Beata FELEDYN-SZEWCZYK, Jerzy KOPIŃSKI
Institute of Soil Science and Plant Cultivation – State Research Institute
Department of Systems and Economics of Crop Production
ul. Czartoryskich 8, 24-100 Puławy, Poland
e-mail: bszewczyk@iung.pulawy.pl

THE COMPARISON OF SUSTAINABILITY OF AGRICULTURAL PRODUCTION OF ORGANIC AND CONVENTIONAL FARMS USING THE RISE MODEL

Summary

*The results of the evaluation of the sustainability of agricultural production in two selected farms: organic and conventional, using RISE model, were presented in the paper. The RISE model (the **R**esponse-**I**nducing **S**ustainability **E**valuation) is a tool (computer program) for easy and holistic assessment of agricultural production sustainability at a farm level in ecological, economic, and social aspects and enables the initiation of measures to improve the sustainability. The analysis showed that only the organic farm was sustainable in accordance with the RISE methodology, as it attained positive values of all the 12 indicators which were used in the analysis. The conventional farm had problems with managing fertilizers and maintaining biodiversity. The values of the indicators of "Nitrogen and phosphorus emission potential" and „Biodiversity" were negative, which did not allow for considering them sustainable. The RISE model can be a useful tool for the assessment and comparison of the degree of sustainability of different types of farms.*
***Key words**: sustainability indicators, RISE model, organic farm, conventional farm*

PORÓWNANIE ZRÓWNOWAŻENIA PRODUCKJI ROLNEJ W GOSPODARSTWIE EKOLOGICZNYM I KONWENCJONALNYM Z WYKORZYSTANIEM MODELU RISE

Streszczenie

*W pracy przedstawiono wyniki oceny stopnia zrównoważenia produkcji rolniczej w dwóch wybranych gospodarstwach: ekologicznym i konwencjonalnym, z wykorzystaniem modelu RISE. Model RISE (the **R**esponse-**I**nducing **S**ustainability **E**valuation) jest narzędziem (programem komputerowym) umożliwiającym przeprowadzenie prostej, a zarazem całościowej oceny stopnia zrównoważenia produkcji rolnej na poziomie gospodarstwa w aspekcie ekologicznym, ekonomicznym i społecznym oraz daje możliwość zaproponowania działań poprawiających sytuację. Przeprowadzona analiza wykazała, że tylko gospodarstwo ekologiczne było zrównoważone zgodnie z metodyką RISE, ponieważ osiągało pozytywne wartości wszystkich 12 wskaźników uwzględnianych w analizie. Testowane gospodarstwo konwencjonalne wykazywało problemy z gospodarką nawozową oraz dbałością o bioróżnorodność. Wartości wskaźników „Potencjał emisyjny azotu i fosforu" oraz „Bioróżnorodność" były ujemne, co wskazuje na brak zrównoważenia gospodarstwa. Model RISE może być przydatnym narzędziem do oceny i porównywania stopnia zrównoważenia różnych typów gospodarstw.*
***Słowa kluczowe**: wskaźniki zrównoważenia, model RISE, gospodarstwo ekologiczne, gospodarstwo konwencjonalne*

1. Introduction

A sustainable agricultural production is understood as a simultaneous realization of production, economic, ecological, and social objectives [10]. Depending on the degree of sustainability assessment (global, national, region, voivodeship, farm) different methods are used [7, 17, 18]. The review of the literature has shown that there are few methods which allow for a broad assessment of the sustainable development at a farm level, and what is more, some of these methods cover only selected aspects of sustainability [1, 11, 12, 13, 19]. One of the tool for easy and holistic assessment of agricultural production sustainability on farm level is RISE model (the **R**esponse-**I**nducing **S**ustainability **E**valuation) [3, 8, 9]. This computer program is a tool which not only aims at diagnosis, but also at the initiation of measures to improve sustainability of agricultural production and optimization of agricultural practices. It has been successfully tested on very different farm types under variable conditions in Brazil, China, Switzerland, India, Canada and other [8, 9]. In Poland, the RISE model was used to evaluate the degree of sustainability of a pilot group of farms in the Lubelskie voivodeship [5, 6].

The aim of the studies was to evaluate and compare the degree of sustainability of two types of farms: organic and conventional ones, using the RISE model. The studies were constructed in the form of case studies.

2. Material and methods

The RISE model (the Response-Inducing Sustainability Evaluation) is a tool (computer program) for holistic evaluation of agricultural production sustainability at a farm level [8]. It is based on the DSR framework (Driving Force-State-Response), developed by OECD for environmental indicators [18]. The model covers ecological, economical, and social aspects by defining 12 indicators for Energy, Water, Soil, Biodiversity, N&P Emission Potential, Plant Protection, Waste, Economic Stability, Economic Efficiency, Local Economy, Working Conditions, and Social Security. For each indicator a "State" (S) and a "Driving force" (D) are determined from more than 60 parameters [4, 8, 9]. The Degree of Sustainability (DS) is calculated as difference (DS=S-D) and yields values between -100 and +100 [8]. The output of the RISE model is designed in a way that a farmer can easily determine where problems ex-

ist and what interventions might lead to improvements. Individual indicators are considered sustainable if the degree of sustainability is above +10, the whole farm is considered sustainable if no indicator has a degree of sustainability below -10. The most optimal situation is when DS values of all the indicators are arranged regularly in an optimum area.

The research included two types of farms: organic, and conventional with a mixed type of production (plants and animals). The interviews with farmers were performed using a special comprehensive RISE questionnaire. The data of the 2011 year were collected.

3. Results and discussion

3.1. Characteristics of the studied farms

The characteristics of the analysed farms were presented in Table 1. The farms differed with the size, intensity of farming and type of agricultural production. In a certified organic farm with 27.0 hectares of agricultural land, 10.3 hectares were taken by meadows and pastures which were covered by *Agri-environment program 2007-2013* "Extensive permanent grassland" package. In addition, permanent crops (hazelnut, and apple orchard) occupied 1 hectare of the area. Apart from crop production, the farm ran cattle rearing and fish breeding. The farm sold fish, cereals, fruits, beef, and potatoes. However, the farmer obtained a price premium for organic quality of products only for the sales of fish and potatoes. Agritourism constituted a significant part of the farm income. A part of crops was used for the needs of the farmer' family and tourists.

In accordance with the principles of organic farming, the farm used only natural fertilizers which were produced on the farm. Catch crops were ploughed to be used as "green manure" (constituting 60% surface coverage of arable land in the autumn and winter). Weeds were removed mechanically. On the farm area, there were numerous trees and bushes which could serve as biodiversity refuges, such as: hedgerows, mature linden trees, reedbeds, peatbog, meadows and pastures with orchids of high biodiversity, a pond with a buffer zone overgrown with plants (Fig. 1).

The analyzed conventional farm conducted an intensive plant production, using large amounts of mineral fertilizers and chemical plant protection products. It had a higher percentage of arable land per agricultural land area and a higher percentage of cereals and commercial crops than the ecological farm as presented in Table 1. The main crops were: spring barley, winter wheat, triticale, rape, and sugar beet (Fig. 2).

Tab. 1. The main characteristics of tested farms
Tab. 1. Najważniejsze charakterystyki testowanych gospodarstw

Profile of production	Organic farm mixed	Conventional farm mixed
Agricultural lands (AL) (ha):	27.0	34.9
arable lands (ha)	10.4 (39%)	34.0
grasslands (ha)	15.6 (58%)	0.9
permanent crops(ha)	1.0 (3%)	-
Cropping patern (%):		
cereals	46.2	68.2
industrial crops (sugar beet, rape)	-	24.4
mixture of cereals and legumes	29.8	-
mixture of legumes and grass	15.4	-
fodder crops on arable lands	-	7.1
remaining crops	8.6	0.3
Livestock load (LU·ha^{-1} AL)	0.3	0.4
N balance (kg·ha^{-1}AL)	-5	41
P balance (kg·ha^{-1}AL)	-2	38
Plant protection products (kg/l a.s.·ha^{-1})	0	1.05
Employment (full-employment person due to RISE method · ha^{-1})	0,05 (employed)	0,05 (self-employed)
Gross margin (thous. PLN)	96.7	95.7
Net profit of farm (thous. PLN)	44.3	49.2
The share of direct and agri-environment payments in gross margin	53	15

* according to RISE methodology (self-employed = 3000 h·yr^{-1}, employment = 2304 h·yr^{-1})

Source: *own work/ źródło: opracowanie własne*

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Fig. 1. Organic farm: on the left – pond with buffer zone, on the right – other biodiversity refuges on farm
Rys. 1. Gospodarstwo ekologiczne: po lewej – staw ze strefą buforową, po prawej – inne ostoje bioróżnorodności

Source: *own work/ źródło: opracowanie własne*

Fig. 2. Conventional farm: on the left – winter rape and sugar beet, on the right – silo for cereal grains
Rys. 2. Gospodarstwo konwencjonalne: po lewej – uprawa rzepaku i buraka cukrowego, po prawej – silosy zbożowe

3.2. The assessment of the degree of sustainability of an ecological farm

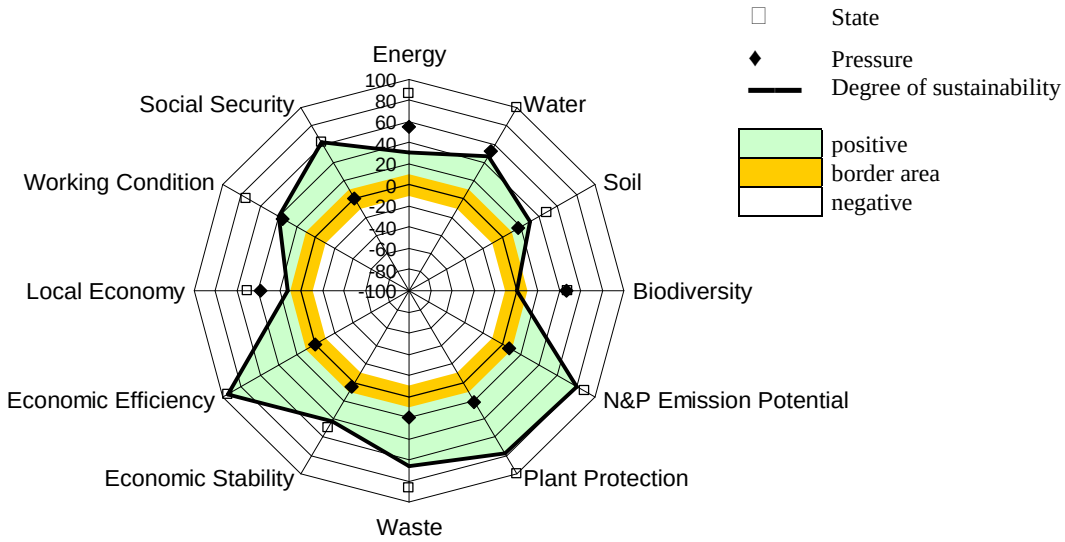
The assessment of the degree of sustainability of an organic farm using the RISE methodology is shown in Fig. 1. All of the 12 indicators constituting the assessment of the degree of sustainability of this farm had positive values, so the farm could be considered sustainable.

The tested farm attached great importance to the protection of biodiversity, preserving a number of natural grassland and plant refuges. Natural values and the system of organic farming itself affected a positive value of "Biodiversity" indicator. The positive assessment could be also attributed to using a mechanical method of weed regulation and not applying chemical plant protection preparations. Literature data confirm a positive impact of organic agricultural production on biodiversity of flora and fauna [2, 16]. On the other hand, biodiversity is negatively affected by an intensive use of agricultural land, and the use of a ploughing tillage instead of conservation tillage.

Nitrogen and phosphorus balances were evaluated positively from the environmental point of view. The farm did not present a risk of polluting waters and soils with these nutrients, but at the same time, the applied natural fertilizers and ploughed crops did not satisfy the requirements of plants for nutrients (N input/output = 0.85). Moreover, the farm sold cereal straw. A total N and P balance per 1 ha of the fertilized agricultural land amounted to -7 kg/ha AL. The deficits were not large and they were possible to adjust. Organic farms experience nutrient deficits quite frequently, which causes the need for periodical controls of soil abundance in nutrients and soil pH [14]. The farms of this type require a proper nutrient management through the incorporation of legumes to crop rotations, the use of catch crops for green fodder, and the application of natural and organic fertilizers, and minerals [15].

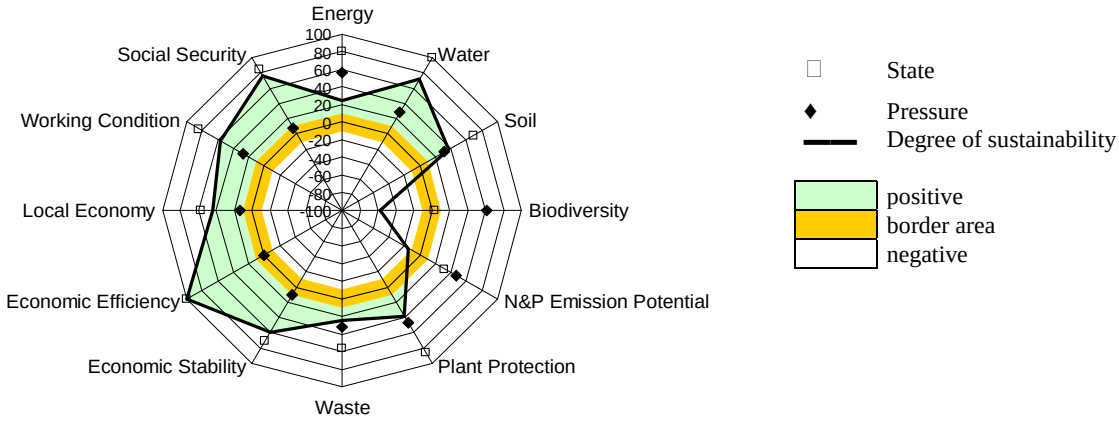
The RISE model positively assessed the farm in terms of the management of energy, water and waste. It achieved a high value of "Plant protection" indicator (78 pts), which resulted from not using chemical pesticides. “Soil” indicator had a relatively low value (31 pts), due to the risks of erosion and acidification on some agricultural parcels.

The farm received a high value of "Economic efficiency" (95 pts) (Fig. 3). Direct payments, agri-environment program payments, and agritourism had a significant share in the farm income.



Source: *own work/ źródło: opracowanie własne*

Fig. 3. The evaluation of the degree of sustainability of organic farm
Rys. 3. Ocena stopnia zrównoważenia gospodarstwa ekologicznego



Source: *own work/ źródło: opracowanie własne*

Fig. 4. The evaluation of the degree of sustainability of conventional farm
Rys. 4. Ocena stopnia zrównoważenia gospodarstwa konwencjonalnego

Taking into account low direct costs incurred by the farm, the calculated net profit amounted to 44 thousand PLN. The values of "Economic stability" (44 pts) and "Local economy" (13 pts) indicators were much lower. These scores were determined by a low productivity, associated with lower yields than in conventional farms. The factors which were taken into account included: a low farm income per 1 ha, a lack of new investments of the farm, and a relatively low income of the persons employed on a full time basis in relation to the average income in the region, achieved in other sectors of the economy (income parity).

3.3. The assessment of the degree of the sustainability of a conventional farm

The assessment of the degree of the sustainability of a conventional farm is presented in Fig. 4. Most indicators used in the assessment of the degree of the sustainability of this farm achieved positive values. It resulted from the proper management of energy, water, and waste, the proper protection of soils and waters, good working conditions which did not pose a threat for the employed persons, and satisfactory farm income. Negative values were recorded only for two indicators, such as “Nitrogen and Potassium emission potential” (-14 pts) and “Biodiversity” (-58 pts) (Fig. 4), so they cannot be considered sustainable in accordance with the RISE methodology.

In the case of „N&P emission potential”, besides the balance of nitrogen and phosphorus, the assessment covered also the method of the use and storage of manure on the farm. A part of manure was stored on a loose ground, which posed a threat of soil and water pollution. Moreover, after being transported onto the field, the manure was not directly ploughed or mixed with the soil, which generated the losses of nitrogen and caused environmental threats. The negative value of this indicator might have been caused by N and P balance surplus (a total surplus for N and P - 80 kg/ha AL).

In the assessment of the degree of the biodiversity of this farm, the lowest value among all the indicators was recorded for the “Biodiversity” one. It was caused by using the production methods which were typical for intensive agriculture, with a high amount of chemical plant protection products (the use of an active substance of 1,05 kg(l)/ha). Chemical plant protection was performed on almost the whole area of the farm, which reduced the biodiversity of useful animals and segetal flora. In the RISE methodology, such treatments are considered to be the pressure for biodiversity. Moreover, the farm did not use any non-chemical plant protection methods. On the farm, there were no balks, valuable natural areas, or any other wildlife refuges, which could be a habitat and feeding area for different species of microorganisms, insects, or birds. Such functions were performed only by permanent grasslands, but they constituted no more than 2% of the farm area.

Intensive agricultural production had an impact on the assessment of the degree of sustainability in terms of soil and plant protection. These indicators reached the values of respectively, 37, and 39 points (Figure 4). The parameters of the "Soil" indicator take into account the threat of erosion, which was visible on some parcels of 5-15%, and 15-30% slopes. No anti-erosion treatments were applied on these fields. Ploughing was the primary way of soil cultivation in this farm, which, according to the RISE methodology, is considered an intensive treatment which increase the threats of erosion and of other soil degrading processes.

As for "Plant Protection" indicator, the methods of performing the treatments were positively evaluated: training of a farmer, maintaining waiting periods, and proper storage of plant protection products, despite the fact that the equipment used did not have the current certificate. Environmental and toxicological risks to humans from the active substances contained in the used preparations were relatively small. The factors which exerted an environmental pressure in terms of "Plant Protection” were: applying plant protection products on a large surface area (98% of the utilized agricultural area), and not using prophylactic, either agri-technical or mechanical, plant protection methods. Waste management was a problematic issue on the farm. The model negatively assessed a too low amount of recycled waste. Also, removing dead animals was not performed in a proper, professional way.

Economic performance of this farm was assessed to be positive. The indicator of "Economic Stability" reached 60 points. This evaluation was affected by a satisfactory state of the machinery and buildings, a small debt, as well as cost-effective, secure investments of the farm. The indicator of „Economic Efficiency” achieved a maximum 100-point value for this farm. Such a good financial result was the effect of relatively high income (gross margin of this farm amounted to 96 thousand PLN, net profit reduced by the labour cost, and potentially stranded costs from interests from the capital employed – 49 thousand PLN) “Local

Economy" indicator scored much lower (44 pts) in the assessment of the sustainability of the farm. "Social Security" however, attained quite a high value (77 pts), which resulted from the fact that all the family members were insured, and the farmer had an additional insurance.

3.4. The comparison of sustainability indicators of organic and conventional farms

In the assessment of the degree of sustainability with the use of the RISE model, the organic farm achieved a higher total score than the conventional one (Table 2). This score resulted from very high values of the environmental assessment of the organic farm. The conventional farm achieved higher values of economic and social indicators. A unilateral shift to the left on the polygon of the sustainability of the conventional farm indicates that this farm prioritized its economic goals over the ecological ones (Fig. 3, 4).

The income and profit of the farm were largely determined by agri-environmental subsidies and the income from agritourism (Table 1). However, as our previous studies had shown, organic and extensive farms may have problems with a low profitability [6]. It was confirmed by the results of the assessments performed with the use of the RISE model in other countries [8, 9]. Organic farms, were more interested in maintaining biodiversity and running a more rational nutrient management compared to conventional, intensive ones [14].

Tab. 2. The list of indicators determining the degree of the sustainability of farms (pts)
Tab. 2. Zestawienie wskaźników charakteryzujących stopień zrównoważenia gospodarstw (pkt)

Indicators of the assessment of the degree of sustainability	Type of the farm	
	organic	conventional
ecological	333	125
economic	152	204
social	101	134
Total of all the indicators	586	463

Source: *own work/ źródło: opracowanie własne*

The tested organic farm, which ran a combined plant and animal production, achieved positive values for all the 12 indicators of sustainability, so it can be considered sustainable in accordance with the RISE methodology. This assessment confirmed the positive qualities of this production system which should be characterized by a closed cycle of matter and energy. It allowed for producing high-quality food, and at the same time for protecting the environment [15]. As for the studied conventional farm, which also ran a mixed production, it did not meet all the criteria to be considered sustainable, as according to the RISE model, because of obtained negative values of „Biodiversity" and „N&P emission potential".

4. Conclusions

1. The assessment of the level of sustainability revealed that only organic farm could be considered sustainable, as it attained positive values for all the 12 indicators of the RISE methodology.
2. The assessment indicated that the tested conventional farm had problems with managing fertilizers (nitrogen and phosphorus balance) and maintaining biodiversity. The values of "Nitrogen and Phosphorus Emission Potential" and "Biodiversity" were negative (respectively, - 14 and - 58 pts), making it impossible for this farm to achieve a positive score of the degree of sustainability.
3. A comparison analysis of the two farms which differed in terms of the system of production showed that the RISE model was a valuable tool for the assessment and comparison of the degree of sustainability of different types of farms in terms of ecological, economic, and social aspects.

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