B14

Developing the Indicator System of Sustainable Agriculture – Application of Composite Indicators

G. Valkó | Hungarian Central Statistical Office, Rural Development, Agricultural and Environmental Statistics Department | Budapest | Hungary

DOI: 10.1481/icasVII.2016.b14

ABSTRACT

The sustainability of agriculture has become one of the most important areas of agricultural research in the last decade. The focus of research has changed from efficiency of production, quality and quantity of product to the impact of agriculture on environment and rural population. An important area of research is the development of indicator systems measuring the sustainability of agricultural systems on micro or macro level.

The aim of this paper is to present the results of the author's research focusing on the development of an indicator system measuring the sustainability of agriculture. The indicator system is built on macro level statistical data and its structure is based on a theoretical framework that was developed using the definition of sustainable agriculture. Data were gathered for the EU Member Countries for the time period of 2000 to 2012. Composite indices of the overall sustainability of agriculture and separately for the four domains (food supply, environment, economy, society) were calculated. The weight system was established based on the results of a primary expert survey.

The indicators and composite indices are suitable for carrying out temporal and spatial comparisons and can also be used for analysing the causes of trends in the European agriculture in terms of sustainability.

Keywords: sustainability, agriculture, indicators

PAPER

1. Introduction

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. Agricultural production is multi-purpose: there are economic, environmental and social roles of agriculture (OECD, 2001; Boody et al., 2005; Rossing et al., 2007; Huang et al., 2015). 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 has become 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.

2. Material and method

The theoretical framework of the indicators of sustainable agriculture is based on the definition of sustainable agriculture, which was created by synthesizing the literature sources including the following: EU, 2012; Kirchmann and Thorvaldsson, 2000; National Research Council, 2010; OECD, 2001; RISE, 2016; SARE, 1997; Smith and McDonald, 1998; USDA, 1999; Valkó and Farkasné Fekete, 2014; Van Cauwenbergh et al., 2007. Four 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 and grouped in 4 domains (food supply, environment, economy and society). The themes covered by the indicators are listed in Table 1. Only those indicators were selected, for which data were available for the EU Member Countries for the years 2000-2012. 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. 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 indicators in the indicator system is reasonable. The weights required for the calculation of the composite indices were determined by expert opinion. In the literature (OECD, 2008), this procedure is referred as the Budget Allocation Process (BAP).

Table 1 - Themes covered by the indicators in the indicator system for sustainable agriculture

Food supply	Environment	Economy	Society
Organic farming	Resource use	Resource use	Production of value
Production of genetically modified crops	Energy use	Efficiency of land use	Employment
Food security	Land use	Labour productivity	Rural development subsidies
Food processing capacity	Livestock density	Competitiveness in foreign trade	Change of population
Food price	Emission of greenhouse gases	Yields	Poverty
Consumption of healthy food	Emission of ammonia	Utilization of agricultural land area	Housing conditions
Safe food	Nutrient balance of soil	Replacement of means of production	Age composition of population
	Manure use	Diversification of production	Internet access
	Pesticide use	Research and development	Environmental harm
	State of flora and fauna	Age composition of farmers	
	Environmental commitment	Agricultural income	
	Organic farming	Subsidy dependency	
	Own produced inputs		
	Land use		
	Training of farm managers		
	Agricultural education		

Source: own research

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 (OECD, 2008):

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

where

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

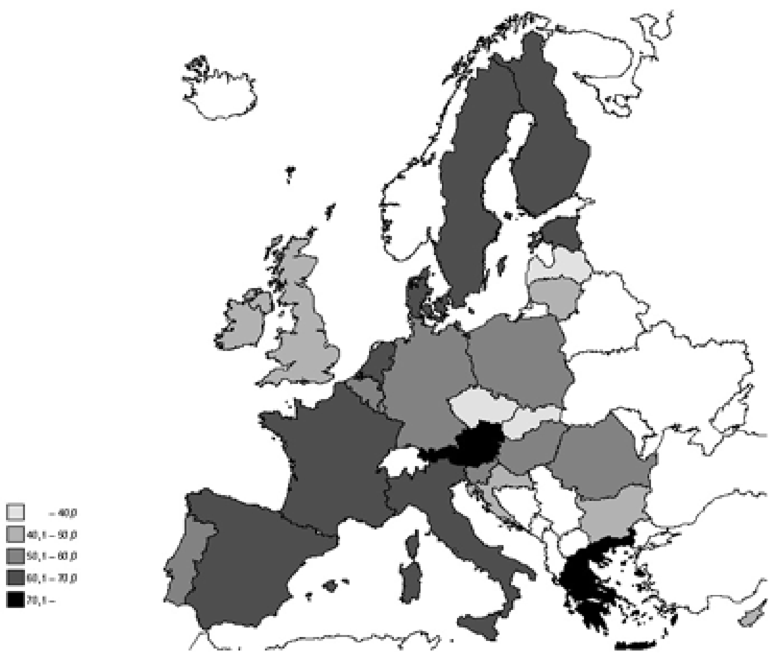
I_{qc}^{t} = normalised value of indicator q for country c and year t.

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 aggregation of indicators was performed using the method of linear aggregation by adding the normalised and weighted values of the indicators. The weight system of the composite indicators was developed by using the results of an expert survey. Sub domains were created for two domains of the indicator system in order to facilitate the work of experts in valuing the different indicators in terms or their contribution to sustainability of agriculture. These sub domains are: Resource use; Environmental pressures, state of the environment and Proper farm management in the domain Environment while Efficiency, competitiveness and Economic viability, profitability in the domain Economy. The survey was carried out between 28 October 2014 and 6 January 2015. A total of 102 experts (including international experts), who have the expertise in sustainability of agriculture, received the questionnaire. During the research, 60 experts returned the questionnaire, representing a return rate of 59% (Table 21). 65% of the respondent experts held at least a PhD degree. The expert survey resulted in the weights for the indicators and the domains of the indicator system. The weights for the four domains are as follows: 30.9 for Environment, 28.3 for Food supply, 20.5 for Society and 20.3 for the domain Economy. When compiling a composite indicator system, a number of subjective decisions are 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: compilation of indicator system, type of weighting system and selection of experts. The values of the Sustainable Agricultural Index (key composite indicator for the sustainability of agriculture) calculated with modified conditions were compared with the results from the original method. Based on the results, only the selection of the type of weighting system influenced significantly the values of the composite indicators.

3. Results

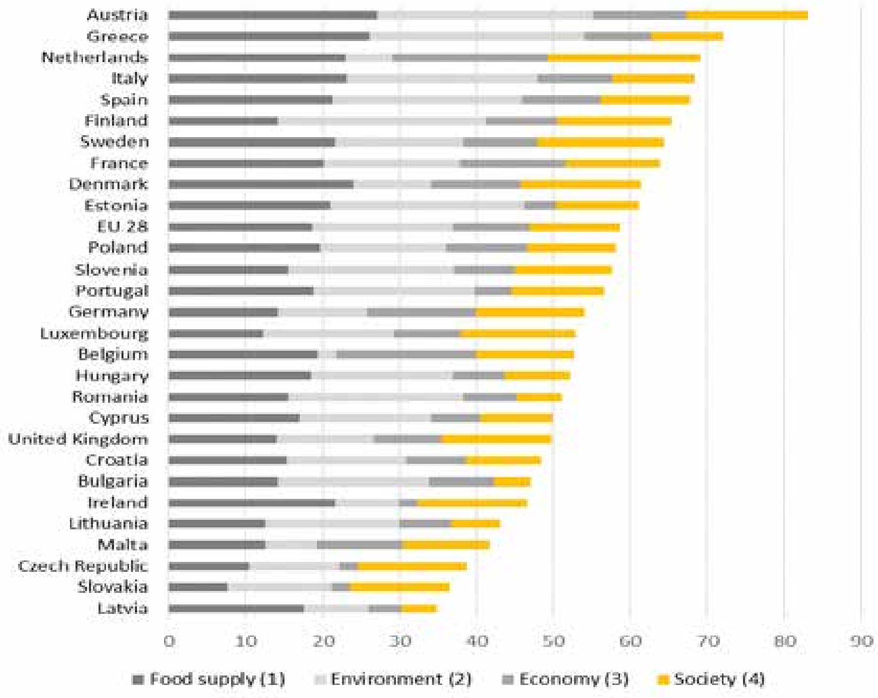
Sustainable Agricultural Index (values for 2010 are shown in the map of Figure 1) had the highest value in Austria in 2010 in the EU, followed by Greece and the Netherlands, while Latvia, Slovakia and the Czech Republic had the lowest values The contributions of components of the Sustainable Agricultural Index to the index values for 2010 are presented in Figure 2. 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 environment and food supply, and the Netherlands achieved high values for the composite indicators of economy and 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". 2010 values of the Sustainable Agricultural Index and the rate of change compared to the 2000 figures are presented in Figure 3. 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.

Figure 1 - Values of the Sustainable Agricultural Index in the EU Member Countries, 2010



Source: own research

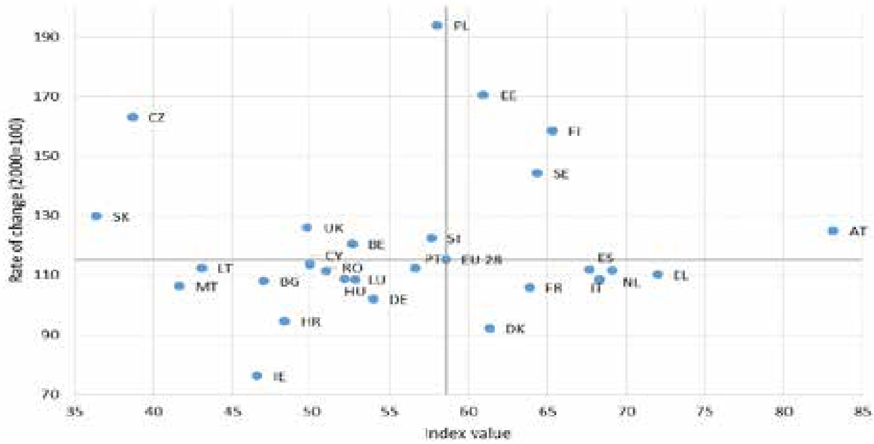
Figure 2 - Values of the components of Sustainable Agricultural Index in the EU Member Countries, 2010



Source: own research

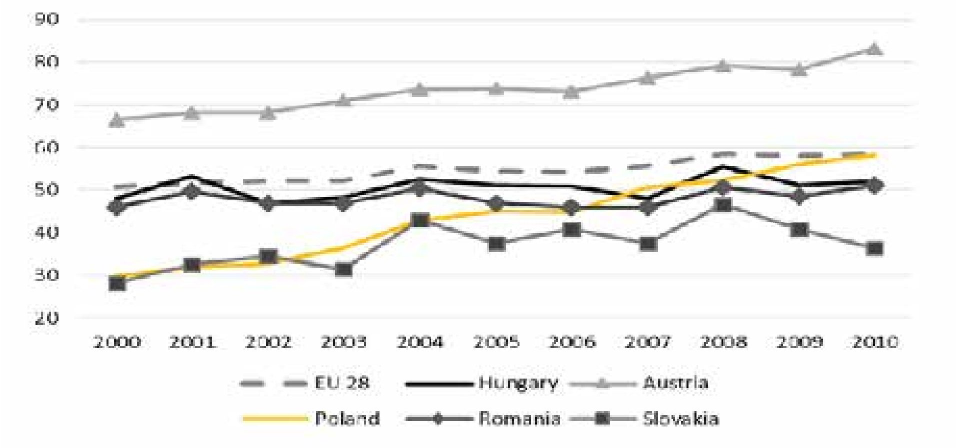
Figures 4 and 5 compare the values of Sustainable Agricultural Index in the region of Central and Eastern Europe. In the whole period, Austria had the highest index value, while Poland achieved a significant increase, and reached a higher value than that of Hungary and Romania in 2010. If we examine 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.

Figure 3 - Values of Sustainable Agricultural Index and the rate of change compared to the 2000 figures in the EU Member Countries, 2010



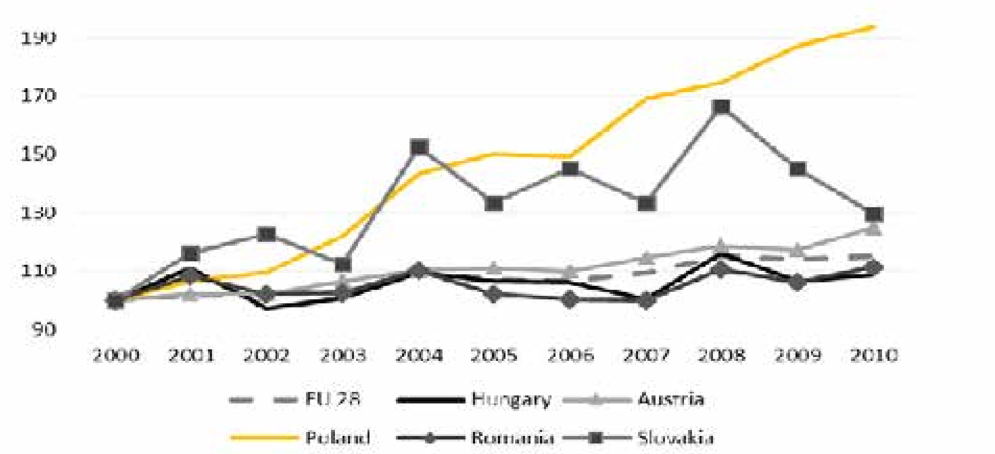
Source: own research

Figure 4 - Sustainable Agricultural Index in Central and Eastern Europe, 2000-2010



Source: own research

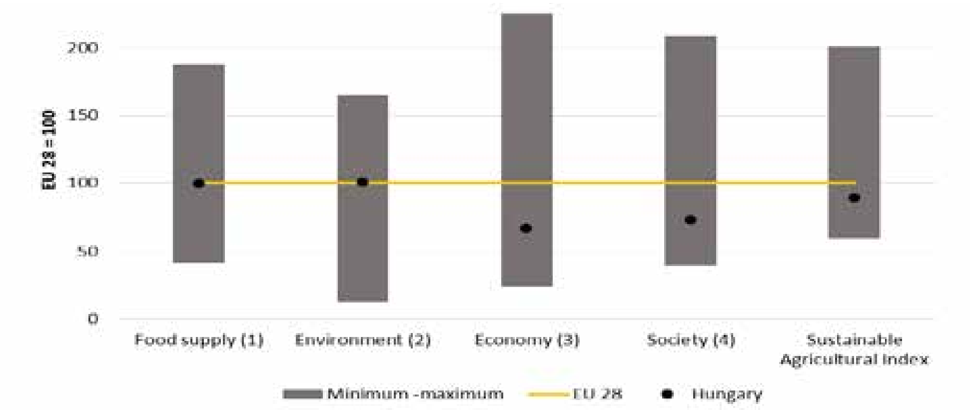
Figure 5 - Changes of Sustainable Agricultural Index in Central and Eastern Europe, 2000-2010 (2000=100)



Source: own research

The indicator system and the composite indices give an opportunity for detailed country analysis where the performance of a country can be analysed by components, against competitors and also temporal changes can be investigated. As an example for country analysis, the values of Sustainable Agricultural Index and its components in Hungary are shown in Figure 6. Sustainable Agricultural Index of Hungary was 11% lower than the EU average in 2010. 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. The values of indices for the "Economy" and "Society" domains were significantly lower than the EU average.

Figures 6 - Sustainable Agricultural Index and the values of the indices for the domains in Hungary compared to the EU average in 2010



Source: own research

4. Conclusion

Numerous institutions and research teams have developed indicator systems for measuring the sustainability of agricultural production; however, none of these gave a summary assessment of the sustainability of the EU Member Countries' agriculture.

The average value of 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 compilation of the indicator system was difficult because of the lack of basic data or the inadequate quality of them in some areas. The quality of the composite indices is basically influenced by coverage of the 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. An additional problem in many areas is the long production time of data; timeliness needs to be improved. 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 data collection methodologies or estimation procedures that could enable the dissemination of data at a lower territorial level.

A major 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 that the development methodology of a composite index should have the appropriate political support to become widely accepted. The system of indicators and the related composite indicators produced as a result of this research are capable of supporting the European and national agricultural policy decisions, as well as of the shaping of 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 the main aspects of agricultural production both at national and at EU level.

References

Boody, G., Vondracek, V., Andow, D.A., Krinke, M., Westra, J., Zimmerman, J., Welle, P. (2005) Multifunctional agriculture in the United States, BioScience, 55 (1), 27-38.

EU (2012) Sustainable agriculture for the future we want. http://ec.europa.eu/agriculture/events/2012/rio-side-event/brochure_en.pdf, last access: 17 April 2016

Huang, J., Tichit, M., Poulot, M., Darly, S., Li, S., Petit, C., Aubry, C. (2015) Comparative review of multifunctionality and ecosystem services in sustainable agriculture, Journal of Environmental Management, 149 (1), 138-147.

Kirchmann, H., Thorvaldsson, G. (2000) Challenging targets for future agriculture, European Journal of Agronomy, 12 (1), 145-161.

National Research Council (2010) Toward Sustainable Agricultural Systems in the 21st Century, The National Academies Press, Washington D. C., 598 p.

OECD (2001) Multifunctionality: towards an Analytical Framework, OECD Publications, Paris, 27 p.

OECD (2008) Handbook on Constructing Composite Indicators – Methodology and User Guide, OECD Publications, Paris, 158 p.

RISE (2016) Response-Inducing Sustainability Evaluation, http://www.hafl.bfh.ch/index.php?id=1472&L=1, last access: 17 April 2016

Rossing, W. A. H., Zander, P., Josien, E., Groot, J. C. J., Meyer, B. C., Knierim, A. (2007) Integrative modelling approaches for analysis of impact of multifunctional agriculture: A review for France, Germany and The Netherlands, Agriculture, Ecosystems and Environment, 120 (1), 41-57.

SARE (1997): What is sustainable agriculture? Sustainable Agriculture Research and Education, http://www.sare.org/Learning-Center/SARE-Program-Materials/National-Program-Materials/What-is-Sustainable-Agriculture, last access: 17 April 2016

Smith, C. S., McDonald, G. T. (1998) Assessing the sustainability of agriculture at the planning stage, Journal of Environmental Management, 52 (1), 15-37.

USDA (1999) Sustainable agriculture: definitions and terms,. Special reference briefs No. SRB 99-02. U.S. Department of Agriculture

Valkó, G., Fekete-Farkas, M. (2014) Measurement of Sustainability of Agriculture, pp. 196-205, in: The Evaluation of Natural Resources, Ugrósdy, Gy., Molnár, J., Szűcs, I. (Eds.), Agroinform Publishing and Printing Ltd, Budapest, 329 p.

Van Cauwenbergh, N., Biala, K., Bielders, C., Brouckaert, V., Franchois, L., Garcia Cidad, V., Hermy, M., Mathijs, E., Muys, B., Reijnders, J., Sauvenier, X., Yalckx, J., Vanclooster, M., Van der Veken, B., Wauters, E., Peeters, A. (2007) SAFE – A hierarchical framework for assessing the sustainability of agricultural systems, Agriculture, Ecosystems and Environment, 120 (2-4), 229-242.