CHEMICAL ENGINEERING TRANSACTIONS

VOL. 107, 2023

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Petar S. Varbanov, Bohong Wang, Petro Kapustenko

ISBN 979-12-81206-07-6; **ISSN** 2283-9216

DOI: 10.3303/CET23107069

Environmental Assessment of Farm Sustainability – A Hungarian Case Study

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Agricultural production is inseparable from environmental sustainability, and several methods have been developed by numerous authors and organizations worldwide to measure and evaluate it. The aim of the study is to comprehensively and accurately assess the environmental sustainability of farms. Concerning the theoretical framework, a set of 8 indicators and 23 sub-indicators was established to estimate the different aspects of environmental sustainability. The practical compliance of the indicators was assessed based on data from Hungarian agricultural enterprises; an agricultural company and three individual farmers were included in the case studies. By grouping the indicators, a new composite environmental indicator was developed to measure environmental sustainability. The results of the study show that the surveyed farms are moderately sustainable, as their composite indicators were at or close to the minimum of 0.5 points, but none of them were outstanding or at least 0.75 points. More significant efforts should be made to improve the farms' environmental sustainability in the future.

1. Introduction

Agricultural production is inseparable from sustainability, as shown by the fact that it is directly linked to 12 out of the 17 UN Sustainable Development Goals (United Nations, 2015). Several methods were developed worldwide to estimate and evaluate the sustainability of agriculture. Due to the complexity of agriculture, these evaluation methods should be simple, cheap and holistic (Talukder et al., 2017). The widely used assessment methods are indicator-based, applicable at various levels, e.g., national level (FAO, 2012), regional level (Abdar et al., 2022). However, as the farm is considered to be the main management unit of the agricultural system (Payraudeau and Werf, 2005), most of the indicators in the literature are also developed at the farm level. Farm models allow relatively quick and cost-effective sustainability assessments once they become operational, although they are often labour-intensive and costly to develop (van der Linden et al., 2020). Most studies on farm models have been carried out in Western European countries, with only a few studies performed in Northern and Eastern European countries (Reidsma et al., 2018). However, of the countries with significant agricultural production, the countries of Central and Eastern Europe and Southern Europe, including Greece, Romania and Hungary, typically have the largest share of agriculture in gross value added production, above 4% (Biró and Toldi, 2022). As of 2022 crop production contributed to the performance of Hungarian agriculture by 57% and livestock production by 37% (Hungarian Central Statistics Office, 2023). Regarding the main activities, two-thirds of farms were mainly engaged in crop production in 2020, while the share of mixed farms and livestock production declined (Biró and Toldi, 2022). This study attempts to evaluate the environmental sustainability of Hungarian agricultural enterprises. The farm level assessment tool presented in the study addresses the shortcomings of indicators found in the literature. Since the assessment tool was not designed for a specific agricultural system, therefore it can be applied generally in the sector. The data required for the model can be easily provided by the farmers. A composite index was established based on 23 sub-indicators which are easily estimated by the farmer in order to determine the level of sustainability of the assessed farms.

Paper Received: 16 April 2023; Revised: 14 July 2023; Accepted: 24 October 2023
Please cite this article as: Koltai J.P., Gombkötő N., 2023, Environmental assessment of farm sustainability – A Hungarian case study, Chemical Engineering Transactions, 107, 409-414 DOI:10.3303/CET23107069

2. Methods

For conducting the primary research, structured interview was considered to be the appropriate data collection method. The list of questions was compiled based on a comprehensive literature review, then the interview script was finalized after pre-testing it with two specialists (agricultural consultants). The structured interviews consisting of 26 open questions were held face-to-face in Hungarian language. Interview data were collected between June and July 2023, and were transcribed in Hungarian then translated to English to analyze them. Indicators can be developed with the broad involvement of experts and stakeholders (bottom up), from top to bottom (top down) or a combination of the previous two. Some authors consider only the bottom up solution to be a good solution (e.g., Mullender et al., 2020), while others suggest that a combination of the previous ones may prove to be a valuable alternative (e.g., Bonisoli et al., 2018). In this study, a combined approach was preferred, i.e., the indicators developed based on professional considerations were agreed to by experts before examining the sustainability of the farms. An indicator can be determined as an observed or measured variable that reflects the state of a system (Mayer, 2008). Individual indicators are used to measure the performance of specific items. The set of individual indicators is essentially a simple aggregation of individual indicators that measure various aspects of sustainability (Abdul Murad et al., 2019). A set of indicators was compiled that was suitable for realistically estimating the sustainability of a given farm from an environmental point of view. Deciding on the number of indicators is a very difficult task, as having too few indicators risks not or not properly identifying the underlying phenomenon, while having too many indicators can lead to distorted results. The list of indicators and their sub-indicators, as well as the definition of the sub-indicators are included in Table 1. Regarding binary variables (such as yes/no questions e.g., Is the cultivated area fragmented? Is the yearly precipitation evenly distributed?) nominal scales were applied. Ordinal scales were used when the respondents were asked to provide data about the quality of a variable from low to high using five levels (e.g., How would you describe the level of manure management at the farm from none to advanced?) Ratio scales were applied in cases, where a true zero can be interpreted regarding quantitative variables (e.g., What is the ratio of manure utilization in the nutrient replenishment applied at your farm?). Besides scales, the scores of the variables were also listed in Table 1 indicating its lowest and highest value. Creating composite indicators by grouping indicators together makes the interpretation easier without dropping the underlying information base (OECD, 2008). From a decision-making point of view, composite indicators are extremely useful because they allow for quick understanding by aggregating and simplifying information from multiple perspectives (Abdul Murad et al., 2019). Therefore, constructing a composite index can help to understand the complicated concept of agricultural sustainability (Abdar et al., 2022). Building composite indicators requires normalization and weighting of individual indicators. Normalization involves calculating the magnitude of the indicator results relative to some reference information (Roesch et al., 2021). Linking an indicator to a reference value is important, because the difference between the indicator raw value and the reference value is more informative than the raw value alone (Soulé et al, 2021). Reference values (optimal values) were determined by experts (authors themselves, via participatory approach, based on relevant scientific data) in the present study (Table 1), and indicator values were expressed in relation to them. Weightings are often based on value choices (Roesch et al., 2021). In the present study a linear aggregation was applied by combining the 23 sub-indicators (location, terrain, average temperature of growing season, distribution of precipitation, extreme weather conditions, type of soil, soil consistency, soil humus content, risk of water erosion, risk of wind erosion, winter soil cover, harmony of crops with the climate, crop rotation, proportion of legumes, green waste and/or stem residue management, manure usage, areas under nature conservation, shelter-belts and other native plant communities, livestock, husbandry technology, methane emissions, manure management, permanent grassland) to 8 indications (land, climate, soil, erosion, cultivation, green waste and manure management, nature conservation, livestock) as it is considered the most commonly used in composite indicators (Greco et al., 2019). The 23 sub-indicators used in the analysis were converted to a common rating scale (0-1 points), taking into account the inverse scales (e.g., location), due to the different measurement ranges (Table 1.) Finally, these indicators were aggregated into a composite environmental indicator, which ranges from 0 to 1, with the following thresholds implemented: under 0.50 the farm is considered not sustainable, 0.50-0.74 for moderately sustainable, 0.75-1.00 for sustainable.

3. Results

3.1 Environmental sustainability indicators

The first two of the eight indicators are external factors, mainly geographic and climatic conditions, over which the farmer has little or no control. Nevertheless, they are important indicators for environmental sustainability as they have a fundamental influence on the whole production process. An important consideration in the spatial arrangement of the cultivated land is that the parcels should be located as close to each other as possible and, from a topographical point of view, be as flat as possible. This is essential from an environmental point of view in order to reduce fuel emissions during production and to avoid nutrient leaching.

Table 1: List of environmental sustainability indicators

Indicator	Sub-indicator	Definition	Scale	Scores	Optimal Value
1. Land	location	The cultivated area is fragmented.	nominal	0 (no) – 1 (yes)	0
	terrain	The ratio of flat terrain within the cultivated area.	ratio	0-100%	100%
2. Climate	average temperature of growing season	The temperature of the growing season is between 10–30 °C.	nominal	0 (no) – 1 (yes)	1
	distribution of precipitation	The yearly precipitation is evenly distributed.	nominal	0 (no) – 1 (yes)	1
	extreme weather conditions	Ratio of years without extreme weather conditions.	ratio	0-100%	100%
3. Soil	type of soil	Proportion of soil types suitable for agricultural production.	ratio	0-100%	100%
	soil consistency	Intensity of applied agricultural technology.	ordinal	0 (overcultivated) – 5 (no tillage)	5
	soil humus content	The weight percentage of humus content reaches 2% in the soil.	nominal	0 (no) – 1 (yes)	1
4. Erosion	risk of water erosion	Ratio of cultivated area not affected by the risk of water erosion.	ratio	0-100%	100%
	risk of wind erosion	Ratio of cultivated area not affected by the risk of wind erosion.	ratio	0-100%	100%
	winter soil cover	Winter soil cover reaches 30%.	nominal	0 (no) – 1 (yes)	1
5. Cultivation	harmony of crops with the climate	Ratio of cultivated crops suitable for the climate.	ratio	0-100%	100%
	crop rotation	Number of crops in the crop rotation.	ordinal	0 (no crops) - 5 (5 or more crops)	5
	proportion of legumes	Ratio of legumes in crop structure.	ratio	0-100%	100%
6. Green waste and manure management	green waste and/or stem residue management	Ratio of composted green waste and/or stem residue recycling.	ratio	0-100%	100%
	manure usage	Ratio of manure utilization in nutrient replenishment.	ratio	0-100%	100%
7. Nature conservation	areas under nature conservation	Ratio of areas under nature conservation to the cultivated area.	ratio	0-100%	100%
	shelter-belts and other native plant communities	Ratio of shelter-belts and other native plant communities to the cultivated area.	ratio	0-100%	100%
8. Livestock	livestock	Animal husbandry is performed at the farm.	nominal	0 (no) – 1 (yes)	0
	husbandry technology	The type of husbandry technology applied at the farm.	ordinal	0 (intensive)-5 (extensive)	5
	methane emissions	Methane emission per year compared to the national average.	ratio	0-100%	0%
	manure management	The level of manure management at the farm.	ordinal	0 (none)-5 (advanced)	5
	permanent grassland	Ratio of permanent grassland.	ratio	0-100%	100%

Climate is made up of several factors, but the most characteristic and easiest to measure are temperature, precipitation, and wind. Regarding temperature, Grigorieva et al. (2010) found that a temperature of 10–30 °C is required for growth of crops during the growing season (from February to November). In the case of precipitation, its distribution within a year was examined, as this is the most important indicator in agriculture. Regarding wind, the wind speed and the number of windy days are usually measured. However, wind is also considered in the case of erosion, which is more relevant to the sustainability of farming, so it was removed from the climate elements to ensure non-overlap between indicators. Additionally, to precipitation and temperature, the examination of the extent of extreme weather in the area was considered.

The next two indicators, soil fertility and exposure to erosion, are also external factors, but they are within the farmer's control and can be influenced by good management practises. Soil suitability can be characterised by a number of indicators (physical, chemical, biological), but to ensure unbiasedness, the three most relevant and easily measurable ones have been included in the model. The farmer has no influence on soil type, a small influence on soil humus content and a large influence on soil compaction. In the latter case, soil compaction from overcultivation should clearly be avoided. Consistency indicators are used to characterize the sensitivity of soils to compaction forces, of which several are available. These indicators provide relatively reliable values on the consistency of the soil in a given area, but are difficult to measure and no national database is available.

Erosion is not only responsible for changing the structure of soils, but also for nutrient leaching. Moreover, when nutrients have to be replenished with fertilisers and chemicals, synthetic substances are introduced into the ecosystem. Erosion can be significantly reduced by appropriate species selection and ground cover.

Environmental impacts related to cultivation are a farmer's responsibility, as crops cultivated in a given area should be in harmony with the crops, which can be cultivated there to ensure sustainable farming. Hence, it is important to choose the right plant species that can be grown safely in the given climate zone. A wide range of agricultural, soil, crop production, plant health, and nutrient management advantages are covered with crop rotation as it prevents the proliferation of pests, pathogens and weeds, and maintains the nutrient utilization and physical condition of the soil. Thus, the quantity and quality of the crop can be improved by applying a synthetic agent. In addition, the variety of plants also contributes to biodiversity. It is expedient to simplify the assessment of crop rotation applied in a given area regarding its complexity as a system. The principles of set-aside should also be considered. Temporary set-aside is a good practice in many countries of the European Union and is now a mandatory element of soil management.

Legumes contribute significantly to environmental sustainability due to several positive attributes (e.g., biological nitrogen fixation, increasing soil fertility, positive carbon balance due to organic matter residues, improving soil water holding capacity, and providing biodiversity), and therefore their inclusion in the cropping structure increases the environmental sustainability of a farm.

Recycling organic materials as part of the circular economy contributes significantly to environmental sustainability. In agriculture, two of these organic materials are highly recyclable, one is green waste and residues, and the other is manure. Of course, their professional use is essential. Another important aspect is the contribution to the conservation objectives. Within this, the proportion of nature conservation areas, as well as the presence of shelter belts and other natural plant communities were considered.

The last group of sustainability indicators consists of issues related to animal husbandry, as livestock farming is considered to be a major contributor to greenhouse gas emissions. Therefore, the first thing to examine is whether the farm keeps animals at all, and if so, what kind of husbandry and feed technology, as well as manure management is applied, and regarding methane emissions, what species of animals are kept on the farm. All of these have a significant impact on the environmental impact of livestock farming.

3.2 Case studies

An agricultural company and three individual farmers were included in the survey. Individual farmers were selected based on the Eurostat classification, so a crop specialist, a livestock specialist and a mixed farm were examined. Each farm is located in the North Transdanubian region of Hungary. The livestock farm is engaged in organic farming, which will be referred back to several times during the evaluation of the results. In terms of the assessment of environmental sustainability, all of the surveyed farms achieved or came close to the desirable minimum score of 0.5, so they are considered to be basically environmentally sustainable, but none of them scored exceptionally well or at least 0.75, so further efforts should be made to improve their sustainability in the long term (Table 2).

Indicators contribute to the overall sustainability score to an extremely different extent, thus farms perform exceptionally well on some indicators, while on others they are lagging behind with significant gaps. Therefore, in order to increase their sustainability, it is sufficient for farms to focus primarily on the poorer performing indicators. In terms of the first indicator (land), the crop specialist, livestock specialist and mixed farm scored higher, while the agricultural company lagged significantly behind. The poorer result for agricultural company is due to the fact that, on the one hand, the cultivated area is highly fragmented, the parts are separated by a large area, and, on the other hand, all the land is located on hills. Both of these conditions significantly increase the fuel consumption of the machinery used in the cultivation process, which is detrimental to environmental sustainability. While for the other three farms these are either not characteristic or only to a small extent. In terms of climate, all four surveyed farms scored poorer, as they reported very extreme weather over the last 5 years (2018-2022), which was not the case in previous years but is now becoming more frequent.

Table 2: Environmental sustainability indicators for the agricultural enterprises

Indicators	Agricultural company	Crop specialist farm	Livestock specialist farm	Mixed (plant and livestock) farm
Land	0.10	0.70	0.90	1.00
Climate	0.33	0.53	0.53	0.40
Soil	0.80	0.87	0.83	0.67
Erosion	0.70	0.83	0.97	0.75
Cultivation	0.67	0.73	0.40	0.83
Green waste and manure management	0.50	0.25	0.50	0.15
Nature conservation	0.05	0.20	0.05	0.05
Livestock	1.00	1.00	0.33	0.64
Composite Environmental Indicator	0.52	0.64	0.62	0.47

These extreme weather conditions (e.g., drought, hail, heavy rainfall) pose a significant risk to crop safety. However, this is a factor that is beyond the control of farms. On the contrary, the soil conditions in all the farms surveyed were favourable, one of the reasons being that the examined region has high-quality soil (e.g., chernozem, meadow soil) with a high humus content. The lower values are caused by excessive soil compaction from over-cultivation. Farms could improve this by reducing and rationalising tillage, therefore, it is advisable to optimise tillage in the long term (Zhao et al., 2022). Exposure to erosion also tends to occur only slightly in the case of the company, due to the exposure of sloping areas to water erosion. Winter ground cover is well managed on all farms. It can be said that the overall geographical, topographical, climatic and soil conditions, which are beyond the farms' control, are suitable for agricultural activity. Cultivation practices show a very varied picture. The lower scores are mainly due to the lack of legumes, as their proportion within the crop structure does not reach 30% on any farm. The lowest score was achieved by the livestock specialist farm, where, in addition to the low proportion of legumes, the lack of crop rotation could be an additional problem. However, the latter is not expected for extensive livestock farming, so this score may be slightly biased. Farms should focus more on increasing the proportion of legumes in the future. The two most problematic areas are the management of green waste and manure, and also the issue of nature sensitive areas should be taken into consideration. Green waste is fully managed by the company and livestock specialist farms, while the crop specialist and mixed farms manage it to a moderate extent. However, the use of manure is not common on any of the farms, according to them they have little or no access to it. But in the future they should definitely increase the proportion of manure in their nutrient supply. However, for the livestock farm it is not relevant due to the permanent grassland. In the future, it would be advisable for farmers to increase the proportion of legumes in the crop structure and to preserve natural plant communities. The livestock issue is obviously only relevant for the livestock specialist farm and the mixed farm, but the other two farms contribute significantly to environmental protection due to the lack of livestock and therefore score maximum points in this respect. The result of the mixed farm was lower due to cattle husbandry, and therefore, methane emissions, as well as the fact that it does not have natural grassland that could be used to keep cattle extensively.

4. Conclusions

The survey of agricultural enterprises in Hungary showed that the indicators defined in the research are a realistic measure of the environmental sustainability of a farm, as the results were clearly established for each type of enterprise (company, crop specialist, livestock specialist, mixed farm). In addition, the indicators developed in the study are supported by expert evidence, and the sub-indicators within them form a coherent whole, so that the indicators are appropriate for highlighting those factors that are stronger or weaker for a company within the framework of environmental sustainability. As the sub-indicators within the indicators are interlinked, the model offers a consistent and ready-made solution to the farmer in case of a weaker category result. The results show that for Hungarian agribusinesses, indicators beyond their control have a significant impact on farming performance; while they have a poorer performance for climate-related indicators, probably due to climate change conditions, on the contrary, their soil conditions are excellent. For the latter, a risk of over-cultivation could emerge, which can be rationalised by agricultural enterprises. Farms in Hungary perform poorly with the inclusion of legumes in the crop rotation and the use of manure. However, the latter is due to the difficulty of access, due to the decreasing number of livestock specialist in Hungary. It is favourable that farms are good at managing green waste. The limitation of the model could be represented by the extensive, grazing livestock farms, as several indicators (e.g., legumes, manure management) could score lower, despite the fact

that these factors are not reasonable for these farms, therefore, the use of some indicators should be reconsidered. Overall, the composite environmental indicator at all surveyed farms was close to the minimum score of 0.5, so they are considered to be basically environmentally sustainable, but none of the farms scored at least 0.75, so further efforts should be made to improve their sustainability in the long term.
The composite environmental indicator can be considered an adequate tool for stakeholders to assess sustainability, as the required data is easily accessible, measurable and interpretable. Since present study only addressed the environmental aspect of sustainability, further research should be carried out focusing on the economic and social features of agriculture as well as their intersections.

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