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Multicriteria assessment of Czech farms

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Abstract: This paper describes a methodology for assessing farms that considers the multi-functionality derived from the requirements and expectations of the agricultural sector. To this end an original, multicriteria method was developed for assessing farms based on their individual data. Five dimensions were assessed (production, economic, financial stability, environmental, social & other), representing the most important aspects of farming. The overall assessment based on these five dimensions aims to express the total sustainability rate of the farms. The methodology used to develop this assessment is described. The results of the assessment for 2016 are presented and classified according to various factors and are linked to other important indicators. The data used is from the Farm Accountancy Data Network database in the Czech Republic.

Keywords: agricultural policy; Farm Accountancy Data Network (FADN); multidimensional assessment; socio-environmental indicators; sustainable agriculture

Optimal assessment of farms should take into account the effort invested by agricultural entrepreneurs, especially efforts towards the sustainable production of foodstuffs; towards employment support, such as reducing the number of people leaving the countryside and strengthening its social and cultural life; towards appropriate farming of agricultural areas focused on functional, high-quality soil; towards economic management of water and protection of water sources; towards region-based maintenance and improvements; and toward preservation of biodiversity. Measuring these and other non-production activities in which agricultural entrepreneurs are involved is usually highly complex, expensive, and difficult to execute. In some cases, neither the appropriate indicators nor any methodology for their measurement are defined. For this reason, a methodology for a complex, multicriteria assessment of farm management that also incorporates production, environmental, social and economic fields, is proposed below. To contribute to the literature review, we have connected the multicriteria assessment to the results of the set of indicators, which were applied uniformly across the European Union (EU). The aim is to extend the ability of farm level databases to evaluate and design new agricultural strategies. This allows us to designate the types of farms with the highest and lowest rate of sustainability, to investigate the structure of those farms, their efficiency and their need for public support. In this sense there is no other similar system applied in the conditions of the Czech

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Republic. It is in the interest of researchers and policy decision makers to know which dimensions are strong or weak within the different groups of farms. Based on this knowledge the specific scheme differentiated by type of farming can be designed to support weak dimensions without jeopardising the well-established dimensions and to maximise the value of total agricultural sustainability.

LITERATURE REVIEW

Requirements for sustainable agriculture are not only defined on the national level but are also integrated on a long-term basis into the Common Agricultural Policy's (CAP) approach, which blends together production and agro-environmental perspectives (EC 2006; Passeri et al. 2016), given how crucial social and economic sustainability is to agricultural activities (Field to Market: The Alliance for Sustainable Agriculture 2016).

A comparison of studies (De Ridder et al. 2007; Ness et al. 2007; Binder et al. 2010; Schader et al. 2014) highlights the differing main goals of assessments of sustainability (research, monitoring, policy/farm advice, etc.), level of assessment (agricultural sector level, field-farm level, etc.), geographical extent (region/country/globally applicable), sector extent (product specific/general agriculture/food industry), thematic extent (environmental, social, economic), and perspective on sustainability (farm/societal/mixed).

In technical studies (Yli-Viikari 1999; Rasul and Thapa 2004; Meul et al. 2008; Schader et al. 2014), understandings of sustainable agriculture feature restricted dimensions, which are then further specified according to more detailed criteria or indicators. These dimensions, however, are not often explored in connection with mutually-influencing economic, social and environmental criteria, being instead analysed individually or in combinations of mutually-influencing components (Payraudeau et al. 2005; Meul et al. 2008; Merlín-Uribe et al. 2013; Schader et al. 2016).

Links between production, economic, ecological, social, and other criteria call for a multicriteria assessment that can serve as a tool for tracking long-term sustainability. Sub-criteria should qualify a dimension qualitatively or quantitatively as suitably as possible (Schader et al. 2014; Schader et al. 2016; Vastola et al. 2017; Ssebunya et al. 2019).

Authors define economic criteria in various ways. Franks and Collis (2003) assess the efficiency of a farm by means of KPIs (Key Performance Indicators). Franks and Haverty (2005) determine KPIs by means of benchmarks with the goal of increasing the economic efficiency of profitability. Astier et al. (2012) point to the necessity of economic analysis in a long-term context (with no emphasis on short-term economic goals).

Meul et al. (2008) include the effectiveness and productivity and risk as economic criteria. Variables focusing on income, costs, yields, and employment are common criteria for limiting the scope of the economic dimension. The social dimension is concerned with input self-sufficiency, equity, risk, and uncertainties in crop cultivation. In the environmental dimension, input-related (use of non-renewable energy and sources, land use, nitrogen fertiliser/pesticide use etc.), emissions-related (pesticides, greenhouse gases, etc.), and system state-related (landscape quality, biodiversity, soil quality, etc.) criteria often appear (Van Der Werf and Petit 2002; Payraudeau et al. 2005; Schader et al. 2014, 2016). Similarly, indicators may be found in the CAP approach from an agro-environmental perspective (EC 2006).

An essential condition of the selection of indicators is their quantifiability, causality, interpretability, and sensitivity to changes (Meul et al. 2008). Rasul and Thapa (2004) emphasise that the selection of indicators is always highly dependent upon the character and conditions of farming that may differ in different areas.

Studies featuring the Sustainability Assessment of Food And Agriculture Systems (SAFA) methodology (FAO 2014), based on an assessment of the dimensions of good governance, environmental integrity, economic resilience, and social well-being, assess their target field through a combination of indicators. The methodology used across the models, however, often differs. In some, weightings are used which allow the importance of indicators in a given dimension to be differentiated according to their applications. According to Meul et al. (2008), setting these weights within the framework of a dimension is always subjective.

MATERIAL AND METHODS

Data. Data were taken from the Farm Accountancy Data Network (FADN CZ 2018) database in the Czech Republic. The assessment was processed with the use of data from 1 351 farms in 2016. Calculations were done on the newly-formed MULTI database on the MS SQL server with MS Transact SQL algorithms. Statistical evaluations were performed using the Statistica 13 software.

A typology according to EU rules was used for classifying farms, enabling the differentiation of farms by their production focus and economic size. The calculation of typology is based on the standard output

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value (SO). SO is the production value per hectare of each crop produced and for each head of the individual category of animal.

This article considers four of the most significant groups of production focuses in the Czech Republic: field production, milk production, mixed production, and grazing livestock. Farms are further divided into four groups according to their total economic size (small, medium, large, largest).

The outcome of the multicriteria assessment is linked to the standard results used within the FADN community for agricultural policy needs. Calculations of standard results were unified across the EU. A detailed description is given by an European Commission document (EC 2019).

Methodology. The model is based on a sample of individual farms. The multicriteria assessment methodology includes 34 indicators falling into 5 areas with a point-based evaluation system. The results of the individual indicators for each farm are used to assign points. The point-based evaluation is then calculated for each dimension, the average point value serving as a complete, unweighted result for a dimension.

A further step is determining the dimension weightings, as the weights of the individual dimensions in the overall assessment may differ. In multidimensional models applying an aggregation of indicators, the weights can be used within one dimension or across dimensions, as in Chen et al. (2018). It is important to keep in mind that not using weights gives each dimension equal importance; therefore, the researcher needs to decide whether or not to establish the importance of each of the dimensions. Both options are the result of a subjective decision. For the purposes of multicriteria farm assessment, a weighting scheme based on statistically-derived weights is the best choice.

According to the *Handbook on Constructing Composite Indicators* (OECD 2008), among the methods used for determining the weights are Principal Components Analysis (PCA), Data Envelopment Analysis (DEA), Analytic Hierarchy Process (AHP), or the Conjoint Analysis (CA).

Here, the PCA method was used to determine weightings. PCA is a multi-dimensional statistical method that describes variability among correlated indicators, which allows the variance to be explained, and which is applied to calculate significant and robust weights (Afifi et al. 2012). Weightings are established based on point-based indicators within the framework of each dimension. The weight is used to evaluate the importance of each dimension. The value of weights may vary over the years due to political, structural, or social developments as they are derived from the evaluation of real data. The weighted result of individual dimensions is obtained by multiplying the unweighted assessments by the weights.

The total of the weighted evaluation of the dimensions then provides the aggregate multicriteria assessment of the farm. The overall results state the average rating of the farm group, differentiated on the basis of criteria such as production focus, economic size, farmer ages, ecological or conventional management, and Less-Favoured Areas and areas with environmental restrictions (LFA).

The multi-dimensional platform is comprised of individual areas which differ in terms of their goals (e.g. political, economic, social), methods of achieving their goals, and methods of measuring them. The individual dimensions that influence the overall ranking were derived from theoretical findings in the literature (EC 1999; Renting et al. 2009; Dolman et al. 2012; Mészáros et al. 2015).

Figure 1 shows the five dimensions defined together with a methodological schema. The production dimension is focused on the quantitative results of the natural production (yield, efficiency, growth, death). The economic dimension assesses the economic results of a farm, focusing on profits and productivity. The financial stability dimension assesses the position of the farm from the perspectives of financial stability and risk management. The environmental dimension assesses the behaviour of the farm with regard to the environment. The social & other dimension assesses the contributions of the farm in both social and other, non-classified areas.

The overall multicriteria assessment *MultiE* (Multicriteria Evaluation) is the sum of the arithmetic means of the point scores of the individual indicators of each dimension:

$$MultiE = w_A \frac{1}{4}\sum_{i=1}^{4} MA_i + w_B \frac{1}{6}\sum_{i=1}^{6} MB_i + w_C \frac{1}{6}\sum_{i=1}^{6} MC_i + w_D \frac{1}{10}\sum_{i=1}^{10} MD_i + w_E \frac{1}{8}\sum_{i=1}^{8} ME_i \quad (1)$$

where: MA – production dimension; MB – economic dimension; MC – financial stability dimension; MD – environmental dimension; ME – social & other dimension, w – weight used for dimensions A (production), B (economic), C (financial stability), D (environmental) and E (social & other); i – number of indicators (1, 2, 3, … n).

Indicators used. The indicators used (Table 1) were chosen based on the technical literature (Rasul and

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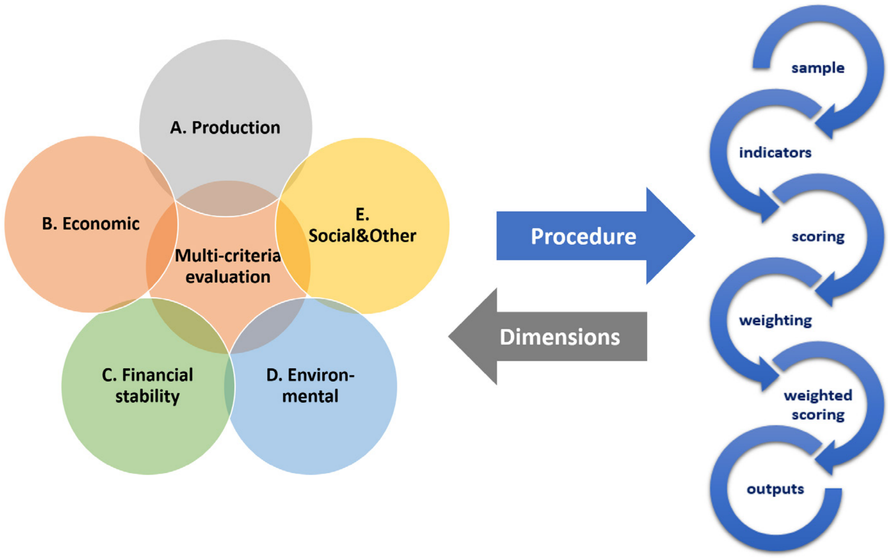

Figure 1. Fields of assessment and methodology

Source: author's own elaboration

Thapa 2004; Meul et al. 2008; OECD 2008; Wrzaszcz 2014; Mészáros et al. 2015) and expert selection. Production dimension indicators evaluate the intensity of a farm's production capabilities. The intensity of crops for which it is not possible to ascertain the yield or where the data is not be meaningful (e.g. flowers, other crops on tillable land, Christmas trees) are evaluated on the basis of the sales of the commodity. For animal products, the indicators evaluated are the growth of animals designated for fattening, the milk yield

Table 1. List of indicators

Code	Name	Code	Name
MA_ALL	**Production dimension**	**MD_ALL**	**Environmental dimension**
MA1	crop yield	MD1	organic manure
MA2	weight increase	MD2	mineral fertilizers
MA3	livestock	MD3	crop protection
MA4	livestock mortality	MD4	share of legumes
MB_ALL	**Economic dimension**	MD5	stocking density
MB1	farm net value added/AWU	MD6	share of grassing
MB2	total production/AWU	MD7	greening
MB3	production/unit	MD8	energy productivity
MB4	specific costs/unit	MD9	share of crops improving soil
MB5	intermediate consumption/production	MD10	renewable energy production
MB6	return on equity	**ME_ALL**	**Social & other dimension**
MC_ALL	**Financial stability dimension**	ME1	gender
MC1	quick ratio liquidity	ME2	age
MC2	cash flow liquidity	ME3	No. of employees
MC3	total debt to total assets	ME4	education
MC4	maturity of receivables	ME5	land ownership
MC5	net working capital index	ME6	protection of origin (PDO/PGI)
MC6	investment without subsidies	ME7	wages
		ME8	diversification

AWU – annual work units; PDO – protected designation of origin; PGI – protected geographical indication

Source: author's own elaboration

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of cows, goats, and sheep, loss of animals, and the yield of honey and eggs.

The final indicator of economic results is Farm Net Value Added (FNVA) per annual work unit (AWU). FNVA expresses the difference between gross value added and depreciation of assets. The production indicator per unit differentiates between the production of animal products in value per livestock unit (LU) and the production of crop products in value per hectare. Production is calculated as the total turnover from individual products, farm use, farmhouse consumption, changes in the stock, and subtraction of purchases.

The share of intermediate consumption to total production expresses whether the farm can cover input costs (not including depreciation and external factors), turn a profit, and move towards expanded production without state support.

The financial stability dimension was included primarily to evaluate the stability and sustainability of a farm's operation in the long term. Apart from the usual financial indicators, the assessment includes whether the farm is able to get by without subsidies on investment.

The environmental function of farming area includes 10 indicators which are instrumental in assessing a farm's relationship with the environment. A farmer can influence the results – positive or negative – of their impact on the soil, water or biodiversity through proper farm management techniques.

One of the more complex areas is that of a farm's participation in social and other agricultural functions. This is mainly due to difficulties in measurement, a lack of information, and generally lower levels of practical experience. Eight indicators were selected for this dimension, of which five focus on the social aspect.

The education of farmers is tracked in the FADN database for managers and for owners of the farms, which classifies farmers into three groups. Full professional farming preparation means university level agricultural education. Basic professional farming preparation indicates secondary school level education focused on agriculture. Practical farming knowledge indicates farming experience gained through practical knowledge.

The labour cost per unit of paid labour indicator is dedicated to the social aspect as well. Labour costs include personal expenses, wages paid, bonuses for members of the corporation, expenditures for social security and health insurance, and social expenses. Only paid labour is considered.

Diversification of farming activities lowers the risks associated with agricultural production. The wider the array of farming activities, the higher the likelihood of a farm's economic stability. In a multicriteria assessment this entails distinguishing between activities concerned with the growing of grains, with other field crops, vineyards, permanent crops, orchards, other permanent crops, feed crops (if no breed animals), dairy cows, other cattle, sheep and goats, pigs, poultry, other crop products, other animal products, other forest products, services for others, renewable energy, and other gainful activities. Points are assigned for each instance of an activity and then added up.

Method of awarding points. The base ranking is calculated by means of a system for awarding points, with three possible ways of doing so: division of values into deciles, interval of values, and evaluation through binary code.

The most frequently used one is the division of the aggregate into deciles. Ordered values of the indicators calculated are divided into deciles and the position in the decile scale is then determined for the values of an indicator for each farm. This method of awarding base points is used for the following indicators: MA1, MA2, MA3, MA4, MB1, MB2, MB3, MB4, MB5, MB6, MC2, MC3, MC4, MC5, MD2, MD3, MD6, MD8, MD9, ME3, ME5, ME7, ME8.

In case of scoring for the quick ratio (MC1), the optimal result is the middle value of the indicator's scale. Only positive values are evaluated. Farms in the last decile receive no points, being outliers. The indicator for total indebtedness (MC3) is scaled and scored only for farms whose leverage value is greater than or equal to one.

The indicators MC6, MD1, MD7, MD10, ME1, ME2 and ME6 are built on a binary number logic that tests for the existence of a given phenomenon. A further method for awarding points is the use of intervals. This method is used for awarding points for the indicators MD4, MD5 and ME4.

RESULTS AND DISCUSSION

Farms in the Czech Republic vary greatly. The selected characteristics of investigated farm groups in terms of the structure of the farm as well as the economic and environmental results are given in Table 2. These results indicate differences among the farm groups as the production focus, farming intensiveness, farm productivity and profitability, and environmental contribution. The FADN database can serve as a rich source of indicators which can be easily linked with the findings of multidimensional farm assessment to define implications and propose the specific actions to be taken in the framework of agricultural policy.

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Table 2. Main characteristics of farm groups classified by type of farming, farm size and value of FNVA/AWU in 2016

Indicator	unit	Type of farming – selection				Farm size				FNVA/AWU		
		field crop	milk production	grazing livestock	mixed farming	small	medium	large	very large	highest	medium	lowest
Structure indicators												
Number of observations		454	140	240	355	307	593	131	320	451	450	450
Annual work unit	AWU	8.9	26.0	4.7	30.0	1.6	3.9	14.5	48.9	15.3	23.7	6.2
Utilized agricultural land	ha	474.3	710.1	231.1	1 072.6	40.1	186.4	704.7	1 690.2	779.4	756.4	142.5
Number of livestock units	LU	32.6	462.0	107.0	522.2	16.9	52.1	184.3	821.4	258.8	383.2	75.4
Share of unpaid labour	%	53.3	34.3	72.6	33.7	94.9	65.7	7.6	0.9	39.1	36.1	79.0
Share of rented area	%	70.0	71.7	57.7	72.1	44.3	60.8	82.6	82.7	73.2	71.9	47.9
Share of crop production on total production	%	90.6	30.6	38.7	54.5	58.1	71.0	68.9	53.3	68.7	58.8	63.5
Share of livestock production on total production	%	3.8	61.4	51.1	36.8	34.7	23.6	22.0	35.2	23.4	32.5	30.2
Economic and financial indicators												
Share of total production and total costs	%	101.8	91.5	67.1	89.9	95.4	101.9	90.0	83.9	103.1	90.5	91.3
Crop production per hectare	EUR/ha	1 185	478	189	743	1 540	4 414	1 452	2 323	1 183	2 731	5 041
Livestock production per livestock unit	EUR/ha	785	1 362	545	1 046	648	820	969	1 259	991	970	790
Farm net value added per annual working unit	EUR/ha	28 506	19 688	18 247	19 712	10 563	23 750	31 430	24 789	39 907	18 803	6 482
Total debt to total assets	%	19.9	30.2	15.9	28.9	6.8	18.4	31.9	37.9	25.0	26.4	13.7
Environmental indicators												
Share of grassing	%	5.3	43.9	87.2	23.8	51.3	26.7	20.8	16.7	23.4	30.0	34.6
Share of legumes	%	1.8	20.4	15.4	9.4	9.4	7.8	5.6	9.1	7.5	9.5	7.8
Quantity of nitrogen (N)	kg/ha	121.9	57.4	5.5	85.3	36.2	75.7	99.4	108.9	94.9	78.3	57.5

FNVA – farm net value added; AWU – annual work unit; LU – livestock unit

Source: author's own calculation based on FADN CZ (2018) database

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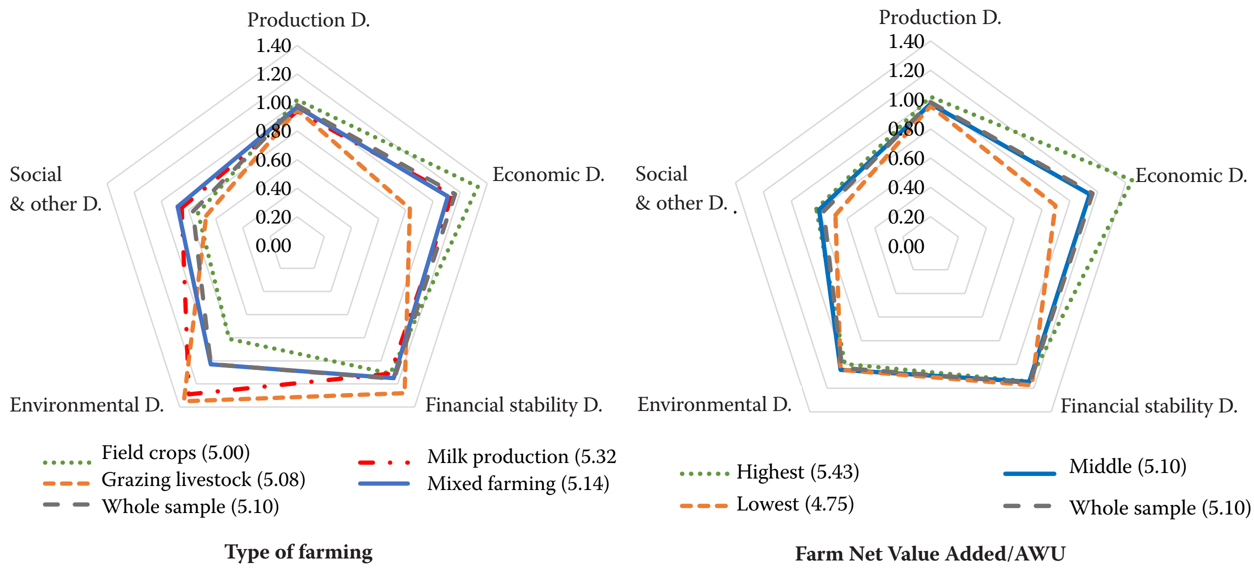
An analytical evaluation of the results obtained by the methodology is described below. Weightings (in brackets) for calculating the multicriteria evaluation of farms for the year 2016 were set by means of the PCA methodology for the production (0.18051), economic (0.20812), financial stability (0.20511), environmental (0.20818) and social & other (0.20016) dimensions. Meul et al. (2008) aggregated the scores of individual indicators of sustainability in the MOTIFS (Monitoring Tool for Integrated Farm Sustainability) tool, which is based on all dimensions (environmental, economic, and social) being equal. SAFA methodology (FAO 2014) also uses equal weights for each dimension. In contrast to previous studies, the methodology proposed here assigns different weights to the five dimensions. The reason is to differentiate the actual priority of the dimensions (Afifi et al. 2012; Chen et al. 2018). Nevertheless, variation in the weights determined is nearly negligible.

The overall analysis of results confirms (Figures 2 and 3) that farms with a higher FNVA/AWU value achieve better results in sustainability and that a higher level of manager education leads to better results in long-term sustainability. The analysis refuted claims, however, that older farmers achieve better results than younger ones (up to 40 years of age), or that female farmers get worse results than male farmers.

To achieve a better rate of sustainability, the research and agricultural policy focus with regard to production should be concentrated on improving environmental results of field crops and mixed farms. In practice this means that these types of farms will have to use a higher share of organic manure instead of mineral fertilisers, less chemicals to protect crops, change the crop



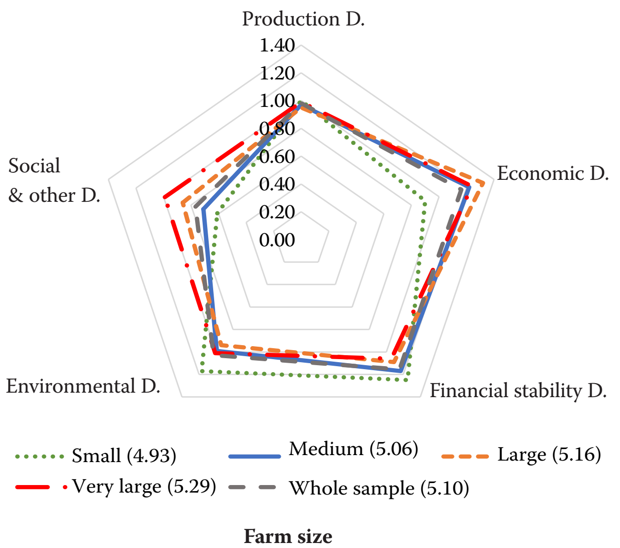


Figure 2. Multicriteria evaluation of Czech farms broke down according to type of farming, farm size and value of FNVA/AWU in 2016

Overall rating in brackets; D. – dimension

Source: author's own calculation based on FADN CZ (2018) database

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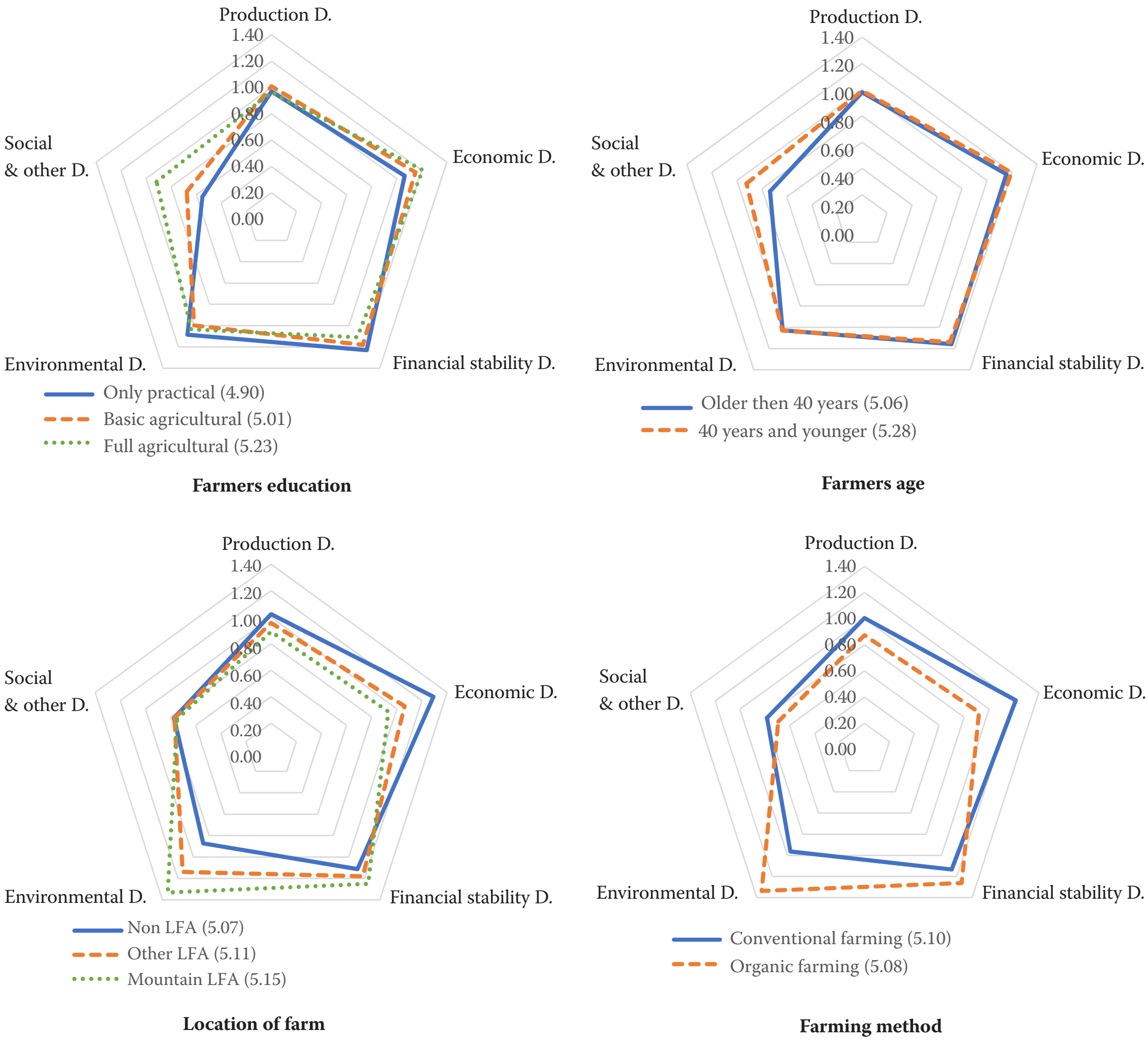

Figure 3. Results of the multicriteria assessment, divided according to education and age of farmers, location of farms and farming method

Overall rating in brackets, D. – dimension, LFA – less-favoured area

Source: authors' own elaboration based on FADN CZ (2018) database

rotation in favour of a higher share of legumes, grass, and soil improving crops, and increase the use of renewable energy. On the other hand, better economic results gained by farms specialised in grazing livestock production, for instance by means of meat market support, increases in meat prices, or accessible slaughtering and meat processing facilities, would also lead to the increase of total country sustainability.

Ratings tend to increase with increasing size of the farm, such that the smallest farms receive the lowest scores and the largest ones the highest. The social & other dimension shows the highest variability in evaluation. Larger enterprises make the greatest contribution to this function in terms of employment and diversification. The results show obvious need for encouragement of the medium and small farms in this area. To increase country agriculture sustainability, it can be recommended to support small farms in profitability and productivity and in social questions, such as simplification of succession of farmers or support of investments in increasing diversification of farm activities. Wrzaszcz (2014) likewise uses the FADN sample in Poland for a two-dimensional evaluation of long-term sustainability of farms. Results for the economic

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and environmental areas are also compared according to their production focus and economic size.

In terms of the division according to income, the important divergence was obviously found in the economic dimension. The evaluation of production, environmental and financial stability dimensions are comparable for all farm classes. Total Czech farm sustainability can be increased by means of income support provided for farms in the lowest and middle groups classified by FNVA/AWU. For instance, via substitution of labour by contract work due to its positive affect to income, as Spicka (2014) found for mixed farms. We confirm the hypothesis that farms with the best FNVA/AWU values achieve the best results in the production and economic dimensions in all evaluation criteria apart from the loss of animals and amount of direct expenses per unit (hectare or livestock unit). These two indicators were highest for groups of farms with the lowest FNVA/AWU.

Taking into consideration other possibilities for classifying farms, Figure 3 shows farms classified according to the age and education of farm managers, according to whether they are in LFA regions, and according to whether a farm is ecological or conventional.

The results point to similar overall ratings for conventional and organic farms in terms of long-term sustainability, though there is a clear difference in the individual dimensions. In the environmental and financial stability dimensions, ecological farms receive higher scores. The results for the social & other dimension are similar for both types of farms. Hence, we can conclude that organic farming is more environmentally friendly and less profitable in comparison to conventional farming methods. Although majority of conventional farms apply CAP greening measure, having positive impact on reducing the use of nitrogen and increasing crop diversity as concluded Cortignani and Dono (2015), the assessment of the environmental dimension shows a capacity to improve. Significant differences between organic and conventional farms were also found by Rasul and Thapa (2004) for several indicators linked to environmental dimension. Higher results were confirmed for financial return. On the other hand, they did not find any differences in economic return and value addition per land unit.

The overall evaluations among LFA areas are close to each other; nevertheless, the inner evaluation of dimensions differs significantly between the economic and environmental dimensions. Income support for farms located in mountain regions (mainly grazing oriented farming) and an increase in the environmental evaluation of farms located out of LFA areas (with intensive farming systems) would lead to an improvement in the overall agricultural assessment. It can be pointed out that agricultural policy measures for difficult farming conditions are worth it from a long-term sustainability standpoint. Sorting according to social criteria (farmer age and education) results in a rather different overall evaluation; the most significant difference, however, is in the social & other dimension, where the policy instruments should be aimed (e.g. slowdown of farmers aging, education support, support of products of region).

A multicriteria evaluation has a similar function as MOTIFS (Meul et al. 2008), as it may be used as a monitoring tool to support the decision-making of owners of the farms evaluated. The results may also reveal strong and weak points and, through a comparison of farms' results over time, may show whether the manager tools used had an impact on the growth of a farm's sustainability.

Methodologically, we defined the assessment covering a large area of the farm activities and we pointed out the most driving indicators of the dimensions. Nevertheless, there are some limitations of our method to be investigated in the future work. Main restriction of our model is a selection of the environmental and social indicators as FADN system is focused mainly on economic questions, and it covers this information marginally. With the knowledge of the future policy requirements it is obvious that those two fields will request broader data base. However, results of this study show high relevance of the model in the current state.

CONCLUSION

The methodology used here describes the possibility of evaluating the long-term sustainability of farms through a complex assessment of individual farms derived from the combined evaluations of five different areas of a farm's operation. Results of the multicriteria evaluation can be extrapolated for FADN's entire scope, which includes 98% of Czech farm production. Our contribution to the other approaches allows modelling of policy measures on the farm level by the means of linking the multicriteria assessment together with the set of standard results, covering production, costs, subsidies, assets, or income indicators. Monitoring of the results development of the multicriteria evaluation allows to evaluate the impacts of the Common Agriculture Policy on individual farm level, farm group aggregates, and national agriculture.

The result of the overall assessment of the sample of farms in 2016 confirms significant differences when

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compared according to the production focus, economic size, FNVA/AWU, and the age and education of the managers. Less significant differences were between LFA areas and organic or conventional farms. The claim that farms in LFAs and organic farms will have higher ratings in the environmental area and lower in the economic area was confirmed. For farms in LFA areas or for organic farms, it may be noted that CAP tools for difficult farming conditions are worth it from a long-term sustainability standpoint. Based on our findings we can suggest that applying these measures to small farms would benefit the overall country farm sustainability.

Our results show that conventional farms, crop and mixed farms have some capacity to increase overall sustainability by improvement of the approach to farming in terms of soil quality (use of organic manure, crop rotation, soil improving crops), renewable energy consumption, or bio-diversity (crop protection techniques). This recommendation is in line with current policy discussions and should be considered while designing new policy measures.

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