REGIONAL CONVERGENCE OF AGRICULTURE SUSTAINABILITY – THE CASE OF POLAND

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Abstract
Sustainable development of agriculture is now advisable direction, both by politicians and scientists. This support is evident in the development strategies and programmes, both on the national level as well as european. The need for assessment of agricultural sector (farms) is growing, in terms of actual changes in the context of the impact of agricultural production on natural environment. Although the need for sustainable agriculture development, the assessment methods of this phenomenon with wide implementation properties are not indicated in scientific literature. An important element of these evaluations is regional aspect, namely to identify whether the process of regional convergence or divergence appears in terms of farms' environmental sustainability. The aim of the paper is to present the approach to farms' environmental sustainability assessment and regional convergence in this scope on the basis of Polish Central Statistical Office data. The presented methodology may be useful in environmental sustainability evaluation of european regions. The presented results indicated a heterogeneous change in farm environmental sustainability, also at the regional level. Taking into consideration synthetic indicator of environmental sustainability, some symptoms of regress were observed, that took place in the central and eastern Poland – the area with relatively lower production potential of agriculture. Regional diversity in the field of environmental sustainability deepens for most considered its determinants, which confirms the divergence process.

Keywords: environmentally sustainable agriculture, sustainable farms, convergence, methodology, Poland.

Introduction

In the last three decades, the world economic and agricultural literature has presented a variety of approaches to the issue of sustainable development. They are expressed in a number of definitions, justification of opportunities and the necessity to implement this concept, based on multi-dimensional empirical research. The idea of sustainable development essentially boils down to conservation of environment and natural resources for the future generations in a condition that is not worse than it was for the current generation. Implementation of this idea mainly requires changes in the consumption patterns, changes in the value system and the introduction of such a system of management where pressure on environment does not exceed its capacity (WCED, 1987).

The implementation of the sustainable development principles is particularly important in agriculture, which has a strong impact on natural environment. The specificity of agriculture are side effects of conducted agricultural activities, which are both positive and negative externalities. In the second case, the consequence of agricultural practices is constituted by the irreversible degradation of valuable natural resources, including the ones in the form of reduction or loss of soil productive potential. According to the idea of sustainable development, every individual

should feel obliged to protect natural environment and apply principles of rational management of natural resources (Woś, Zegar, 2002). Unfortunately, externalities generally are not taken into consideration in the microeconomic criterion of making decisions by agricultural producers. Consequently, this leads to a discrepancy between the economic entity`s goal and the goal of the public (Zegar, 2010).

The european and national policy, changing consumer preferences and growing environmental awareness of the society have brought about the need to assess agricultural activity in terms of its sustainability. This evaluation should be carried out at various levels, i.e. from the global to the local one. The global approach is focused on world supply of food, maintenance of an adequate area of arable land, determining legal regulations on trade in agricultural products and minimising the impact of agriculture on climate. The continental and national approach is interpreted similarly. The quality of agricultural practices is also analysed at the regional, farm and field level. Each level is equally important and the effects (negative and positive ones) generated at one level are expressed in another (Loon et al., 2005).

In assessing farms` and agriculture sustainability, of particular importance is regional dimension. The need for economic and agricultural research in regional terms indicates a variety of scientific studies (e. g. Adamowicz, Szepeluk, 2018; Smędzik-Ambroży, 2014). Significant diversification of agriculture, both at the level of Poland (national consideration), as well as European (international approach) mandates to regional studies conducting. Regional diversity of agriculture is related to a number of issues, including agriculture sustainability. The important thing is to define the scale of the diversification and progressive changes in this scope, in other words, the phenomenon of regional convergence or divergence. Taking into consideration the scale of farms` support under the Common Agricultural Policy in the last decade (2005-2016), the question arises, whether agriculture in the regions of Poland become similar in terms environmental pressure, or regional agriculture development was independent (areas with a higher level of development had a greater potential to faster development).

The aim of the paper was the presentation of the approach to farms' environmental sustainability assessment and regional convergence in this scope based on Polish Central Statistical Office data for 2005, 2007 and 2016. General population of farms was analysed in the moment of Poland accession to the EU and after 11 years of membership. The main research results were presented, concerning farms` development direction in regional perspective. The presented methodology may be useful in the environmental sustainability evaluation of agriculture in european regions, on the basis of EUROSTAT data, including convergence phenomenon measurement.

1. Measurement of agricuture environmental sustainability – phenomenon complexity

Measuring the sustainability of agriculture is very complex, that was underlined in numerous scientific studies[17]. The common approach to this issue is associated with using certain indicators relating to three aspects of sustainability, namely: environmental, economic and social (Pretty, 2008). The indicators measuring sustainable development in general, formulated by international organizations are also useful in measuring sustainable development of agriculture, however, they usually require adaptation to the specific nature

[17] See e.g. (Loon et al., 2005; Toczyński et al., 2013; Harasim, 2014).

of this economy sector (e.g. OECD, 1999). Attempts in this field using a variety of approaches have not resulted in a generally accepted set of sustainability indicators.
The difficulties in measuring the sustainability of agriculture have many causes. First of all, the term of sustainable agriculture is not clearly defined. The measurement is hampered by multifunctionality of agriculture, a huge diversity of farms, different impact of the same activity effects on the environment and economic performance, diverse aspirations of farmers and others. There are also attempts to formulate a synthetic indicator of agricultural sustainability (e.g. Harasim, 2014; Wrzaszcz, 2014; Feledyn-Szewczyk, Kopiński, 2015). Commonly, the most attention in research is paid to environmental order, which was the base for the sustainable development idea, because of the dramatic violation of this order).

A separate, although very important issue is the method to measure agriculture sustainability that would enable an international application. In connection with the use of various sustainability definitions, various data (from various sources and studies), as well as various study methods (including different indicator and synthetic methods), the results obtained for agriculture sustainability in a specific country are usually not useful for international comparisons. The problem is that both researchers and international organizations often do not use international data collected in a uniform manner. This problem justifies a need to adapt the theoretical considerations (widely discussed in the literature) to the scope of available, unified national data in order to develop a useful method to make the international comparison of agriculture sustainability, including farms evaluation. The comparability of data is provided by EUROSTAT, although the scope of this data does not make it possible to analysed agriculture (farms`) sustainability to the full extent, hence, it does not exhaust the scientific considerations.

2. Convergence issue – the essence and measurement

The problem of sustainability measurement increases in the context of the need for monitoring of changes in terms of regional (voivodships) and periodic approach. Agriculture in regions varies significantly, including sustainability phenomenon (Toczyński et. al., 2013). There is, however, a need to determine whether this diversity of interregional deepens over time, or the regions become similar. Hence, determination of regional convergence or divergence of farms` environmental sustainability is very important.

The concept of regional convergence/divergence have been widely defined in the literature (e.g. Malaga, Kliber, 2007). Convergence in the macroeconomy means the process of aligning the values of main macroeconomic variables between countries or regions with different baseline (Trojak, Tokarski, 2013). The study of convergence phenomenon allows to determine whether the analysed regions that differ in the level of selected variables at the starting moment, they become similar to each other over time, or the differentiation deepens between them. Making up the distance to regions with best results means the convergence process, while its increase proves divergence process.

In the literature there are two commonly-used measure of convergence: σ-convergence and β-convergence (Malaga, Kliber, 2007). σ-convergence occurs when the diversity of a variable between regions decreases over time, and β-convergence occurs when we are dealing with declining dependency between the average level of the analysed variable and initial level of the variable. Usually, the σ-convergence is measured by the change in the standard deviation of the analysed variable, as evidenced by decreasing its value with the passage of time. The process of σ-convergence can also be tested by changing variation coefficients (based on standard deviation, average deviation and quartile deviation), which are relative measures of

differentiation (Trojak, Tokarski, 2013). Variation coefficient is the quotient of the absolute measure of variation to respective average values (Zeliaś, 2000).

3. Methodology of the research

Public statistic of Central Statistical Office – 2005, 2007 and 2016 Farm Structure Survey (FSS) data were used[18]. The analysis concerns all individual farms with at least 1 ha of agricultural land maintained in good agricultural and environmental condition (GAEC). These data were collected on the basis of uniform methodology that allowed to investigate the direction in which tends Polish agriculture in regions with regard to environmental sustainability. In Poland, 16 voivodships (administrative units, NUTS 2) are stood out and this division was used in the study[19]. FSS research are carried out in individual EU countries and research results are finally aggregated in EUROSTAT databases. The proposed use of data in farms` environmental sustainability measurement and convergence evaluation can be applied to other countries to conduct comparative national analyses.

Based on the environmental indicators, there was established environmental sustainability of farms with arable land cultivation. Presented indicators are not, however, universal list but they bring a measurable range of farms' environmental sustainability adapted to the substantive criteria and available official national statistical data. Each of the selected indicators was calculated on the farm's level. Selected indicators allowed to determine crop diversity, stocking density as well as fertilization and soil quality level[20]. The indicators are a stimulants, destimulants or nominants, with varied significance in the context of environmental sustainability. As a point of reference in farms` sustainability evaluation, certain indicator thresholds were established. The following indicators have been included as environmental sustainability determinants[21]:

- **the share of cereals in crop structure on arable land** determines the correctness of crop rotation and the degree of agrocenose biodiversity. The share of cereals should not exceed 2/3 (the reference value) of the area.
- **the number of plant groups cultivated on arable land** is complementary indicator to the above one, that indicates the possibilities of crop selection and rotation, which increases the guarantee of limiting the development of pest populations, reducing weeds and losses. At least 3 plant groups should be cultivated, out of: cereals, legumes and papilionaceous, root crops, industrial crops, grasses on arable land, other crops.
- **the index of winter vegetation cover on arable land** – is a synthetic indicator for the assessment of land resources and natural resources protection, the balance of ecosystems and the degree of implementation of sustainable production system in agriculture. Vegetation cover should be at least 1/3 of the crop area.
- **stocking density on agricultural land** – provides information about the level of livestock intensity, and also indicates the scale of the environmental impact of natural fertilizer. Stocking density should not exceed 2 LU/ha.

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[18] Initial calculations prepared in cooperation with the Statistical Office in Olsztyn to conduct the research on "Global and national conditions of the sustainable development of agriculture" of Multi-Annual Program 2015-2019.

[19] The term: *regions* and *voivodships* were used interchangeably in the paper.

[20] In the case of fertilization, 2007 and 2016 data were used, as in 2005, the scope of research of Farms` Structure Survey didn`t take into account fertilization issue.

[21] Rich literature reference to specified indicators were presented in e.g. (Wrzaszcz, 2018).

- **balance of soil organic matter on arable land** – a positive result reflects good crop rotation and systematic enrichment of the soil with humus. The one of the most important sustainability indicators. The reference value should be positive, above zero.
- **gross balance of nitrogen (N), phosphorus (P) and potassium (K) in the soil** – is a very important source of information on the impact of agriculture on environmental conditions, which is a consequence of the intensity and efficiency of agricultural production measured by the level of mineral fertilization, stocking density and crop yields. In the context of environmental farms` evaluation, nitrogen balance is the most important because of high pressure to ecosystem. Optimal level of NPK balance is regionally diversified (Kopiński, 2017).

On the basis of the adopted indicators of environmental sustainability and assigned them threshold values, farms` percentage with environmental criteria fulfilment was established in each administrative region. The higher percentage of farms that meet sustainability criteria, the more favourable phenomenon evaluation is. Sustainable farms` percentage should be treated as a stimulant of this phenomenon.

Then, to synthetically assess the changes that have been made in the environmental diversity of agricultural holdings, normalization of variables was carried out (x'_{ij}, formula 1). Normalized values enabled the construction of a synthetic indicator of farms` environmental sustainability in various voivodships.

In connection with the fact that sustainability indicators were varied in terms of their importance, weights were assigned, that were used in calculation of sustainability synthetic indicator, in accordance with formula 2. The studies assumes that soil organic matter and nitrogen balances are the most important, thus the weight amounted to 2 was used. In the case of other indicators, the weight was 1 (for crop diversification indicator based on cereal and crop groups criterion, winter crops indicator, balance of phosphorous and potassium). However, due to the lack of diversity of regions in terms of stocking density, this indicator was omitted in synthetic one. Higher values of synthetic indicator provided with a higher level of farms` environmental sustainability in the region.

Convergence process of farms` environmental sustainability was verified on the basis of differences in variation indicators values of individual variables (V_j; formula 3), based on the standard, average and quartile deviation (V_{SD}, V_{AD} i V_{QD}). Variation coefficients allows diversification assessment of the same population in terms of several different features and homogeneity degree of analysed population. It is assumed that if variation coefficient doesn't exceed 10%, the features exhibit statistically insignificant diversity (Zeliaś, 2000). Variation coefficients were calculated respectively for each variable in the analysed years. The reduction of variation indicator value with the passage of time informs about convergence process, while its increase confirms phenomenon divergence.

Using these formulas, the variability of farms' production potential in voivodships was also assessed. In the case of synthetic indicator of farms` production potential, weights were not used to individual components, there is agricultural area, labour input, livestock density and standard production values. Each element was equally important.

$$(1)\ x'_{ij} = \frac{x_{ij}}{\max(x_j)} \qquad (2)\ S = \frac{\sum_{j=1}^{m} x'_{ij} * w_j}{\sum_{j=1}^{m} w_j}$$

$$(3)\ V_{jk} = \frac{\overline{x_j}}{D_{jk}} * 100\%$$

x_{ij} – value of the j-th variable in i-th object (voivodship), were ($i = 1,...,n$; $j = 1,...,m$)
$\max(x_{ij})$ – maximum value of j-th variable between voivodships
w_j – weight for j-th variable (concerns sustainability indicators)
S – synthetic indicator
$\overline{x_j}$ – average value of j-th variable
D_{jk} – deviation of j-th variable, k – deviation: standard, average, quartile
V_{jk} – variation indicator of j-th variable, with k-th deviation

4. Farms` production potential in voivodships

Agriculture in Poland has changed significantly over the last several years. These changes concerned mainly farms' number, their potential and production profile. In 2016, there were 1.4 million individual farms. The number of farms and labour inputs decreased by almost 1/5 in comparison to 2005, that indicated the withdrawal of many farmers from this economic activity. Simultaneously, the area of agricultural land in good agricultural condition was more than 13 million ha. The area in absolute terms increased by 121 thousand ha, which was the result of the introduced commitments relating to the receipt of direct payments by maintaining land in good agricultural condition.

Table 1. Production potential of an average farm in Poland and voivodships in 2016 and its changes in the period 2005-2016 (%)

No.	Specification		AL[1] (ha)	LI (AWU)	LD[3] (LU)	SO[4] (thous. EUR)	S_P[5]
1	**Poland**	2016	9.43	1.16	8.31	15.61	0.54
		2016/05, %	24.44	-2.04	61.28	29.22	x
2	Dolnośląskie	2016	13.55	1.01	4.48	16.89	0.52
		2016/05, %	38.48	12.76	26.82	34.69	x
3	Kujawsko-pomorskie	2016	14.71	1.36	14.13	27.83	0.80
		2016/05, %	17.69	0.31	53.97	17.87	x
4	Lubelskie	2016	7.63	1.13	4.74	11.02	0.43
		2016/05, %	17.67	-7.59	33.06	14.67	x
5	Lubuskie	2016	17.39	1.03	13.14	23.61	0.72
		2016/05, %	48.00	12.76	132.43	60.29	x
6	Łódzkie	2016	7.57	1.15	8.23	14.02	0.50
		2016/05, %	10.25	-9.16	65.55	19.73	x
7	Małopolskie	2016	3.82	1.15	2.15	6.11	0.33
		2016/05, %	23.88	-0.83	2.54	15.94	x
8	Mazowieckie	2016	8.77	1.24	11.81	17.92	0.60
		2016/05, %	16.30	0.45	97.67	35.96	x

No.	Specification		AL[1] (ha)	LI (AWU)	LD[3] (LU)	SO[4] (thous. EUR)	S_P[5]
9	Opolskie	2016	14.57	1.15	9.23	22.16	0.65
		2016/05, %	43.81	6.36	65.41	37.90	x
10	Podkarpackie	2016	4.15	0.94	1.39	5.10	0.28
		2016/05, %	21.71	-12.09	-19.27	4.29	x
11	Podlaskie	2016	13.21	1.23	18.17	21.11	0.75
		2016/05, %	18.64	-2.17	74.34	26.03	x
12	Pomorskie	2016	16.10	1.19	11.10	21.78	0.70
		2016/05, %	31.33	4.78	49.98	23.82	x
13	Śląskie	2016	6.32	0.93	4.54	9.17	0.37
		2016/05, %	54.96	7.24	65.17	53.34	x
14	Świętokrzyskie	2016	5.62	1.18	3.28	9.13	0.39
		2016/05, %	17.54	-9.51	7.41	8.82	x
15	Warmińsko-mazurskie	2016	21.68	1.26	22.13	30.99	0.97
		2016/05, %	23.57	0.42	63.73	32.95	x
16	Wielkopolskie	2016	12.30	1.33	16.44	26.91	0.78
		2016/05, %	10.74	-1.74	69.58	24.87	x
17	Zachodniopomorskie	2016	22.62	0.94	10.04	25.67	0.74
		2016/05, %	26.82	3.70	56.74	31.24	x
18	V_{SD}	2016	47.43	11.14	59.71	43.00	31.79
19	V_{AD}	2016	40.66	8.88	49.11	37.06	27.49
20	V_{QD}	2016	30.40	8.96	44.78	35.08	26.04

[1] Agricultural land in hectares; [2] LI, Labour input in annual work units (1 AWU = 2120 work hours); [3] LD, Livestock density in livestock farms (1 LU = 1 dairy cow); [4] SO, Standard output in thousand euro (an average five-year value from an agri. activity), See: (Florianczyk, Osuch, Płonka 2016); [5]S_P – synthetic indicator of production potential; Coefficients of divergence (V) based on standard (V_{SD}), average value (V_{AD}) and quartile deviation (V_{QD}).

Source: Own calculation based on data 2005 and 2016 of Central Statistical Office

During the analysed period, many farms resigned from the livestock production – farms` number with livestock breeding decreased by 43%. This process had negative environmental impact, due to reduction in natural fertilisers amount of livestock origin and the progressive dependence of the agricultural production on industrial means of production (mineral and chemical fertilisers) (Wrzaszcz, 2018b).

As indicated in Table 1, an average individual farm is small, both in terms of agricultural land and generated standard agricultural output. Nevertheless, in the analysed period, an average farm significantly increased its area – by around ¼, which resulted in an improvement in their economic potential – almost by 30%. Having regard to an average farm's area, the input intensity of human labour has decreased significantly in the analysed years. Simultaneously, farms specializing in livestock production increased its scale (livestock population increased by 60%). These figures confirmed, on the one hand, progressive process of farms` specialization oriented towards livestock production, on the other, pointed to the growing population of non-livestock farms in which livestock production wasn't dominant production activity in previous years (Wrzaszcz, 2018).

Taking into account the regional division, farms significantly differed from each other in terms of production potential (variation standard coefficient of agriculture production potential amounted to 32% in 2016), and the highest values characterised Wielkopolskie and Kujawsko-pomorskie voivodships (table 1). At the opposite side, with the lowest production potential, Podkarpackie and Małopolskie voivodships were placed. Livestock population was a factor deeply differentiating farms between regions (V_{SD_2016} = 60%), then agricultural area and standard production (V_{SD_2016} = 47% and 43%), while on the border of statistical significance was the labour input variability.

During the period 2005-2016, farms in regions changed significantly in terms of production potential, although these changes took place with different pace and terms. In general, the process of farms` extension was observed, that concerned their area and production volume. Farms focused on livestock production, in majority of regions, increased the scale of this production (with Podkarpackie voivodship exception), usually maintaining or even reducing labour inputs per a farm. These data confirmed the process of land and livestock production concentration, with accompanied increase in labour efficiency.

Developing processes caused increasing differentiation, divergence process, of Polish farms in terms of their production potential. The process particularly applied to livestock production, and next farms` size and generated volume of production (that was also confirmed by increasing variation indicator, comparing 2005 and 2016). Whereas, farms in different regions assimilated in the scope of labour inputs, that indicated convergence process. It can be concluded, regardless of development direction of production organization, farms in regions aim to improvement of human factor exploitation. The employment problem in agriculture, associated with both the number of people interested in this work, the quality of work performed by employees, as well as remuneration obligation (which is less favourable in comparison to salaries in non-agricultural activities) are undoubtedly incentives for farmers to look for organisational and technological solutions aimed at the efficient use of labour input (Karwat-Woźniak, 2015).

5. Farms` environmental sustainability in voivodships

The results for the environmental sustainability of farms are presented in Table 2. Based on the percentage of farms that met the threshold values for each of sustainability criteria, it can be concluded that analysed criteria were varied in terms of difficulty level in their fulfilment. The most farms met the criterion of stocking density (in 2016 r., 98% of farms in Poland had stocking density up to 2 LU/ha), then the balance of soil organic matter (a positive result characterized 72% of farms), and winter vegetation cover (in this case, 61% of farms had winter crop cover that took up at least 1/3 the sown surface). As research results indicated, appropriate crop diversification was the most difficult to meet, which provided the relatively

low farms` percentage with desired crop structure (at least 3 different crop groups were cultivated by the fifth analysed farm, while only in the case of 30% of farms, cereals covered below 2/3 of cultivated arable land).

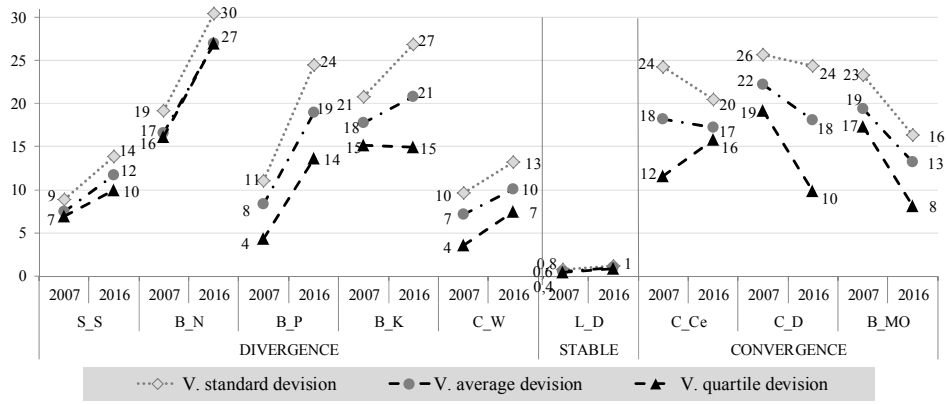
The evaluation of fertilizer balance, covering the main macronutrients, is more complex issue. The balance of individual components may be understated, optimal or overstated in comparison to the recommended level (threshold values). It is dictated by both local circumstances, including soil content in macronutrients, then supplied ingredient quantity to soil in the form of various fertilizers (natural, organic and mineral), as well as macroelement amount consumption by cultivated crops. The most difficult issue is to ensure optimum (recommended) balance, to not create excessive macroelement surplus (which may create hazard to natural environment), as well, the result may not be very low (which can lead to macronutrients depletion from soil, that requires restoration during the next years) (Kopiński, 2018). As 2016 data indicated, less than 6% of farms stands out desired nitrogen balance, and in the case of phosphorus is 7% of farms. While the least beneficial situation applies to potassium, as 3% of farms actually balances the ingredient.

Table 2. Farms` sustainability in Poland and voivodships in 2016 (% of farms fulfilling environmental sustainability criteria and synthetic indicator value)

No.	Specification	C_W	C_Ce	C_D	B_OM	L_D	B_N	B_P	B_K	S_S
1	Poland	61	30	20	72	98	5.5	7,1	2.5	0.74
2	Dolnośląskie	77	27	14	85	99	8.2	6.6	2.8	0.87
3	Kujawsko-pomorsk.	60	36	31	78	97	7.6	9.0	3.0	0.90
4	Lubelskie	60	27	21	78	99	6.4	8.5	2.7	0.81
5	Lubuskie	75	25	15	84	99	5.7	7.9	2.0	0.78
6	Łódzkie	63	23	17	75	97	8.3	7.9	3.0	0.84
7	Małopolskie	55	36	20	55	98	3.0	3.4	1.4	0.56
8	Mazowieckie	58	28	17	71	97	4.6	6.8	2.1	0.68
9	Opolskie	79	22	17	92	99	7.3	9.6	3.6	0.92
10	Podkarpackie	60	33	19	49	99	3.1	6.1	2.0	0.59
11	Podlaskie	45	38	21	61	96	3.7	5.2	2.0	0.62
12	Pomorskie	59	31	25	79	98	7.6	7.6	2.5	0.85
13	Śląskie	64	26	13	84	98	3.7	7.4	2.0	0.69
14	Świętokrzyskie	61	30	30	55	99	7.2	7.0	2.5	0.77
15	Warmińsko-mazurs.	58	44	23	76	97	4.1	4.3	2.5	0.72
16	Wielkopolskie	69	25	18	88	95	5.4	10.6	3.9	0.87
17	Zachodniopomorskie	68	41	19	83	99	6.9	8.8	1.4	0.85

* Sustainability criteria:, C – crops, W – in winter, Ce – cereals, D – diversification, L_D – livestock density per ha, B – balance: OM – of organic matter, N – of nitrogen, P – of phosphorus, K – of potassium, S_S – environmental sustainability synthetic indicator.

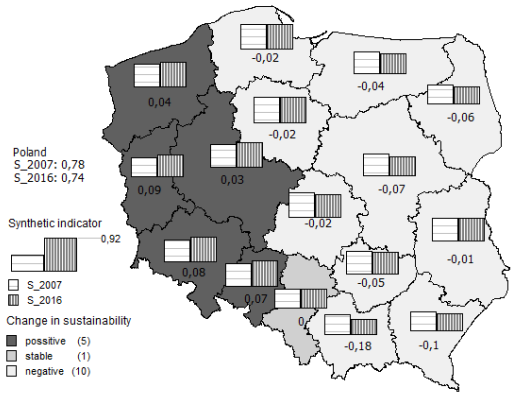
Source: Own calculation based on 2016 data of Central Statistical Office.



* signs as in tab. 1 and 2.

Source: Own calculation based on unpublished 2007, 2016 data of Central Statistical Office

Figure 1. Regional convergence and divergence of agriculture sustainability based on variation indicators (%)



* values on the map: change in synthetic indicator value of environmental sustainability (S).

Source: Own calculation based on unpublished 2007, 2016 data of Central Statistical Office

Map 1. Farms` environmental sustainability in Poland in 2007 and 2016 (synthetic indicator value and its changes)

In 2016, in the regional division, farms significantly differed from each other in terms of sustainability (considering most of analysed indicators). Only stocking density criterion didn't diversify farms between voivodships. While, the largest regional diversity concerned macronutrients balancing, as well as crop diversification, that was provided by the high level of variation indicators (fig. 1). Also synthetic indicator of farms` sustainability significantly differentiated farms between regions (V_{SD_2016} =14%), and the best outcome characterized Opolskie and Kujawsko-pomorskie voivodship, while the worst value concerned Podkarpackie and Małopolskie region.

Between 2007-2016 there were observed changes in farms` sustainability in Poland and its regional diversity. In the case of cereal indicator and soil production potential regenerating, progress was observed at the state level, while deterioration mainly concerned macroelements balancing. Positive changes were the effect of increasing surface of soil improving crops, especially legumes and papilionaceous. In the case of negative changes in agricultural production, the problem can be seen in terms of reduced natural fertilization (Wrzaszcz, 2018).

Synthetic sustainability indicator slightly decreased in Poland during the considered period (S_S_{2007} = 0.78, S_S_{2016} = 0.74). Having regard to the regional aspect, in most voivodships was observed deterioration in farms` sustainability level (of Central and Eastern Poland), while the improvement was found in Western side (map 1). Western voivodships are also an area with a high production potential, that can indicate wider farms` organizational possibilities.

Based on the value change of variability indicator of individual sustainability criteria in the period 2007-2016, convergence and divergence phenomenon was assessed (fig. 1). Taking sustainability synthetic indicator, voivodship diversity deepened, that was mainly the effect of increasing regional differences in macronutrients balancing in soil and assurance of adequate winter crop cover. Whereas the part of the regions become similar to each other in the scope of crop production organization and soil organic matter balancing, which means convergence process. Comparing those processes, it can be concluded that divergence process was more intensified (as was evidenced by larger differences in variation coefficients values between 2007 and 2016).

Conclusions

The article presents the proposal for measuring environmental sustainability of farms in Poland using the data of the Farm Structure Survey 2005, 2007 and 2016, putting particular attention to convergence process evaluation. Based on the research, the main conclusions are as follows:

- Statistical data collected under Farm Structure Survey 2005, 2007 and 2016, that are in possession of national statistical offices (in the EU members) and EUROSTAT, allow the multifaceted assessment of farms` environmental sustainability, including regional convergence of this phenomenon.
- Presented approach to research can be useful in the EU region analysis in the scope of sustainability diversification and agriculture development direction.
- Between 2005-2016 significant changes were observed in individual agriculture in Poland, which concerned land concentration and agricultural production simplification. Further intensification of those processes can bring environmental costs of agricultural activity.
- Agriculture at the regional level is significantly different in terms of production potential, and this phenomenon has deepened, reflecting regional divergence. Regional divergence in the largest extent applies to livestock production.
- Farms' environmental sustainability includes various issues related to crop and livestock production. Studies have indicated that the considered sustainability criteria differ in terms of difficulty level of their fulfilment.
- Agricultural holdings at the regional level significantly differed in terms of the environmental sustainability, which in particular concerned proper macroelement balancing in soil. In this respect, regional divergence is the most intensive.

- The presented results indicated a heterogeneous changes in farm environmental sustainability, also at the regional level. Taking into consideration synthetic indicator of environmental sustainability, some symptoms of regress were observed, that took place in the central and eastern Poland – the area with relatively lower production potential of agriculture.
- Regional diversity in the field of environmental sustainability deepens for most considered its determinants, which confirms the divergence process.
- Equalization of regional disparities requires the development of actions/programs at the local level, taking into account the production capacity of the region, resulting from agriculture production potential of a specific area.
- The accession of Poland to the EU has helped to partly improve farms` environmental sustainability as a result of rural development programmes implementation and conditional subsidising of direct payments (including greening, implemented in 2015). The presented farms` state is definitely not sufficient, thous additional governmental incentives are desirable to move forward environmental sustainability, especially such focusing on getting the distance of the regions with a lower sustainability.
- There was emphasized the need for further research to wider recognition of farms` sustainability and the causes of this phenomenon, both of external conditions (national), and arising from the peculiarities of individual regions (internal conditions).

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