from the European average.	Analysis of composite indicators
H_5	Correlation can be detected between the composite indicators describing the domains of sustainable agriculture.	Analysis of composite indicators
H_6	The differences between countries in terms of sustainable agriculture are mainly caused by economic factors.	Cluster analysis
H_7	The domain “Economy” shows the strongest territorial determination out of the composite indicators of sustainable agriculture.	Spatial autocorrelation method
H_8	The Sustainable Agricultural Index is more determined in Hungary by regional effects than structural ones.	Shift-share analysis

Source: own compilation

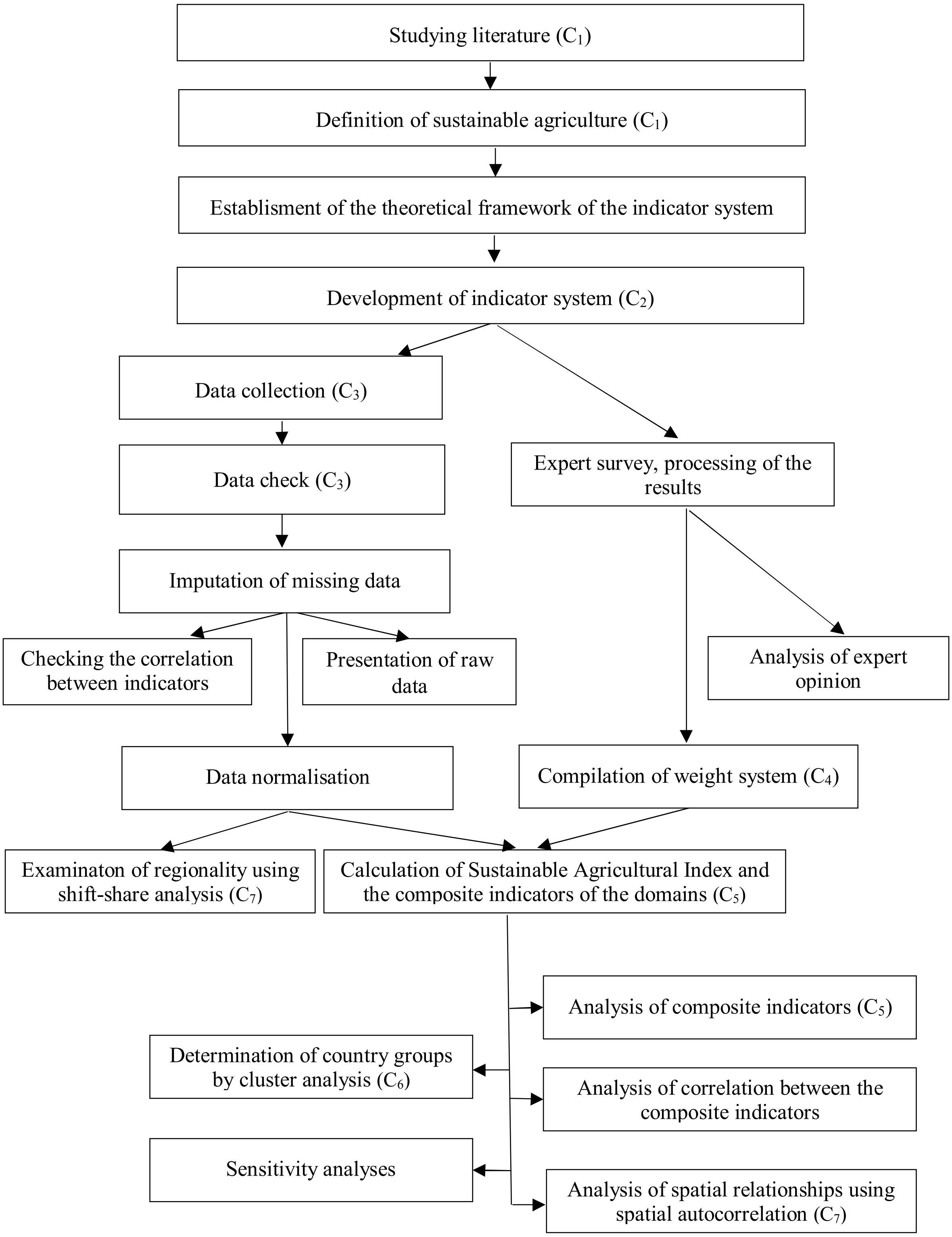


Figure 1: The research process

Source: own compilation

2. MATERIAL AND METHOD

2.1. Development of the indicator system on sustainable agriculture and collection of basic data

The theoretical framework of the indicators of sustainable agriculture was based on the definition of sustainable agriculture, which was created by synthesizing the literature sources. Four main points of the definition identified the domains of the indicators system, which are as follows:

- production of good quality, safe and healthy foods, satisfaction of needs – food supply,
- conservation of natural resources, protection of the environment, creation of animal welfare – environment,
- efficiency, competitiveness, economic viability, ensuring profitability – economy,
- improving the quality of life in rural areas, social justice, and development of attractive rural landscape – society.

According to the theoretical framework, 44 indicators were chosen. Only those indicators were selected, for which data are available for the EU Member Countries in 2000-2012 years. The most important data source was the Eurostat database, but to a lesser extent, other data sources were also used (FAO, WHO, etc). 15 thousand data items were gathered, which phase was followed by their check and editing, as well as the imputation of missing data. All phases of the process were carried out in a planned way, in all cases the most appropriate method for the particular data type was used. Through the phases of selection of indicators and collection of basic data, quality requirements developed by Eurostat and the OECD were followed. An examination of the relationship between indicators using correlation matrices was carried out prior to the finalization of the indicator system. The revealed relationships between the individual indicators in several cases exist and can be explained. However, the number and strength of these relationships is not such that would reduce the reliability of the indicator system. Based on the correlation analysis, the inclusion of each of the indicators in the indicator system is reasonable.

2.2. Compilation of the Sustainable Agricultural Index and the related composite indicators

In order to develop the Sustainable Agricultural Index, first the normalization of data of the indicator system was carried out using min-max method with the application of the following formula:

$$I_{qc}^{t} = \frac{x_{qc}^{t} - \min_{t \in T} \min_{c}(x_{q}^{t})}{\max_{t \in T} \max_{c}(x_{q}^{t}) - \min_{t \in T} \min_{c}(x_{q}^{t})}$$

where

x_{qc}^{t} = value of indicator *q* for country *c* and year *t*,

I_{qc}^{t} = normalised value of indicator *q* for country *c* and year *t*.

The weights required for the calculation of the composite indices were determined by expert opinion. In the literature, this procedure is referred as the Budget Allocation Process (BAP). During this process, the experts distribute 100 points for the indicators according to their importance in terms of the target determined by the theoretical framework of the indicator system. Determination of the weights is complex, and it is very difficult to make an informed decision because of too many circumstances to be considered and the limited information. For this reason, an opportunity was offered for the experts who had difficulties in the distribution of 100 points to determine the rank of indicators in terms of their importance. The opinion of the experts giving ranks was processed by converting the ranks to weights using the following formula:

$$w_i = \frac{r_{\max} - r_i + 1}{\sum_{i=1}^{n} r_i}$$

where

w_i = weight of indicator *i*,

r_i = rank of indicator *i*.

The aggregation of indicators was performed using the method of linear aggregation by adding the normalized and weighted values of the indicators according to the following formula:

$$KI_c = \sum_{q=1}^{Q} w_q I_{qc}$$

where

$\sum_q w_q = 1$ and $0 \leq w_q \leq 1$ for all $q = 1,...,Q$ and $c = 1,...,M$

KI_c = value of composite indicator for country *c*,

w_q = weight of,

I_{qc} = value of indicator *q* for country *c*.

2.3. Analysis of the Sustainable Agricultural Index and the related composite indicators

When compiling a composite indicator system, a number of subjective decisions have to be made, which may even substantially influence the composite indicator values. Therefore, the robustness and the reliability of the composite indicators were measured using sensitivity analyses, which were carried out for the following areas: the compilation of indicator system, the type of weighting system and the selection of experts. The values of the Sustainable Agricultural Index calculated with modified conditions were compared with the results from the original method. Based on the results, only the selection of the weighting system type of the factors listed above influenced significantly the values of the composite indicators.

Groups of countries were determined according to the indices of domains of sustainable agriculture using cluster analysis method. As a first step in the separation of clusters, the appropriate number of clusters was determined by a hierarchical clustering method (Ward's method). Afterwards, the creation of clusters was made by a non-hierarchical method according to the cluster centers of the hierarchical method.

As part of the analysis of territoriality of Sustainable Agricultural Index, spatial relationships were examined by regional autocorrelation method. The Moran's I metrics was used for the measurement of global autocorrelation, while for local autocorrelation, the Local Moran I value was applied. Shift-share analysis was carried out for the examination of the share of territoriality.

3. RESEARCH RESULTS

3.1. Indicator system of sustainable agriculture

As a result of the theoretical research, the definition of sustainable agriculture was compiled, which was kept in mind during the implementation of the research objectives and which served as a theoretical framework for the established system of indicators. The indictor system of sustainable agriculture was compiled, and filled with data for the years 2000-2012 and for the 28 EU Member Countries. The established system of indicators is shown in Table 2.

Table 2: Indicators of the indicator system for sustainable agriculture

Code	Theme	Indicator	Unit	Goal*
1		**Food-supply**		
101	Organic farming	Share of organic farming in percentage of utilised agricultural area	%	+
102	Production of genetically modified crops	Ratio of GMO crops in utilized agricultural area	‰	-
103	Food security	Ratio of exports and imports of agricultural products	-	+
104	Food processing capacity	Production value of manufacture of food, beverages and tobacco as a ratio in manufacturing	%	+
105	Food price	Food price volatility index	-	-
106	Consumption of healthy food	Average amount of fruits and vegetables available per person per year	kg	+
107	Safe food	Microbiological foodborne diseases per 100 000 inhabitants	-	-
2		**Environment**		
21		*Resource use*		
211	Resource use	Output per intermediate consumption in agriculture	-	+
212	Energy use	Final energy consumption of agriculture per gross value added	tons of oil equivalent/ 1000 Euro	-
213	Land use	Change in share of utilised agricultural area in total land area	1999=100	-
214	Livestock density	Livestock density (livestock units/utilised agricultural area)	livestock unit/ha	-
22		*Environmental pressures, state of the environment*		
221	Emission of greenhouse gases	Emission of greenhouse gases in agriculture/gross value added in agriculture	tons of CO_2 equivalent/ 1000 Euro	-
222	Emission of ammonia	Emission of ammonia in agriculture/gross value added in agriculture	kg/1000 Euro	-
223	Nutrient balance of soil	Nitrogen balance per hectare of utilised agricultural area	kg/ha	0
224	Manure use	Ratio of manure in total nutrient input (N content)	%	+
225	Pesticide use	Sales of pesticides per hectares of utilised agricultural area	kg of active ingredients/ha	-
226	State of flora and fauna	Bird index of farmland species	2000=100	+

Code	Theme	Indicator	Unit	Goal*
23		*Proper farm management*		
231	Environmental commitment	Share of utilised agricultural area under agri-environmental measures	%	+
232	Organic farming	Share of organic farming in percentage of utilised agricultural area	%	+
233	Own produced inputs	Share of mixed crops-livestock farms based on standard output calculation	%	+
234	Land use	Change in share of arable land in utilised agricultural area	1999=100	-
235	Training of farm managers	Share of farm managers with full agricultural training based on standard output calculation	%	+
236	Agricultural education	Share of graduates in agriculture and veterinary field as % of all fields	%	+
3		**Economy**		
31		*Efficiency, competitiveness*		
311	Resource use	Output per intermediate consumption in agriculture	-	+
312	Efficiency of land use	Gross value added per hectares of utilised agricultural area	Euro/ha	+
313	Labour productivity	Gross value added per labour input in agriculture	1000 Euro/ annual work unit	+
314	Competitiveness in foreign trade	Ratio of exports and imports of agricultural products	-	+
315	Yields	Yields of cereals	100 kg/ha	+
316	Utilization of agricultural land area	Share of not utilized agricultural area in percentage of total agricultural area	%	-
32		*Economic viability, profitability*		
321	Replacement of means of production	Gross fixed capital formation per consumption of fixed capital in the agriculture	Euro	+
322	Diversification of production	Standard output of farms with non agricultural activities as percentage of total standard output	%	+
323	Research and development	Research and development in agriculture per 1000 Euros of gross value added	Euro	+
324	Age composition of farmers	Ratio between percentage of farmers less than 35 years old and percentage of farmers 65 years old or older in terms of standard output	-	+
325	Agricultural income	Agricultural income – indicator "A"	2005=100	+
326	Subsidy dependency	Agricultural subsidies in percentage of gross value added	%	-
4		**Society**		
401	Production of value	GDP per inhabitant in the rural regions as % of total GDP per inhabitant	%	+
402	Employment	Rate of employment in the thinly populated areas (20-64 years)	%	+
403	Rural development subsidies	Rural development subsidies per inhabitant in the predominantly rural regions	Euro/capita	+
404	Change of population	Rate of total change of rural population	%	+
405	Poverty	Share of households with risk of poverty or social exclusion in the thinly populated areas	%	-

Code	Theme	Indicator	Unit	Goal*
406	Housing conditions	Severe housing deprivation rate in the thinly populated area	%	-
407	Age composition of population	Dependency ratio of rural population over 65 years	%	-
408	Internet access	Ratio of households with Internet access in the sparsely populated areas	%	+
409	Environmental harm	Ratio of pollution, grime or other environmental problems in the thinly populated areas	%	-

* "+" means a maximization goal, "-" means a minimization goal, while "0" means 0 as a goal.
Source: own research

3.2. Development of the weight system of composite indicators

The weight system of Sustainable Agricultural Index was developed by using the results of an expert survey. The survey research was carried out between 28 October 2014 and 6 January 2015. A total of 102 experts (including international experts) received the questionnaire. During the research, 60 experts returned the questionnaire, representing a return rate of 59% (Table 3). 65% of the respondent experts held at least a PhD degree.

Table 3: Number of sent and received questionnaires in the expert survey

Expert	Number of questionnaires sent	Number of questionnaires received	Return rate, %
Hungarian expert	60	41	68.3
International expert	25	12	48.0
Expert of an international organisation	17	7	41.2
Total	102	60	58.8

Source: own research

Table 4: Number of comment elements in the expert survey by their types

Type of comment	Comment element	Total
General comment on the indicator system	22	25
Comment on the indicators	57	64
Proposal for a new indicator	15	16
Proposal on the research, not relating the indicator system	8	9
Difficulty in filling out the questionnaire	4	8
Other comment	2	3
Total	108	125

Source: own research

A secondary objective of the survey research was the assessment of the adequacy of the theoretical framework, the indicator system and the selected indicators. A total of 125 comment elements were received from 38 experts. The number of repeated observation elements was relatively low (Table 4). There were three comment elements that were common at three experts, and 11 comment elements which were indicated by two experts. Comments on specific indicators were formulated at the highest rate.

I had the expectation regarding the assessment of the four domains (food supply, environment, economy, society) that this would be the most difficult for the experts. I expected that many experts would not wish or would not be able to carry out the evaluation, or if evaluated, equal importance would be attached to the domains. My preliminary expectation has not been confirmed, the experts (except for one expert) carried out an assessment of the domains, and only a small percentage of them (8.5%) assigned the same weights to the four areas. Table 5 contains the weights belonging to the four domains, established on the basis of the expert survey.

Table 5: Weights of the domains of Sustainable Agricultural Index

Code	Domain	Weight
1	Food supply	28.3
2	Environment	30.9
3	Economy	20.3
4	Society	20.5

Source: own research

The results of the verification of hypotheses related to the expert survey are the following:

H_1 – The assessments of national experts are not considerably different from the opinion of international experts on the importance of indicators of sustainable agriculture – partly proved. Although some areas show a significant difference in the evaluation of the opinions of national and international experts, on the whole I did not experience major differences between the evaluations by the two groups.

H_2 – A significant proportion of experts make no difference in the evaluation of the four domains of sustainable agriculture – not proved. The vast majority of experts evaluated the four main areas, and assigned different evaluations to each area.

3.3. Sustainable Agricultural Index

Sustainable Agricultural Index (values for 2010 are shown in the map of Figure 2) had the highest value in Austria in 2010 in the EU, followed by Greece and the Netherlands, while Latvia, Slovakia and the Czech Republic had the lowest values. The value of Hungary (52.1) was below the EU average of 58.6.

The contributions of components of the Sustainable Agricultural Index to the index values for 2010 are presented in Figure 3. The agriculture of Austria performed well in all major areas. The Austrian value of "Food supply" indicator is the highest in the EU, while second for that of the "Environment", and third for the indicator for the "Society". Greece showed an outstanding performance in the domains for the environment and food supply, and the Netherlands achieved high values for the composite indicators for the economy and the society. At the other end of the country order, Latvia reached the lowest level in the EU in the domain "Society", while Slovakia had the lowest value in the domain "Food supply".

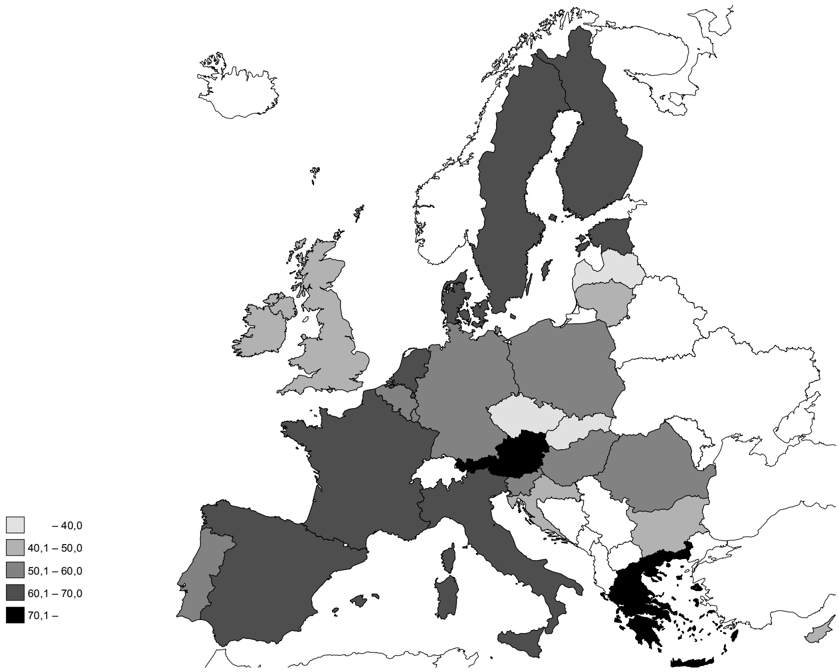


Figure 2: Values of the Sustainable Agricultural Index in the EU Member Countries, 2010

Source: own research

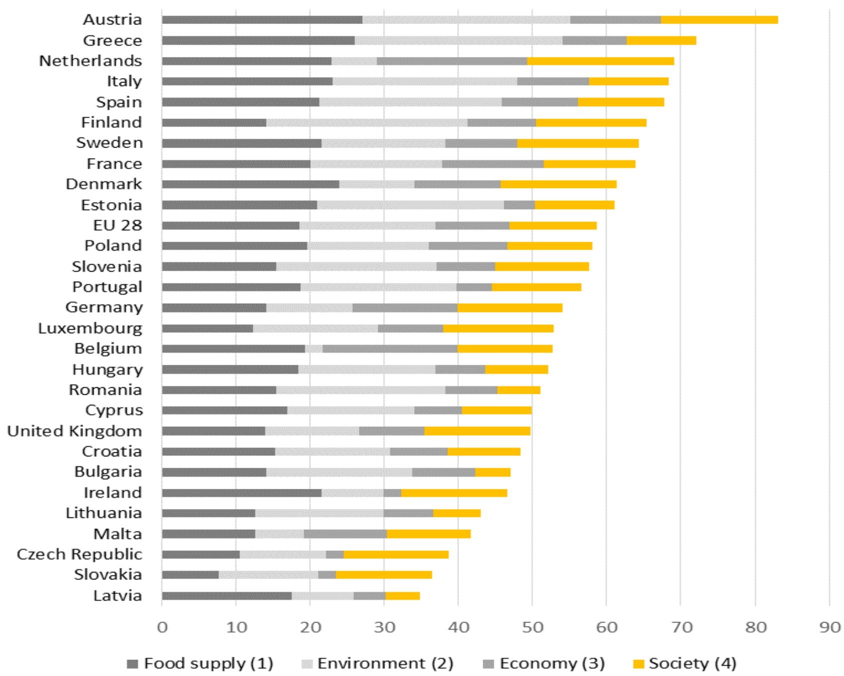


Figure 3: Values of the components of Sustainable Agricultural Index in the EU Member Countries, 2010

Source: own research

2010 values of the Sustainable Agricultural Index and the rate of change compared to the 2000 figures are presented in Figure 4. The Sustainable Agricultural Index of the Polish (94%), the Estonian (71%) and the Czech (63%) agriculture reached the strongest improvements between 2000 and 2010, while decrease in Ireland (24%), Denmark (8%) and Croatia (6%) can be detected. In Hungary, the indicator increased by 9% in the period under review, which is an increase of 6 percentage points lower than the average increment measured in the EU.

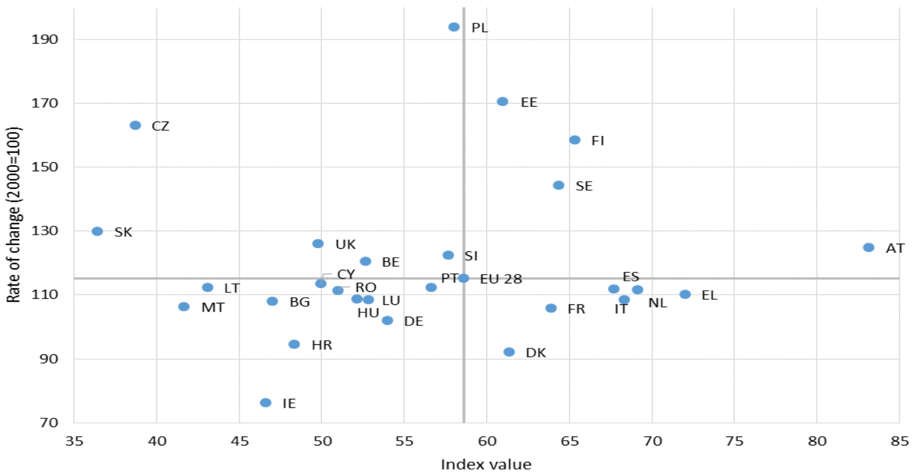


Figure 4: Values of the Sustainable Agricultural Index and the rate of change compared to the 2000 figures in the EU Member Countries, 2010
Source: own research

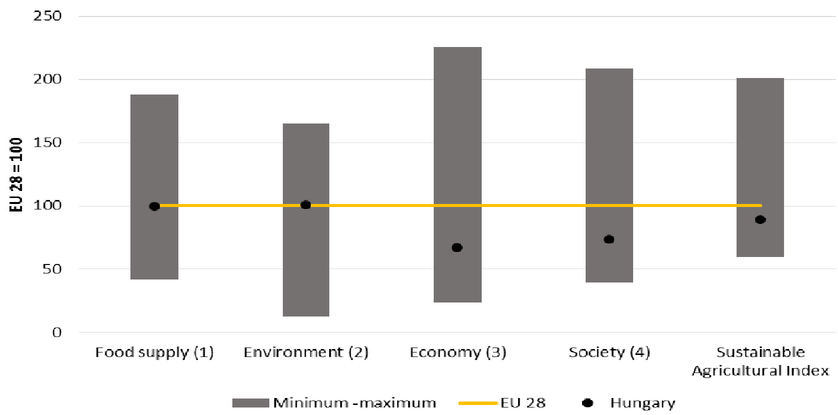
The results of the verification of hypotheses related to the values of Sustainable Agricultural Index are as follows:

H_3 – European agriculture is moving in the direction of sustainability in the period under review – proved. The EU average for Sustainable Agricultural Index increased by 15%.

H_4 – The sustainability performance of Hungarian agriculture does not differ greatly from the European average – proved. Hungary performed below the EU average on the basis of a Sustainable Agricultural Index according to the 2010 figures, but showed no significant difference from the average.

3.4. Values of Sustainable Agricultural Index in Hungary

The Hungarian value of Sustainable Agricultural Index was 11% below the EU average in 2010 (Figure 5). The index for the environmental dimension showed a slightly higher value than the average, while the index for the "Food supply" domain was slightly lower than the average, while the values of indices for the "Economy" and "Society" domains were significantly lower than the EU average.



Figures 5: Sustainable Agricultural Index and the values of the indices for the domains in Hungary compared to the EU average in 2010
Source: own research

Figures 6 and 7 show the changes of Sustainable Agricultural Index and the indices of the domains between 2000 and 2010. Values between 2000 and 2010 show a relative stability in the "Food Supply" and in the "Society" domains, while there is a high degree of volatility in the "Environment" and in the "Economy" domains. The value added and the output of agriculture is highly dependent on the amount of the particular year's harvest, which affects numerous indicators belonging to the main areas "Environment" and "Economy". Many indicators of the environmental domain have the value added as benchmarks therefore a lower environmental impact is indicated in case of year with a better harvest and a high value added (e.g. in Hungary in 2008). Compared to the EU average, the indicators of the domain "Society" increased in the period under review, while the relative position of the Hungarian agriculture has deteriorated in terms of the domain "Food Supply" in addition to the volatility of the indicators of two other domains.

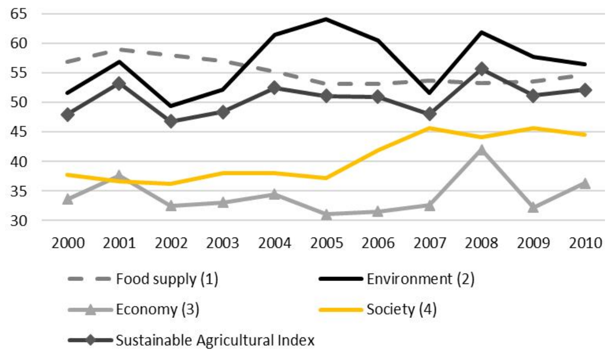


Figure 6: Sustainable Agricultural Index and the values of the indices of the domains in Hungary, 2000-2010
Source: own research

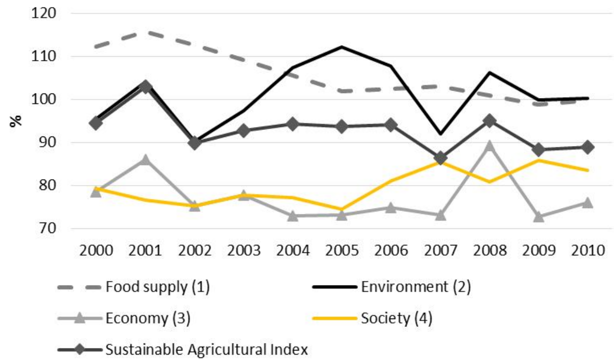


Figure 7: Sustainable Agricultural Index and the values of the indices of the domains in Hungary as a percentage of the EU average
Source: own research

Figures 8 and 9 compare the values of Sustainable Agricultural Index in Hungary with those of regional competitors. In the whole period, Austria had the highest index value, while Poland achieved a significant increase, and reached a higher value than that of Hungary and Romania in 2010. If we examine changes in the values of individual countries, we can conclude that Poland reached the most significant growth during the decade studied, while changes in the values of other countries were not significant apart from the minor growth in Slovakia.

3.5. Correlation analysis of the indices of the domains of sustainable agriculture

Correlation analysis was performed between the indices for the four domains of sustainable agriculture (food supply, environment, economy and society) using the 2010 data. The results of the correlation analyses are shown in Table 6. A significant, moderately strong relationship can be discovered between the domains "Economy" and "Society"; and "Economy" and "Food supply".

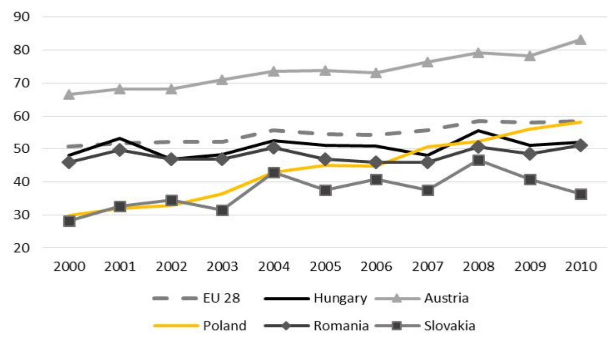


Figure 8: Sustainable Agricultural Index of Hungary and the regional competitors, 2000-2010
Source: own research

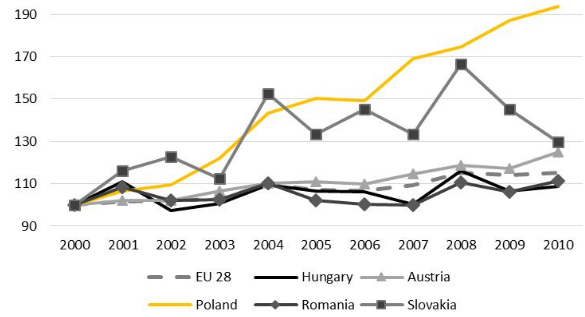


Figure 9: Changes of Sustainable Agricultural Index of Hungary and the regional competitors, 2000-2010 (2000=100)
Source: own research

The result of the verification of the hypothesis related to the correlation analysis of composite indices of the domains is as follows:

H_5 – Correlation can be detected between the composite indicators describing the domains of sustainable agriculture – partly proved. As the results of the correlation analyses, moderately strong and significant relationships can only be detected between the domains "Economy" and "Society"; and "Economy" and "Food supply".

Table 6: Results of the correlation analyses between the indices describing the four domains of sustainable agriculture

Domain	Food supply	Environment	Economy	Society
Correlation				
Food supply	1.000	0.258	0.381	0.214
Environment	0.258	1.000	-0.240	-0.202
Economy	0.381	-0.240	1.000	0.424
Society	0.214	-0.202	0.424	1.000
Significance				
Food supply		0.093	0.023	0.137
Environment	0.093		0.109	0.151
Economy	0.023	0.109		0.012
Society	0.137	0.151	0.012	

Source: own research

3.6. Separation of country groups based on the domains of sustainable agriculture

My aim was the separation of country groups based on the indexes of sustainable agriculture. The creation of groups was carried out on the basis of 2010 data using cluster analysis. Three groups of countries were separated. Groups of countries formed on the basis of the separation of three clusters and the characteristics of cluster centers are summarized in Figure 10.

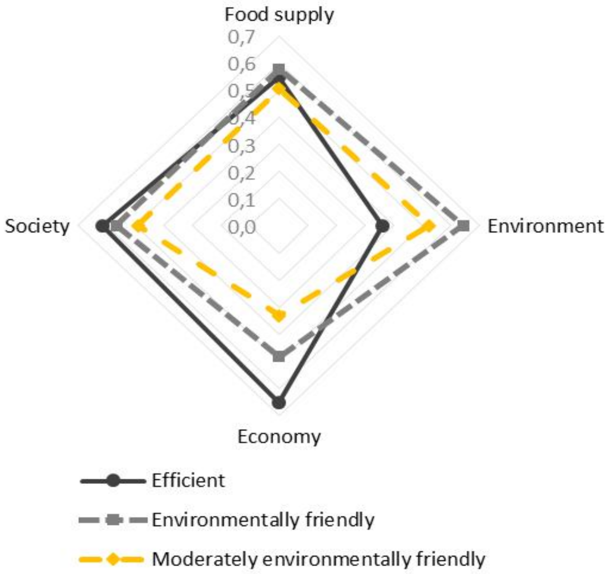


Figure 10: Groups of countries formed on the basis of indicator groups and the final cluster centers

Source: own research

Countries belonging to the "Efficient" group show higher values in the domains "Economy" and "Society", while there is a lower environmental performance of agriculture. In the case of the "Environmentally friendly" group, there is a higher value for the domain "Environment", while the economic performance is weaker. The third group of countries has lower values for the areas "Economy" and "Society" and the environmental aspect does not get a higher value than in the case of the second group, but it is higher than in the case of the first group. The values of the domain "Food supply" hardly distinguish the groups from each other. A list of the countries belonging to the separated country groups are shown in Table 7.

Table 7: Countries belonging to the developed country groups

Efficient	Environmentally friendly	Moderately environmentally friendly
Belgium Denmark Netherlands Malta Germany	Austria Finland France Greece Poland Italy Spain Sweden Slovenia	Bulgaria Cyprus Czech Republic United Kingdom Estonia Croatia Ireland Latvia Lithuania Luxembourg Hungary Portugal Romania Slovakia

Source: own research

Based on the ANOVA F values, the country groups are most separated by the indicators of the economy (F=27.2) and the environment (F=16.9). In each case, the separation is significant.

The result of the verification of hypothesis regarding the separation of the country groups is the following:

H_6 – The differences between countries in terms of sustainable agriculture are mainly caused by economic factors – proved.

3.7. The examination of the territorial aspects of Sustainable Agricultural Index

The examination of the spatial relationships of Sustainable Agricultural Index was carried out by using the method of spatial autocorrelation. Input data of the analysis were the values of composite indices of Sustainable Agricultural Index for 2000 and 2010. Figure 11 shows the values of spatial autocorrelation for the EU. Based on the results, significant spatial autocorrelation can be detected for the composite indicators of the domains "Economy" and "Society", meaning that the values of these indicators are geographically determined, spatial relationships exist between them. The closest relation can be detected in respect of the indices of "Economy" for 2010. Poor relation can be observed in case of the indicators of "Food Supply" and "Environment", so in these domains there is a smaller role of regional relations.

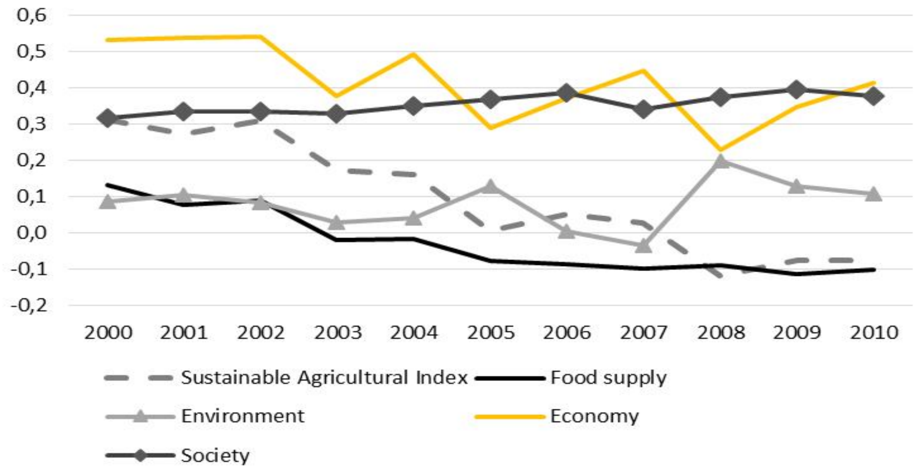


Figure 11: Values of spatial autocorrelation in the EU regarding the Sustainable Agricultural Index

Source: own research

The result of the verification of hypothesis regarding spatial autocorrelation is as follows:

H_7 – The domain "Economy" shows the strongest territorial determination out of the composite indicators of sustainable agriculture – proved.

The examination of territoriality was performed using shift-share analysis. The normalized values of the 44 core indicators for 2000 and 2010 corrected by the weights of composite indicators were the input values of the analysis. The results show the variety of EU agriculture both in terms of the dynamics of change and the weight of territoriality regarding the domains of sustainability. There are only three countries, where there are more dynamic developments than the average in all domains (the United Kingdom, Estonia and Poland) and where there are slower developments than the average in all areas (Denmark, France and Ireland). The Hungarian agriculture shows dynamics in the domains of "Environment" and "Society" between the end points of the period under review, while for the rest of the domains and for the aggregated sustainability index there is a slower pace than the average growth. We could experience a decline in the period under review on the basis of the indicators of Sustainable Agricultural Index; however, if we examine the components of the decline, the territorial effects were positive, so the decrease was mainly caused by the structural effects.

The result of the verification of hypothesis regarding territoriality is as follows:

H_8 – The Sustainable Agricultural Index is more determined in Hungary by regional effects than structural ones – not proved.

3.8. New scientific achievements

T_1: *I developed a complex system of indicators built on macro data for the measurement of sustainable agriculture based on the systematization of relevant literature.*

My goal was to create a system of indicators, which is suitable for measuring the components of sustainable agriculture. The established indicator system is based on data with appropriate quality, suitable for temporal and spatial comparisons and made it possible to assess overall sustainability of agriculture, to assess sustainability by domains or on the basis of single indicators.

T_2: *I created the complex database on sustainable agriculture for the EU Member Countries.*

Based on the evaluation of possible data sources, I collected the basic data necessary for the indicator system for the EU Member Countries and for the years 2000-2012. The data were analysed in terms of data quality and missing values were imputed in order that appropriate quality of data would be ensured and the database would be suitable for the calculation of Sustainable Agricultural Index.

T_3: *I developed the composite indicators describing the domains of sustainable agricultural and the Sustainable Agricultural Index and applied for the agriculture of the EU Member States. Country groups were separated on the basis of sustainability of agricultural production using the method of cluster analysis.*

An objective weight system was necessary for the development of Sustainable Agricultural Index, which properly assesses the sustainability of agriculture. The creation of the weight system was carried out using the method of budget allocation process whereby primary expert survey of national and international experts was conducted. The experts carried out an assessment of certain areas of sustainable agriculture, which served as a basis for creating the weight system underlying the composite indicators. The calculation of the composite indicators of sustainable agriculture – such as Sustainable Agricultural Index – was carried out for the EU Member Countries and for the years under review. The performance of the various Member States and the changes between 2000 and 2010 were evaluated along the four domains of sustainable agriculture and the overall assessment was also carried out. The development of the performance of Hungarian agriculture in comparison with its regional competitors was analyzed separately. The adequacy of the design of composite indicators was evaluated using sensitivity analyses.

Groups of countries of the EU Member States were separated using cluster analysis method according to the performance of individual Member Countries in the domains of agricultural sustainability measured by the indicators of Sustainable Agricultural Index. Three groups of countries were created, which were named as follows based on the values of the composite indicators of four domains ("Food supply", "Environment", "Economy" and "Society"): "Efficient", "Environmentally friendly" and "Moderately environmentally friendly".

T$_4$: *The sustainability of the EU's agricultural production was analyzed in terms of territoriality and I detected spatial relationships and the role of territoriality in the changes was analysed.*

The indicator system of sustainable agriculture and the composite indicators created an opportunity for regional analyses of the EU agricultural production in terms of sustainability. Spatial relationships were detected using spatial autocorrelation method on the basis of the indicators of Sustainable Agricultural Index. It was proved that territorial determinism is the strongest in case of the composite index for the domain "Economy". Shift-share analysis was used to detect the weight of territoriality in the changes of the sustainability of agriculture between 2000 and 2010. The method is suitable for separating the changes into regional and structural impacts, and it was carried out for the composite indicators of the four domains of sustainable agriculture and the Sustainable Agricultural Index for all Member States.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the processing of literature, the indicators related to agricultural production represent a smaller proportion in the indicator systems of sustainable development compared to the weight of agriculture. Numerous institutions and research teams have developed indicator systems for measuring the sustainability of agricultural production; however, there is not one of them, which would have given a summary assessment of the sustainability in the EU Member Countries' agriculture. A definition of sustainable agriculture was developed based on the processing of literature, which served as a theoretical framework and a structure for the indicator system.

The indicator system on sustainable agriculture for the EU Member Countries was compiled during establishing the empirical research of the thesis. The basic data necessary for the indicators were gathered and verified, the missing data were imputed and the weight system of the indicators was developed based on a primary expert survey in order to determine the composite indicators. Indices were calculated for the domains of sustainable agriculture which reflect the performance of agriculture in the particular domains. The "Sustainable Agriculture Index" was developed, which gives a summary evaluation of the sustainability of agricultural production in the EU Member States.

The average value of the Sustainable Agriculture Index rose in the EU in the period between 2000 and 2010, according to which the EU agriculture moved towards sustainability. The index values showed the most significant increase in the domain "Economy" during the period under review, while the lowest growth rate was measured in the domain "Environment". There are significant differences between the sustainability performances of the Member Countries. The sustainability performance of Hungary was below the EU average in 2010, which is primarily caused by the lower performance in the domains "Economy" and "Society". Therefore, it would be advisable if Hungarian agriculture and rural Hungary would develop in these areas.

Based on the values related to the domains of Sustainable Agricultural Index, groups of countries were separated. The country groups are most distinguished by the indicators of the domains "Economy" and "Environment". The Sustainable Agricultural Index was also studied from the territorial point of view. It was found as a result that the spatial autocorrelations of the domains "Economy" and "Society" were the highest.

During the research, eight hypotheses were formulated, of which four were fully and two partly proved. Table 8 provides an overview of the verification of the hypotheses.

The compilation of the indicator system was difficult because of the lack of basic data and the inadequate quality of them in some areas. The quality of the composite indices is basically influenced by the coverage of specific areas in the theoretical framework by relevant indicators supported by basic data with adequate quality. For this reason, it is essential to improve the accessibility and quality of basic data for the more informed examination of sustainable agriculture. An additional problem in many areas is the long production time of data, which also needs an improvement. The production of indicators at a lower territorial level is currently not possible in many areas because raw data are not available, which deficiency could be eliminated by applying proper data collection methodologies or estimation procedures that could enable the dissemination of data at a lower territorial level.

Table 8: The hypotheses formulated during the research, the methods of proof and the results

	Hypothesis	Method of proof	Result of proof
H_1	The assessments of national experts are not considerably different from the opinion of international experts on the importance of indicators of sustainable agriculture.	Primary expert survey	Partly proved
H_2	A significant proportion of experts make no difference in the evaluation of the four domains of sustainable agriculture.	Primary expert survey	Not proved
H_3	European agriculture is moving in the direction of sustainability in the period under review.	Analysis of composite indicators	Proved
H_4	The sustainability performance of Hungarian agriculture does not differ greatly from the European average.	Analysis of composite indicators	Proved
H_5	Correlation can be detected between the composite indicators describing the domains of sustainable agriculture.	Analysis of composite indicators	Partly proved
H_6	The differences between countries in terms of sustainable agriculture are mainly caused by economic factors.	Cluster analysis	Proved
H_7	The domain "Economy" shows the strongest territorial determination out of the composite indicators of sustainable agriculture.	Spatial autocorrelation method	Proved
H_8	The Sustainable Agricultural Index is more determined in Hungary by regional effects than structural ones.	Shift-share analysis	Not proved

Source: own compilation

The biggest difficulty related to the composite indicators is the lack of their widespread acceptance. The value of the indicators can be significantly affected by the theoretical framework, the scope of indicators in the indicator system and the methodology of the weight system that is needed for the calculation of the indicators. In many cases, subjective decisions are needed for the development. However, the communication value and the role of composite indicators in decision support are indisputable. It is necessary for a composite index to become widely accepted, and for that the development methodology should have the appropriate political support and be laid for a broad consensus. The system of indicators and the related composite indicators produced as results of this research are capable of supporting the European and national agricultural policy decisions, as well as of the shaping of the Common Agricultural Policy and its components. A distinct advantage of the indicator system is that it is suitable for the systemic tracking of changes in agricultural production both at national and at EU level.

Sustainable development – due to its complex nature – is an appropriate discipline for the evaluation by composite indicators. In this thesis, I studied sustainable agriculture, but I think that the emergence of sustainability in other sectors could as well be examined with similar systems of indicators and composite indices, and it could also be a topic of future research.

In conjunction with the research for the thesis – taking into account the findings above – I make the following recommendations.

J_1: Basic conditions of the compilation of indicator systems are the availability of basic data that are comparable in time and space, and have an adequate quality. The data related to sustainable agriculture, in many areas, do not meet these requirements; therefore, my first recommendation is that

- accessibility,
- comparability and
- quality of basic data should be improved.

J_2: A separate proposal is that estimation methods should be elaborated for the data currently not available for eliminating at least the most important data gaps (e.g. data on soil).

J_3: I suggest the development of the timeliness of data production. Currently, there are indicators that are published internationally only 24-30 months after the reference period. The time required for data production should be shortened at both national and international levels.

J_4: The analysis was carried out for the EU Member States; the primary reason for it was that most of the data are not available at territorial levels lower than the country level. I suggest that the EU and national institutions in data production should take measures regarding the availability of basic data for the indicators at lower territorial levels (NUTS 2 or NUTS 3) to ensure that the Sustainable Agricultural Index could be prepared at regional level.

J_5: I suggest that the indicator system and the weight system of the Sustainable Agricultural Index should be reviewed and approved by an international team of researchers to ensure that the indicator system and the conditions of calculation of the composite index are based on a broad consensus.

J_6: Sustainable Agricultural Index and the indices covering the domains of sustainable agriculture are capable of providing information to decision-makers and the interested public on the sustainability of agriculture. For researchers and for those interested in details, data from the indicator system may be interesting. Accordingly, I recommend that the information from the indicator system and the indices should be made public and their regular production and publication should be arranged by one of the EU institutions.

J_7: Finally, I propose that sectoral sustainability indicator systems and composite indicators should be compiled using the methodology outlined in the dissertation. So those interested could get information on sustainable industry, sustainable services – or even on parts of these sectors, for example sustainable tourism.

5. LIST OF PUBLICATIONS RELATED TO THE TOPIC OF DOCTORAL DISSERTATION

Scientific articles

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