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MEASUREMENT OF SUSTAINABILITY OF AGRICULTURE

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Annotation

There has been a general agreement between researchers and policy-makers that agriculture plays a crucial role with respect to sustainability. However, studies centering on sustainable development have not paid sufficient attention to agriculture, especially in developed countries where the sector has only a marginal share in the national economy. In order to measure the sustainability of agriculture it is necessary to create a system of indicators that makes it possible to monitor the development of agriculture with respect to the three pillars of sustainability, namely the environment, the society and the economy. This study attempts to set up an indicator system that enables us to measure sustainable development in the agriculture.

KEYWORDS: sustainability, agriculture, indicators.

Introduction

Sustainable development has become one of the most important issues in environmental policy. The objective of integration of environmental dimension in Community policies has been set in the EU. The importance of developing indicators to assess the impact of different economic sectors on the environment; and to monitor the progress in integrating environmental concerns has been underlined.

There has been a general agreement between researchers and policy-makers that agriculture plays a crucial role with respect to the three pillars of sustainability, namely the environment, the society and the economy. It is also accepted that in order for a certain system to become sustainable it has to exploit its resources the most efficient way possible. However, studies centering on sustainable development have paid only a little attention to agriculture, especially in developed countries where the sector has only a marginal share in the national economy. This study attempts to set up an indicator system that enables us to measure sustainable development of agriculture.

The concept of sustainable agriculture

Several researchers and organizations have defined the concept of sustainable agriculture in many ways. However, there are some common items in the different definitions (SARE, 1997; Smith and McDonald, 1998; USDA, 1999; Kirchmann and Thorvaldsson, 2000; National Research Council, 2010; Robertson and Harwood, 2013):

- preservation of environmental quality,
- the provision of good quality food,
- the viability of agricultural operations, profitability,
- social justice, equality.

The EU defines the main goals regarding the sustainability of agriculture as follows (EU, 2012):

- producing safe and healthy food,
- conserving natural resources,
- ensuring economic viability,
- delivering services to the ecosystem,
- managing the countryside,
- improving quality of life in farming areas,
- ensuring animal welfare.

These definitions correspond to the 3 dimensions of sustainability: environmental (or ecological), economic and social dimensions. There are several approaches to the concept of sustainability. The most commonly used models are based on the 3 dimension and on the capital approaches. The latter one requires that at least the same amount of wealth is given to our children that we have inherited from our ancestors. The dimensional model (also known as mosaic approach) defines three components of sustainable development (Smith and McDonald, 1998):

- „ecological sustainability which requires that development is compatible with the maintenance of ecological processes,
- economic sustainability which requires that development be economically feasible; and
- social sustainability which requires that development be socially acceptable".

There are different requirements of the three dimensions. The ecological sustainability gives priority to the preserving and enhancing the soundness of environment and management practices. The economic sustainability aims for the profitability of the production and the income generated from agricultural activity while from a social perspective the equal possibilities, the living standard of rural areas are in the focus.

The criteria of the three approaches must be met at the same time. A farm can not be sustainable if it is productive but it does not take into consideration the environmental requirements or it follows an environmentally-friendly production pattern that is not viable.

There is a controversial relation between the different dimensions of sustainability, especially between the environmental dimension and the other dimensions. Usually, the increase of the agricultural output, which is favourable for the indicators of the economic and often of the social dimension, involves the worsening of the environmental performance. The aim can be the decoupling of the economic performance and the pressure on the environment. According to the OECD definition, decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force (e.g. GDP) over a given period. (OECD, 2002) In the case of agriculture, decoupling means that the increment of the pressure on the environment (e.g. emission of nitrous oxide due to the use of fertilizers) is less than the growth rate of the crop production (relative decoupling). The term absolute decoupling can be used when the production grows while the pressure on the environment remains the same or it lessens.

Indicators of sustainable agriculture

Several international and national organizations have worked out their systems of sustainable development. As for the indicators of sustainable agriculture, there are also plenty of institutions and researchers formulating different sets of indicators with various goals, structure and methodology. Before compiling the indicator set, we had studied the available major indicator systems of sustainable agriculture (Eurostat, 2013a; OECD, 2013; SARE, 1997; Van Cauwenbergh et al., 2007). Summaries of the existing indicator systems are given by Binder et al. (2010) and Van Passel and Meul (2012). Previous research in this field was also used (Fekete-Farkas et al., 2007; Valkó and Fekete-Farkas, 2008). Since the European Union is in our focus, priority was given to the indicator sets compiled particularly for this region.

We chose the mosaic (3 dimension) approach for setting up the indicator system. The indicators were selected for the three dimensions separately and compiled taking into consideration the following requirements of indicators:

- relevance,
- reliability,
- accuracy,
- comparability,
- easy interpretation and
- good quality basic data.

There are two possibilities of selecting an indicator for a particular topic:

- using raw data (e.g. consumption of energy in agriculture),
- using a ratio (e.g. ratio of agriculture in energy consumption),
- using a relative indicator (e.g. energy consumption per gross value added).

When making a temporal comparison, pure raw data is the most proper indicator since there is no distortion of the information by another data. If our aim is a spatial comparison, using raw data may be misleading because there are considerable discrepancies between the different countries in size and in production patterns. Let us take the example of the indicator of energy consumption: using a relative indicator (energy consumption per gross value added) may not show the pressure on the environment correctly. In a certain year it may decrease because the gross value added increases due to the favourable weather for crop products while the energy consumption remained the same. The same applies, though less likely, to the ratio type indicators. It may also be misleading to compare the indicators of different countries using raw data. The environmental performance of Hungary and France regarding the energy consumption of agriculture without using a ratio or a relative indicator can not be compared. It is a choice that has to be made when compiling an indicator set. Since our main goal is the temporal comparison, we usually use raw data and ratio type indicators in our compilation. In the future research, this compilation of indicators is intended to be used as a starting point in developing composite indicators for the dimensions of sustainable agriculture. In the process of developing composite indicators, a normalization will be executed which makes the indicators spatially comparable.

The main data source was the database of Eurostat for the compilation of indicators. Our main goal was to compile comparable data for the EU Member States for the years 2000 to 2010 therefore national data sources were not used. When selecting indicators, the data availability was an important factor. The main problems can be summarized as follows:

- relevance,
- no data available,
- data availability for certain countries (e.g. environmental expenditure),
- only short time series,
- problems with data quality (e.g. waste generated in agriculture, 10-fold increase within 4 years for Hungary).

The indicators not included in the set of indicators are listed in Table 1.

Table 1. Indicators not selected in the initial set of indicators

Indicator	Reason for non inclusion
Environmental dimension	
Emission of carbon monoxide in agriculture	Not relevant for agriculture
Emission of particulates < 10µm in agriculture	Problems with data availability - only partial data for the EU Member States
Emission of particulates < 2.5µm in agriculture	Problems with data availability - only partial data for the EU Member States
Percentage of holdings with manure storage facilities	Data only available for 2000 and 2003
Generation of waste in agriculture	Data are not reliable e.g.10-fold increase within 4 years for Hungary
Land cover data on heavy environmental impact	Only 2009 data are available, not really relevant
Percentage of high nature value land	No available data
Percentage of NATURA 2000 areas of agricultural land	Partial data are available
Soil conservation	Only 2010 data are available
Tillage methods	Only 2010 data are available
Soil quality	No available data
Nitrate content of water	No available data
Pesticide content of water	No available data
Landscape	No available data
Genetic resource conservation	No available data
Erosion	Partial data are available
Environmental expenditure of agriculture	Partial data are available
Economic dimension	
Production of renewable energy	Only 2010 data are available
Volatility of agricultural prices	Methodology is not available
Production of inputs	Partial data are available
Ratio of land owned and rented	Not relevant
Social dimension	
Quantitative or qualitative information on rural infrastructure	No available data
Quality of houses and flats in rural areas	No available data
Volatility of food prices	Methodology is not available
Percentage of food products in total purchase	Partial data are available
Percentage of genetically modified products	Partial data are available

The result of the compilation of indicators is 26 indicators for the environmental dimension, 15 indicators for the economic dimension and 16 indicators for the social dimension.

Missing data were handled by trend function of Excel in case a clear trend could be observed and by repeating the last (or first) available data if data were volatile.

Environmental dimension

Environmental data can be grouped according to Pressures-State-Response framework developed by OECD. A wide range of data is available for the pressures that are harmful to the environment. These domains include energy consumption, emission of air pollutants, use of fertilizers and manure, sale of pesticides, irrigation and production patterns (livestock density, share of arable land). Much less data are available on the state of the environment (nutrient balances and bird index of farmland species). Concerning the responses, data only exist on the participation in agro-environmental schemes and on organic farming. The 26 indicators give a wide selection of information however some areas (waste generation, tillage, pollutant content of water and soil, landscape) could not be covered in the indicator set.

Environment statistics and other related areas of statistics (e.g. agro-environmental statistics) face various problems. Environment statistics is a relatively new area of statistics. The methodologies and important definitions are still under construction. This field of statistics has a low priority in most of the statistical institutions. It includes various areas (waste, water, air, forest, etc.) and it is very difficult to acquire the professional experience of these areas that sometimes differ completely from each other in terms of methodology. Part of the data related to environment statistics stem from measurements or monitoring systems instead of statistical surveys. Since it is usually not the statistical institution that performs such measurements, sometimes it is very difficult to gain this information and to use it in a coherent way with other information of environment statistics.

The factors that hamper the use of environmental data in the environmental policy process are as follows (Srebotnjak, 2007):

- environmental science is complex and uncertain,
- environmental issues often carry negative perceptions,
- constructive environmental debates are still hampered by ideological and emotional prejudices,
- the divide between environmental policy and science has contributed to persistent language barriers between environmental statisticians on one side and policy makers and subject-area scientists on the other.

In order to have a reliable picture in terms of sustainability, there is a need for the development of environment statistics. The international and national statistical institutions have to give priority to this area of statistics. The methodologies used in the different countries should be harmonized so that spatial comparisons could be done. Statistical institutions should try to reach an agreement with other data owners in order that important information on environment can be used by analysts and scientists.

Economic dimension

15 indicators cover the performance, gross value added and income generated by agriculture. Foreign trade, structure of the production, research and development and subsidies were also included in the indicator set. Prices were taken out from the set of indicators as it is not relevant for sustainability. The volatility of prices could be a possible sustainability issue; proper methodology should be developed for this indicator. Data were only partly available for the wealth of agricultural sector in terms of buildings, machinery and land prices.

Social dimension

Data were available and used in the system of indicators on farm managers with respect to their education, age and gender. Data were also applied on agricultural education and labour force used in agriculture. Rural development indicators on the ratio of rural population over 65 years, on changes in population and on unemployment rate were selected as well. Additional data from income statistics concerning thinly populated areas were included in the system. Data were not available for infrastructural supply and its quality and on food safety and security. In social statistics, the main problem is that usually information can not be used for reflecting to the issues of farmers and rural areas. Some indicators could only be created using data of the thinly populated areas which have an overlap with rural areas but are not the same.

Examination of indicators

In order for the association of indicators to be measured, correlation matrices of Hungarian data were created separately for the three dimensions using the time series from 2000 to 2010. The objective of the analysis was to select those indicators that had a strong correlation with each other therefore they would not bring significant additional information to the system of indicators. For this purpose, the correlation matrices were analyzed and those indicators were selected whose correlation value is larger than 0.9 (or less than -0.9). In future research we plan to repeat this exercise with the data of other Member States so that a properly selected indicator set would be available.

Three indicators were taken out from the environmental dimension as a result of the analysis (Table 2.):

- Emission of sulphur oxides in agriculture (strong correlation with 5 indicators)
- Irrigable area in percentage of utilized agricultural area (strong correlation with 6 indicators)
- Livestock density (livestock units/utilized agricultural area) (strong correlation with 6 indicators)

Table 2. Indicators of sustainable agriculture for Hungary – environmental dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
EN1	Final energy consumption of agriculture	1000 tonnes of oil equivalent	Y	501	530	444	491
EN2	Emission of greenhouse gases in agriculture	1000 tonnes of CO_2 equivalent	Y	9237	9113	8578	8531
EN3	Emission of ammonia in agriculture	Tonnes	Y	68457	66915	66032	63656
EN4	Emission of sulphur oxides in agriculture	Tonnes	N	437	924	771	790
EN5	Emission of nitrogen oxides in agriculture	Tonnes	Y	2206	2385	2104	2122
EN6	Emission of non-methane volatile organic compounds in agriculture	Tonnes	Y	75	445	437	443
EN7	Emission of methane in agriculture	1000 tonnes	Y	194	194	194	185
EN8	Emission of nitrous oxide in agriculture	Tonnes	Y	16 715	15 949	15 258	15 547
EN9	Use of inorganic fertilizers - nitrogen	kg/ha	Y	76	67	61	60
EN10	Use of inorganic fertilizers - phosphorus	kg/ha	Y	9	6	4	4
EN11	Nitrogen balance per hectare of UAA	kg/ha	Y	35	-24	-4	9
EN12	Phosphorus balance per hectare of UAA	kg/ha	Y	-6	-20	-17	-16
EN13	Use of manure per hectare of UAA	kg/ha	Y	27	24	24	23
EN14	Sales of pesticides	tonnes of active ingredients	Y	11178	12084	11103	9911
EN15	Irrigable area in percentage of UAA	%	N	3.3	2.3	1.9	1.5
EN16	Water use of agriculture per UAA	M^3/ha	Y	71	63	59	55
EN17	Biomass production of agriculture	1000 tonnes	Y	29773	43361	36784	33094
EN18	Ratio of low input farms	%	Y	62	62	62	62
EN19	Share of mixed crops-livestock farms	%	Y	15	15	15	15
EN20	Share of not utilised area in the agricultural area	%	Y	10	12	13	15
EN21	Share of arable land in UAA	%	Y	84	83	82	81
EN22	Livestock density (livestock units/UAA)	livestock units / ha	N	0.6	0.5	0.5	0.5
EN23	Grazing rate (livestock units / fodder area)	livestock units / ha	Y	1.0	0.9	0.9	0.9
EN24	Bird index of farmland species	2000=100	Y	99	105	88	91
EN25	Share of UAA under agro-environmental measures	%	Y	27	27	19	21
EN26	Share of organic farming in percentage of UAA	%	Y	1.7	1.4	1.1	0.8

UAA: utilized agricultural area; source: Eurostat (2013b), own estimation

In the economic dimension two indicators were selected to be taken out (Table 3.):

- Agricultural income – indicator "A" (strong correlation with 2 indicators)
- Entrepreneurial income/utilized agricultural area (strong correlation with 2 indicators)

Table 3. Indicators of sustainable agriculture for Hungary – economic dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
EC1	Output per intermediate consumption in agriculture		Y	1.3	1.7	1.6	1.5
EC2	Gross value added	million Euro, constant prices (2005=100)	Y	1478	2677	2051	1601
EC3	Gross fixed capital formation	million Euro, constant prices (2005=100)	Y	643	689	820	619
EC4	Exports of agricultural products	million Euro	Y	3462	3850	3476	4058
EC5	Foreign trade balance of agricultural products	million Euro	Y	900	1185	709	975
EC6	Agricultural income (Indicator "A")	2005=100	N	116	153	104	122
EC7	Crop output / animal output		Y	1.2	1.8	1.6	1.4
EC8	Factor income	million Euro, at current basic price	Y	2267	2944	1912	2337
EC9	Output of non agricultural activities	million Euro, constant prices (2005=100)	Y	175	149	125	111
EC10	Number of holdings with other gainful activities	number of holdings	Y	31830	36925	42020	47270
EC11	Research and development in agriculture	million Euro	Y	10	10	11	13
EC12	Subsidies in percentage of entrepreneurial income	%	Y	93	83	143	112
EC13	Total area under 20 ha / total area over 100 ha		Y	0.2	0.2	0.2	0.2
EC14	GDP of the rural territories	Euro per capita	Y	7246	7720	6511	6605
EC15	Entrepreneurial income / UAA	Euro per ha	N	281	421	195	280

UAA: utilized agricultural area; source: Eurostat (2013b), own estimation

Two indicators proved to be needless in the social dimension (Table 4.):

- Share of standard output of farm managers over 65 years (strong correlation with 2 indicators)
- Severe material deprivation rate in the thinly populated areas (strong correlation with 2 indicators)

Table 4. Indicators of sustainable agriculture for Hungary – social dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
SO1	Share of farm managers with full agricultural training	%	Y	56	51	46	42
SO2	Share of standard output of farm managers over 65 years	%	N	7	8	8	9
SO3	Share of standard output of farm managers under 35 years	%	Y	4	4	4	4
SO4	Share of standard output of female farm managers	%	Y	6	7	8	9
SO5	Labour force in agriculture	1000 annual working units	Y	459	430	442	440
SO6	Share of graduates in agriculture and veterinary field as % of all fields	%	Y	2.6	2.0	2.0	2.4
SO7	Ratio of rural population over 65 years	%	Y	16	16	16	17
SO8	Rate of natural change of rural population	%	Y	-3.9	-3.9	-4.4	-5.1

SO9	Rate of net migration of rural population	%	Y	-2.5	-2.5	-1.9	-2.1
SO10	Share of households with risk of poverty or social exclusion in the thinly populated areas	%	Y	34	32	33	35
SO11	Share of households with very low working intensity in the thinly populated areas	%	Y	14	15	15	15
SO12	Share of households below 60 % of the median equalised income in the thinly populated areas	%	Y	8	8	8	9
SO13	Share of households with housing cost overburden in the thinly populated areas	%	Y	11	11	9	11
SO14	Severe material deprivation rate in the thinly populated areas	%	N	22	19	21	23
SO15	Severe housing deprivation rate in the thinly populated areas	%	Y	14	22	12	19
SO16	Rate of unemployment in the thinly populated areas	%	Y	9	10	12	13

Source: Eurostat (2013b), own estimation

For the rest of the indicators the correlation is acceptable. The indictors to be taken out are unnecessary or have an overlap with other indicators. For example in case of the economic dimension, the content of the two indicators to be taken out is similar to the remaining indicator “Factor income”.

Conclusions

In our research it was proven that it is possible to set up an indicator system of sustainable agriculture using data available for the EU Member States. Although there is considerable lack of available information and also there is a need for imputation of the missing figures, the database that was compiled seems to be appropriate for developing a composite indicator of the three dimensions of sustainable agriculture. The analysis of correlation proved to be a proper method of taking out redundant indicators.

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