

Changes in Farms' Environmental Sustainability in Poland—Progress or Regress?

Wioletta Wrzaszcz

Institute of Agricultural and Food Economics—National Research Institute

In the year 2012, the European Commission adopted the strategic document underlining the need for bioeconomy development, which requires the implementation of sustainable agriculture. In view of the above, the need for defining the direction of farm development arises, whether it is sustainable or industrial development. Research conducted on the basis of Polish public statistics from 2005, 2007, and 2016 indicated some progress in farms' sustainable development. Data analysis indicated that there is still a need to support farms in order to stimulate their environmental organization and desirable agricultural practice implementation.

Key words: farms, environmental sustainability, sustainable development, bioeconomy, Poland.

Introduction

Agriculture is one of the most important sectors that build the bioeconomy, especially the model of sustainable agriculture. Different benefits are the attributes of this model, e.g., production (allowing to ensure food security), economic (pertaining to income level), environmental (approaching to reduce the pressure of agriculture on the natural environment), as well as social ones (seeking to maintain the vitality of rural areas, ensuring safe food; Zegar, 2005). An important part is the rational use of agricultural production space to maintain the production potential of soil (Krasowicz, 2005).

The concept of sustainable development of agriculture is not uniformly understood and defined. The discourse is designated by two lines of thinking. The first takes as a basis the relation between the spheres i.e., a certain equilibrium. The second takes into consideration the meeting of certain criteria—critical thresholds of sustainability in the individual spheres (Zegar, 2005). Additionally, sustainable agriculture should be considered at the different levels of vertical order, paying particular attention to microeconomic level of sustainability—the farm level (Wrzaszcz & Zegar, 2016). Economic objectives are the most important in the case of farms, while others—social and environmental goals—should be achieved simultaneously, according to sustainability theory. Taking into consideration limited environmental resources, the superiority of this system should be the benchmark for the social and economic activity of farmers.

The main environmental requirement of farmers' activity is to maintain soil productive potential, which is one of the basic elements of the natural environment used in agriculture. The basic principles for conducting

agricultural production with respect for natural resources are suitable crop rotation and plant fertilization, adapted to local environmental conditions. Crop rotation—which can be defined as a rational sequence of cultivated plants, considering their diverse needs concerning position in crop rotation—comprises the canon of traditional agrotechnics (Manteuffel, 1984, p. 310). Proper crop rotation and fertilization should ensure a positive balance of soil organic matter, recognized as the basic principles of proper management in agriculture (Kuś, Krasowicz, & Kopiński, 2008, p. 13). Positive balance is the necessary condition for ensuring appropriate productivity of cultivated crops. Organic matter, and its conversion into humus, plays the main role in creating and maintaining soil fertility at a high level, i.e., favorable for plant growth and yields, and their physical, chemical, and biological properties. Humus content in the soil leads to obtaining crops of high quality and increasing yield level.

The above issues point to the important role of sustainable agriculture, including agricultural land, in the creation of the bioeconomy. Development of the bioeconomy is not possible without the implementation of sustainable agriculture, due to the need to provide agricultural biomass, produced in accordance with respect for natural resources and processes. Development of this model of agriculture comes in other sectors of the bioeconomy, at least in terms of renewable energy generation and distribution or the support of tourism in rural areas. The concept of the bioeconomy means an extensive strategy and action plan for the sustainable use of renewable biological resources in different areas of the economy. Maintaining natural resources and their rational use is leading to this concept (Adamowicz, 2016). In accordance with the guidelines, the bioeconomy should

lead to economic, social, and environmental benefits, mainly by eliminating negative impact of production on the natural environment. The bioeconomy includes a collection of sectors of the economy concerned with the production, processing, and use of resources of biological origin, including the agricultural sector (European Commission, 2012). The primary function of the bioeconomy is the generation of added value by use of renewable biological resources. It is based on natural resources, such as crop and livestock products, as well as microorganisms (Chyłek & Rzepecka, 2011).

In view of the above, the need for defining direction of farm development arises, whether it is to be sustainable or industrial development. As pointed out in the literature, agriculture development has found itself at a crossroads whose two main paths are designated by the model of industrial agriculture (one characterized by intensification of agriculture, concentration of production potential and production, specialization of agricultural holdings and entire regions, commercialization, and financialization) and the model of sustainable agriculture (one that considers not only production and economic outcomes but also social and environmental issues; Zegar & Wrzaszcz, 2017).

The accession of Poland to the EU in 2004 resulted in the launch of many programs to support economic development, including the development of agriculture. The orientation of the agricultural policy towards the sustainable development of agriculture and rural areas has been associated with implementing a series of measures and instruments facilitating the transformation of farms. In the case of Poland, these instruments have been mainly implemented since 2005. These instruments, on the one hand, were intended to promote the reorganization of farms in the environmental direction and, on the other, to improve their economic situation, which largely determines their innovation and competitiveness (Ministry of Agriculture and Rural Development, 2018). Now, several years after the Polish accession to the European Union, there is a need to identify the current sustainability level of farms. Identification and evaluation of progress in the field of environmental sustainability of agricultural holdings is particularly important in the context of present and future agricultural policy. The need for monitoring policy results is the basis for our recommendations and suggestions for the development of future agricultural policy. The literature review portion of this research is also important, because there is currently no clear scientific or political indication as to which direction Polish

farms should be supported and developed—sustainable or industrial.

The objective of the paper is to investigate the development patterns in farms' environmental sustainability which have occurred in Poland, over the years 2005-2016.

Environmental Sustainability—The Problem of Economics¹

The issue of sustainable development of agriculture is a problem of economic importance, both from the point of view of determining the value of the natural environment and the process of making optimal decisions. Operation of a profitable agricultural activity while respecting natural resources reflects the *trade-off* idea. Intensive agriculture can result in external environmental and social costs. The conflict means that improvement in one area (economic) may result in the deterioration of another (environmental). The ratio of economic benefits (unit's effect) to environmental ones (social effect) encourages actors to search for opportunities to implement the *win-win* principle. Resolving the conflict is certainly not easy. It seems that without appropriate political and financial support implementation of this principle is hardly feasible.

The optimum solution in economics is understood as achieving maximum effects with the available production resources (the static approach). On the other hand, in the dynamic approach this is not a simple quantitative relation but a qualitative one, related to the process of development. The process of agriculture industrialization was oriented towards microeconomic rationality connected with the maximum quantity of products, resulting in externalities.² Externalities can be viewed as the element that differentiates the optimum criterion of the entity (a business unit) and society. As a result, a question has arisen as to what kind of rationality, micro- or macroeconomic, should guide the further development of agriculture. The former one results in the production of food that is cheap, mass-produced, and often

1. See more in Wrzaszcz (2014).

2. The issues pertaining to externalities were discussed at the end of the 19th century by British neoclassical economist Marshall. In the 1920s, this term was specified in more detail by Pigou, co-author of the theory of welfare and a student of Marshall, who created the basis for neoclassical analysis regarding the justification for governmental intervention to correct externalities. In 1950s, Nobel laureate P.A. Samuelson developed the theory of public goods (Samuelson, 1954).

of doubtful quality, creating external costs and reducing public goods. On the other hand, the latter one leads to food products of higher quality, while respecting the limits of the ecosystem and minimizing environmental costs. Macroeconomic and social rationality is convergent with the idea of sustainable development of agriculture. The macroeconomic criterion should define the boundary conditions of agricultural production at the level of farm that, as an economic entity, is primarily focused on achieving the private optimum. In this case, a fundamental role is played by the political factor, which should provide internalization of externalities, in particular in the present economic conditions, as necessary due to the process of globalization (Zegar & Wrzaszcz, 2017).

The idea of sustainable development has been reflected in economic theory,³ ranging from neoclassical economics, which during the second half of 20th century began to include environmental issues, to ecological economics, which is based on the importance of ecosystem as a foundation of business activities. The theoretical foundation of neoclassical theory is based on the assumption of *homo economicus* and the market sustainability model. Such an approach does not correspond to the balance of the superior system—the social system, and all the more the environmental one. Supporters of neoclassical theory have noticed the issue of natural capital, which resulted from the exhaustion of those resources and increasing degradation of the natural environment. The fundamental issue of the theory is the treatment of natural capital only as a production factor, in addition an insignificant one, that loses its importance. According to this concept, the natural environment has been subordinated to human activities (Prugh et al., 1999, p. 16-19). Most neoclassical economists assume that environmental services will be replaced by new technologies (Costanza, Cumberland, Daly, Goodland, & Norgaard, 1997, p. 69).⁴ At the same time, natural boundaries of economic growth have been rejected.

The idea of sustainable development is based upon a theoretical foundation in ecological economics,⁵ which assumes superiority of the natural environment over economic development (Figure 1). According to ecological economics, the economic system may be developed

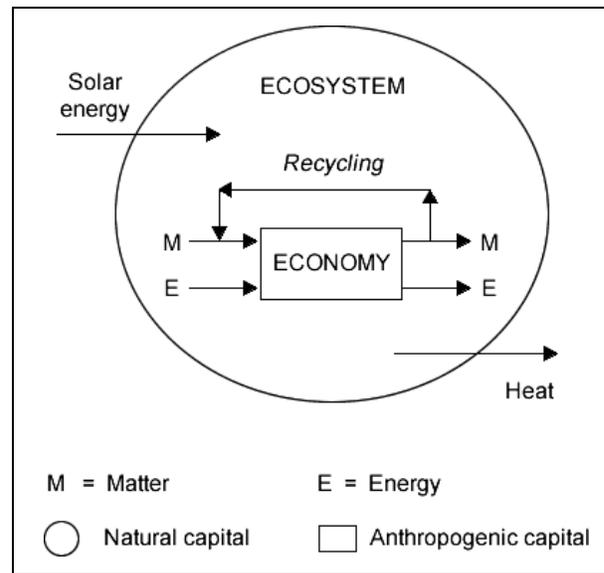


Figure 1. Economy as a subsystem of the global ecosystem in ecological economics.

Source: Prugh et al. (1999, p. 20).

only within an environmental system because the global ecosystem has its natural boundaries. In this system, the natural environment is the most significant factor that determines the limits of human existence and activity, including agriculture (Baker, 2006, p. 27-35; van Loon, Patil, & Hugar, 2005, p. 3). The interest of supporters of a hierarchical system is focused on the protection of natural resources, including setting the threshold of environmental security. Departure from material to natural capital as a factor that limits the existence is a function of the growing scale and impact of human activity (Prugh et al., 1999, p. 102). In order to maintain business activity within limits that are safe for the biosphere, it is necessary to find an appropriate environmental policy of the state (Costanza et al., 1997, p. 85-86).⁶

3. The review of the theory of economics concerning the positioning of sustainable development problems, including the need for environmental protection, is presented in Poskrobko (2012) and Rogall (2012), among others.

4. Nobel laureate R. Solow even claimed that the world may actually cope without natural resources (Solow, 1974).

5. Ecological economics was established in mid 1980s by economists and environmentalists from Sweden and the United States. In 1989, the International Society for Ecological Economics (ISEE) was established (Costanza & Daly, 1987; Costanza et al., 1997, p. 48-49; Jansson, 1984).

6. Rogall (2010, p. 25-26) distinguishes the economics of sustainable development as a wider theory in comparison to ecological economics. According to Rogall, the essential differences between these theories relate to economic and socio-cultural matters. The economics of sustainable development is generally recognized as a continuation of ecological economics, however, as these two schools are similar on most issues.

Agriculture Sustainability Measurement—A Few Comments

Measuring the sustainability of agriculture is a very complex issue, as underlined in numerous scientific studies.⁷ The phenomenon is defined and measured differently by various researchers.⁸ Diversified approaches to sustainability measurement are dependent on the level of agricultural activity analysis, data accessibility, and statistical methodology implementation. Most of the research is carried out at the level of a country or region, and less frequently at the farm level. Typically, researchers apply evaluation of non-pattern methods, applying a wide list of indicators with varying degrees of detail and substantive justification. A multitude of indicators have been used, which often makes it difficult to unambiguously interpret research results or directly compare the results of different studies. In addition, many studies are based on research samples that may not be completely representative, making it impossible to generalize their

conclusions to the wider population of farms in that country or to compare the results of studies done in different countries. The issue also was complicated by the condition that the measurement of agriculture sustainability should be adapted to local conditions and specific agricultural production areas (region, country, etc.).

The common approach to this issue is associated with using certain indicators related to three aspects of sustainability: environmental, economic, and social (Pretty, 2008; The Royal Society, 2009; van Huylenbroeck & Durand, 2003; Woś & Zegar, 2002). The indicators measuring the sustainable development in general, formulated by international organizations, are also useful in measuring the sustainable development of agriculture. However, they usually require adaptation to the specific nature of this economic sector (Commission of the European Communities [EC], 2000; EC, 2008, Food and Agriculture Organization of the United Nations [FAO], 2013; Organisation for Economic Cooperation and Development [OECD], 1999, 2001; Schaefer, Luksch, Steinbach, Cabeca, & Hanauer, 2006). Attempts in this field using a variety of approaches have not resulted in a generally accepted set of indicators to measure sustainability. There have also been attempts to formulate a synthetic indicator of farm sustainability (e.g., Feledyn-Szewczyk & Kopiński, 2015; Harasim, 2014; Wrzaszcz, 2014).

The difficulties in measuring agricultural sustainability have many causes. First of all, the term sustainable agriculture is not clearly defined. Measurement is hampered by the multifunctionality of agriculture; a huge diversity of farms; different directions of the same effects on the environment, production, and economic performance; the diverse aspirations of farmers; and others. Commonly, most attention in research is paid to environmental order, which was the basis for the idea of sustainable development (or, more precisely, a dramatic violation of this order). The term “sustainability” originates in ecology and refers to the capacity of an ecosystem to regenerate (Reboratti, 1999). The global ecosystem is finite and contains limited resources in terms of raw materials that may be used for economic development, as well as the possibility of adopting and disposal emissions as a result of economic development

7. *International research on an environment-friendly agriculture was started on the initiative of the European Commission in the early 1990s, by the establishment of COST Action, which was aimed at developing a system of integrated environmental production at the farm level. A tangible outcome of the works that lasted several years was constituted by the models (prototypes) of agricultural holdings with integrated production. The characteristics of an environmentally friendly farm were defined, and the following issues were considered the most important ones: multifunctional crop rotation, sustainable fertilization, rational cultivation of plants, construction of environmental infrastructure, integrated plant protection, optimization of organization in farms (assurance of a proper income). The research pointed out that assessment of environmental friendliness of agriculture should include specifics of habitat conditions and the regional conditions of agriculture, and it should refer to the generally accepted standards of agri-environmental indicators, which are the determinant of the desired or acceptable level of a parameter (Bockstaller, Girardin, & van der Werf, 1997; Halender & Delin, 2004; Vereijken, 1997, 1999). Empirical research in agriculture and farms' sustainability has been conducted intensively from the beginning of the 21st century, particularly in North America and Europe (e.g., Brennan, Ryan, Hennessy, Cullen, & Dillon, 2016; Cauwenbergh et al., 2007; Eilers, MacKay, Graham & Lefebvre, 2010; Gomez-Limon & Sanchez-Fernandez, 2010; O'Donoghue et al., 2016; Osteen, Gottlieb, & Vasavada, 2012; Paracchini et al., 2015; van Loon et al., 2005). In parallel, for many years, studies in this field have carried out in Poland, that were concentrated on micro-level (farm level) analysis (e.g., Faber, 2007; Harasim, 2014; Harasim & Włodarczyk, 2016; Jankowiak & Bienkowski, 2007; Madej, 2015; Majewski, 2008; Sadowski, 2012; Toczyński, Wrzaszcz, & Zegar, 2009; Wilk, 2005; Wrzaszcz, 2014; Zegar, 2012).*

8. *In the paper, those research approaches and results were not compared. Some comparative studies have studied this phenomenon (e.g., Herrera et al., 2016; Latruffe, Diazabakana, Bockstaller, Desjeux, & Finn, 2016; de Olde, Oudshoorn, Sørensen, Bokkers, & Boer, 2016; de Olde, Sautier, & Whitehead, 2018).*

and anthropocentric pressure. This is reflected in the already established facts exceeding 3 of 9 identified biophysical thresholds (Rockström et al., 2009, p. 472-475). It is not possible to maintain the pressure exerted by industrial agriculture on natural environment in the long-term future (Zegar, 2018, p. 65). Those arguments emphasize the need of agriculture-natural environment relation capture.

A separate, although very important, issue is the development of a method to measure agricultural sustainability⁹ that would enable international application. In connection with the use of various definitions of sustainability, various data (from various sources and studies), as well as various study methods (including different indicators and synthesis methods), the results obtained for the sustainability of agriculture in a specific country are usually not useful for making 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 be used when making an international comparison of agricultural sustainability, including farms, in an economic dimension.¹⁰ The comparability of data is provided by EUROSTAT, although the scope of this data does not make it possible to study the sustainability of agriculture (farms) to the full extent, thus, it does not exhaust the scientific theoretical considerations.

Research Method

Data and Research Approach

Public statistical data from the 2005, 2007, and 2016 Farm Structure Survey (FSS) of the Central Statistical Office were used.¹¹ FSS research is carried out in individual EU countries, and results are finally aggregated

in EUROSTAT databases. The proposed use of data from FSS to measure the environmental sustainability of farms and agriculture can be applied to other countries to conduct comparative analyses between them, taking into account the different requirements of sustainability. The analyzed period allowed researchers to identify the state of farms prior to the implementation of the CAP instruments and after multi-annual implementation of different mechanisms directed toward agricultural producers. These data were collected on the basis of uniform methodology in the analyzed years that allowed us to investigate the direction in which Polish agriculture tends with regard to environmental sustainability.

The aim of this research was to propose a method of evaluating farm sustainability based on public statistical data that can be comparable with other international outcomes. The idea of the research was the use of available and reliable statistical data to evaluate the population of farms, and next the agricultural sector. Taking the above into consideration, a few methodological assumptions were adopted in the study.

The first assumption was associated with using representative data of the Polish agricultural sector. Such studies were conducted under FSS, which is generally not used to assess farm sustainability, because of methodological difficulties and the problem of micro-data access. FSS studies are conducted cyclically in each EU member state. Thanks to the cooperation of the regional Statistical Office in Olsztyn, which is responsible for agricultural sector data and manages those unit data, the study of the Polish agricultural sustainability was carried out. We selected the research method based on individual data of farms in Poland.

The second issue was to identify and adjust the scope of the available FSS data to sustainability measurement. This identification indicated that such a partly economic assessment can be developed in the field of environmental sustainability (Wrzaszcz, 2018), while issues such as the value of the capital or farms' outcomes must be passed over because of the limited scope of FSS research. The question of the scope of collected data in the FSS framework determined further selection of environmental sustainability indicators.

The third issue was indicator model (pattern) evaluation—the choice of those indicators, which were substantially justified and had indicated reference values enable to evaluate sustainability phenomenon (positively or negatively). Reference values of indicators were important to state clearly whether the critical level in analyzed scope was exceeded or not¹². The use of multiple sustainability indicators in research, without

9. *The sustainability of agriculture is determined by the sustainability of farms, although the latter does not exhaust the first (Toczyński et al., 2013).*

10. *Feasibility of collecting sustainability data (farm level considerations based on Farm Accountancy Data Network) were the research problem presented in (Vrolijk, Poppe, & Keszthelyi, 2016).*

11. *Statistical charts were prepared in the Statistical Office in Olsztyn, in connection with the realization of Multi-Annual Programme 2015-2019; research task "Dilemmas of sustainable agricultural development in Poland."*

their explicit evaluation, obstructs their interpretation in the context of ecological economic theory, which refers to the economy not exceeding the critical threshold values of the natural environment.

Additionally, environmental sustainability measurement should be adjusted to the specifics of local agriculture. Farms with crop production (arable land cultivation) dominate in Poland, thus most indicators correspond with crop rotation, soil quality, and fertilization practices (as the effect of crop and livestock production organization). Hence, indicator selection was based on both substantive considerations and statistical premises.

The fourth issue was arrangement of the level of data calculation within the framework of cooperation with the regional Statistical Office. The Statistical Office calculated the specific values of the indicators at the level of individual agricultural holdings, on the basis of the author's methodology. Researcher's analyses were conducted on aggregated data, prepared according to substantive premises and legal statistic circumstances.

The analysis concerns all individual agricultural holdings with at least 1 ha of agricultural land maintained in good agricultural and environmental condition. The research also eliminated farms with legal personality,¹³ due to differences in organization, functioning, and production potential in comparison to individual ones.

The farms' characteristics concerning economic and production potential used in the research were the following: area of agricultural land (ha), labor input (expressed in annual work units [AWU]),¹⁴ animal population (livestock units [LU]),¹⁵ the value of standard output (thousand Euros)¹⁶ and standard gross margin (European Size Units—ESU)¹⁷. The authors adjusted the FADN methodology of farm typology to the scope

of public statistical data and reference indications to calculate average values of standard output and standard gross margin for further research development.¹⁸

Environmental Indicator Selection

The environmental sustainability of farms was established and assessed based on the environmental indicators.¹⁹ Each of the selected indicators was calculated on the farm level. Selected indicators allowed determination of crop diversity, stocking density, and the level of fertilization.²⁰ An important determinant of the organization of agricultural production is the balance of soil organic matter. The selected references in this paper concerning environmental indicators can be treated as the state of the art, that were useful in practice—in sustainability measurement of farms, adopted to model (pattern) farms' evaluation, as well as available and representative data of the Polish agricultural sector.

The indicators are a stimulants, destimulants or nominants of farms' sustainability, with varied significance in the context of environmental sustainability. The study assumes that each indicator is equally important in the assessment of farm sustainability, hence there is no ranking of indicators. As a point of reference in farm sustainability evaluation, certain indicator thresholds were established (Zegar, 2005). Those thresholds were used in farm environmental sustainability evaluation as

12. *The approach to sustainability measurement based on the indicator reference values was also presented in Cauwenbergh et al. (2007).*

13. *In Poland, excluding individual holdings there were also 4,100 farms owned by legal persons (2016), using 1,249 thousand ha of agricultural land (8.6% of agricultural land in total) and producing standard output with a value of EUR 2,314 million (9.5% of total value).*

14. *1 AWU is equivalent to full-time, that is, 2,120 hours of work a year.*

15. *1 LU is a conventional unit of farm animals with a mass of 500 kg. See tables of conversion coefficient for livestock from physical units to livestock units (Toczyński et al., 2013).*

16. *Standard output is the mean of 5 years of the value of production corresponding to the average situation in the region.*

Total standard production of farms is the sum of the values obtained for each agricultural activity on the farm by multiplying the coefficients of the standard output for a given activity and the number of hectares or number of animals; see (Goraj et al., 2012). It is an economic category that allows for comparing the volume of production, while offsetting the impact of price fluctuations in regional and temporal terms. There were used 2013 standard output indicators (based on the average values for the period 2011-2015).

17. *Sum of standard gross margins (SGM)—the difference between output and specific (direct) costs of all activities occurring on the farm—indicates the economic size of the farm, otherwise the productive potential of the farm. 1 ESU is equivalent to EUR 1,200. The standard gross margin is the average gross margin by region. Standard gross margin on a particular crop or animal is a standard (average of three years in a particular region) value of production obtained from one hectare or from one animal less the standard direct costs necessary to produce. There were used 2004 standard gross margin indicators - the last SGM calculated indicators, used in Farm Accountancy Data Network (FADN). In subsequent years, there was used FADN farms' typology based on the coefficients of standard output.*

model (pattern) approach. The indicators presented are not, however, a universal list, but they bring a measurable range of farms' environmental sustainability, adapted to the substantive criteria and available official national statistical data.

The following indicators have been included as determinants of environmental sustainability (Harasim, 2014; Toczyński, Wrzaszcz, & Zegar, 2013; Wrzaszcz, 2014):

- **The share of cereals in crop structure on arable land** determines the correctness of crop rotation and the degree of agronomic biodiversity. Narrow specialization of crop production (crop monoculture or crop production with low species diversity) shows that such agricultural practices are far from the ones included in the principles of sustainable agricultural development (Faber et al., 2010). A high share of cereals in the crop structure means that they must be sown after each other throughout a period of two, three, or more years. Such agricultural practices prevent the use of proper crop rotation, resulting, among other things, in the spread of diseases among crops, the growth of weeds, higher threat of infestation by pests, or impoverishment of organic matter in the soil (Grabński, 2011; Smagacz, 2000). The consequence of consecutive cereal crop production for several years is a marked decline in their performance, which depends largely on the cultivated species, habitat conditions, and the level of agricultural technology (Smagacz, 2011). 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 a complementary indicator to the one above, indicating 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 crops, root crops, industrial crops, grasses on arable land, and other crops (Toczyński et al., 2013).

Proper organization of crop production should be based on multifunction crop rotation, whose principal functions include the providing the soil with suitable physicochemical and biological properties (fertility), thus generating good conditions for growth and yield of plants, protecting against soil erosion, preventing nutrient leaching (primarily nitrogen into groundwater and drainage), and reducing weeds and crop pathogens, so that crop productivity can be less dependent on the use of chemical crop protection (Majewski, 2008). Crop rotation, which can be defined as a rational sequence of plants one season after another, taking into account their diverse requirements for their position, belongs to the canons of traditional agricultural technology (Manteuffel, 1984). Unfortunately, with the progress of mechanization and the use of chemicals, the classical form of crop rotation was abandoned, often resulting in monoculture. Very low crop diversity is particularly problematic with reference to the chemical control of insects and diseases. Overly simplified crop rotation results in an imbalance between various organisms, causing increased incidence of pathogens and reduced soil fertility, thus having a negative impact on crop yield and favoring weed compensation (van Loon et al., 2005). According to research, the value of these crop rotation indicators is strongly correlated with participation in the structure of sown cereals on arable land (Majewski, 2008). The crop structure is the primary determinant of the crop rotation ability, which reflects the degree of crop diversity. From the environmental point of view, the more diverse it is, the better (Nieżgoda, 2005). The crop structure, however, is changed on an annual basis, and the degree of utilization of arable land by farmers is essential to improve the level of income and to shape the quality of natural resources, in particular land and water.

- **The index of vegetation cover on arable land in winter** is a synthetic indicator for the assessment of land resources, the balance of ecosystems and the degree of implementation of a sustainable production system in agriculture (Harasim, 2009). Vegetation cover should be at least 1/3 of the crop area.

Vegetation cover during the winter prevents negative impact of climatic factors such as rain and wind on soil. Growing plants on arable land during the period between the two main crops reduces water pollution (it reduces the risk of nitrate leaching) and protects the soil from erosion (Faber et al., 2010; Krasowicz, 2005). It is advisable for the cropped area of winter plants to be as

18. According to those indicator values, Statistical Office in Olsztyn could calculate farms' typology and prepare further data aggregation.

19. The issue of farms' economic sustainability was presented in: (Wrzaszcz, 2018).

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.

large as possible. It is particularly dangerous to leave the soil without plant cover for a longer period because as a consequence of the destructive impact of rainfall, wind and sunlight, soil is subject to physical, chemical and biological degradation (Dębicki, 2000).

- **Livestock density on agricultural land** provides information about the level of livestock intensity, and also indicates the scale of the environmental impact of natural fertilizer (Kopiński & Madej, 2006; Kuś, 2006). Livestock density should not exceed 2 LU/ha. This limitation stems from the likelihood of exceeding the capacity for manure absorption by the agri-ecosystem (Faber et al., 2010). The admissible level of livestock density on agricultural land should be based on the equivalent of the legally permissible dose of livestock manure amounting to 170 kg of nitrogen per hectare of agricultural land (Dz. U. No. 147, item 1033; CEC, 1991). Each European Union Member State was required to determine the equivalent of the amount of nitrogen in the number of livestock units.
- **Balance of soil organic matter on arable land** reflects the results of crop rotation and systematic enrichment of the soil with humus. The reference value should be positive, above zero.

Proper crop rotation and plants fertilization should provide a positive balance of soil organic matter. Balance outcome is considered an important ecological indicator (Krasowicz, 2005), an important element of assessment of organization and plant production (Harasim, 2006) and a basic principle of good management in agriculture (Kuś et al., 2008). Soil organic matter is a set of all organic compounds except for the non-decomposed parts of plants, the remains of animals, and living microorganisms (Gosek, 2008). Organic matter and its transformation into humus compounds play a vital role in creating and maintaining soil fertility at a high level, i.e., physical, chemical and biological properties favorable for the growth and yield of plants. The content of humus in soil results in good quality and high level of achieved crops. The balance of organic matter reflects the soil quality level, which is in part a result of human activity, which may be conscious or may result from lack of knowledge and concern about the quality of basic agricultural production factors (Harasim, 2006).

- **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, livestock density, and crop yields (Kopiński, 1999). The optimal level of NPK balance is regionally diverse (Kopiński, 2017).

Sustainable agriculture must preserve nutrient cycling (fertilizers—soil—plants) (Kopiński, 2006) in as much of a closed system as possible. Fertilizing is an essential yield-generating factor and one of the main indicators to assess farming intensity (Igras & Kopiński, 2007). Fertilization level should be adapted to the nutrition needs of the cultivated crops and the conditions of a specific habitat (soil quality, climate) since the reversal of the irrational fertilizing practices is very difficult, and often impossible. Fertilizing should balance the nutritional needs of plants, but at the same time it should not create too high macronutrient reserves in the soil. Deviation from the optimum condition adversely affects the environment (Fotyma, Igras, Kopiński, & Podyma, 2010). Nitrogen and phosphorus compounds are considered the most serious threat generated by agriculture, as they can enter groundwater and surface water and, in the case of nitrogen, can also escape into the atmosphere (Kopiński, 2007, 2010). Unsustainable fertilizer management has an adverse impact on the profitability of production and also poses a serious threat to the health of humans and animals. Over-fertilization leads to economic losses that result from higher costs incurred to practice industrial production and from lower crop yields, in terms of both weight and quality. Unfortunately, too low fertilization—a deficit of even one nutrient—contributes to the underutilization of soil productivity and production capacity of plants, and therefore lower yields. Nutrient deficiency also leads to a reduction in soil fertility, and sometimes even to its degradation. Renewal of the reserves of phosphorus and potassium on heavily depleted soils is very costly and time consuming.

Due to environmental reasons, agricultural production profile is particularly important. It justified including farming type in the analysis of farms' environmental sustainability (Wrzaszcz, 2014, 2017). In accordance with the specification used in EUROSTAT and agricultural accounting system FADN, we applied the General Types of Farming (GTF) classification, based on agricultural standard output value (Bocian, Cholewa, & Tarasiuk, 2017; Goraj, Bocian, Cholewa, Nachtman, & Tarasiuk, 2012). According to this classification, farming types reflect a farm's agricultural production orien-

Table 1. Number, production, and economic characteristics of individual farms in Poland.

No.	Specification ^a	In agricultural sector				Per an average farm		
		2005	2016	Change		2005	2016	Change
				Numbers	Percentage ^b			Percentage ^b
1	Farms' number (thousand)	1,723.9	1,398.1	-325.8	-18.9	x	x	x
2	Agricultural land (thousand ha) ^c	13,060.6	13,181.4	120.8	0.9	7.6	9.4	23.7
3	Labor input (thousand AWU)	2,035.2	1,617.0	-418.2	-20.5	1.18	1.16	-1.69
4	Livestock (thousand LU)	6,430.3	5,923.5	-506.8	-7.9	5.2 ^d	8.3 ^d	59.6 ^d
5	Standard output (million EUR) ^e	20,824.1	21,824.3	1,000.2	4.8	12.1	15.6	28.9
6	Standard gross margin (thousand ESU)	9,963.9	9,283.4	-680.5	-6.8	5.8	6.6	13.8
7	Standard output (thousand EUR/ha)	x	x	x	x	1.59	1.66	4.40
8	Standard gross margin (ESU/AWU)	x	x	x	x	4.90	5.74	17.14

^a Units for agricultural sector

^b "-"decrease

^c agricultural land cultivated according to GAEC requirements

^d average livestock number in livestock farms

^e for sector in million EUR, per farm in thousand

Source: Prepared on the basis of FSS 2005 and 2016 data

tation and activity, as well as the scope of specialization. Farms are classified into the following types: 1) specialized in field crops, 2) specialized in horticulture, 3) specialized in permanent crops, 4) specialized in rearing grazing livestock, 5) specialized in rearing granivores, 6) non-specialized with mixed crops, 7) non-specialized with mixed livestock, 8) non-specialized with mixed crops and livestock.

Livestock production is of key importance for the natural environment. Its main positive impact comes through the use of livestock manure in crop fertilization, thus enriching soil organic matter. Achieving a balance of soil organic matter and macronutrients is much more difficult in farms without livestock. Potential threats to the ecosystem are also observed in the case of highly intensive livestock production due to ammonia emissions and the risk of groundwater pollution. As indicated in numerous studies, farms with mixed plant and livestock production are characterized by the highest level of environmental sustainability (Wrzaszcz, 2014, 2017; Zegar, 2012). In the case of mixed farms, the connection between crop and livestock production is much stronger than in other types of agricultural holdings. Two important elements interact here, namely: the adjustment of the structure of field crops for animal forage requirements and the use of natural fertilizers in crop fertilization. Those links reduce the dependence of agricultural holdings on external entities, in terms of the purchase of feed and chemical fertilizers. The use of natural fertilizers and a relatively low input of industrial means of production result in higher quality agricultural products.

Relatively lower livestock density in the non-specialized farms, relative to these specialized in livestock production, limits the risk of local water and soil contamination (Kopiński, 2010). Empirical studies also confirm the favorable results of fertilizer balance in the case of mixed farms (Kopiński, 2006). A diversified crop structure and the use of natural fertilizers are also factors determining the maintenance of soil production potential, one of the basic requirements of sustainable agriculture (Krasowicz, 2005; Kuś et al., 2008).

Research Results

Changes in Agricultural Production Potential in the Period 2005-2016

Agriculture in Poland has changed significantly over the last several years. These changes concerned mainly the number of farms, their potential and production profile, as well as their economic outcomes (Table 1). In 2016, 1.4 million individual farms with an area of 1 ha or more of land in good agricultural condition operated in agriculture. Comparing 2016 to 2005, the number of those farms decreased by almost one-fifth. These were significant changes, indicating the withdrawal of many farmers from this economic activity. The reasons for this transformation can be seen in the fact that agricultural producers chose the state pension (by virtue of reaching the required age) and early retirement (for farmers of working age), and undertook other economic activities not related to agriculture. Economic conditions in agriculture have led farmers to cease this activity, in particu-

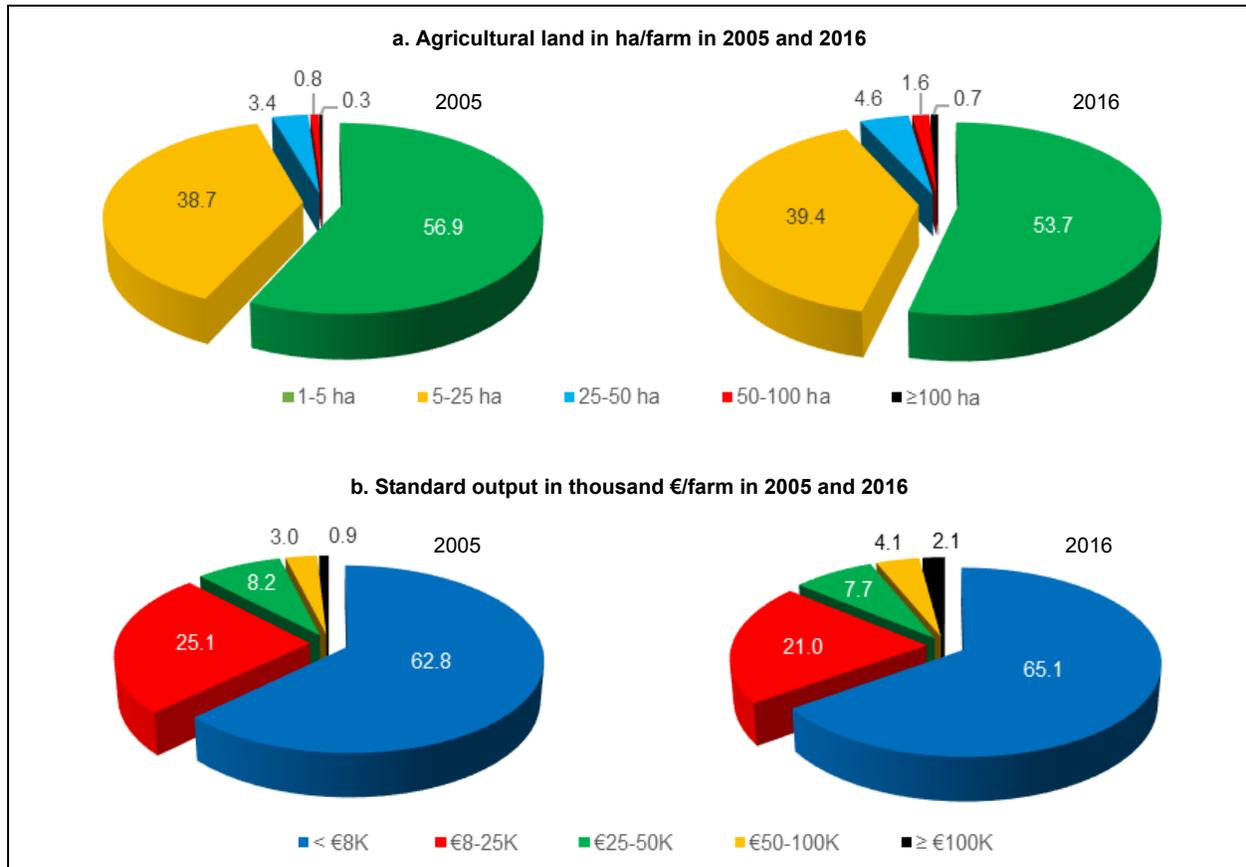


Figure 2. Farm structure according to production and economic potential.

Source: Prepared on the basis of FSS 2005 and 2016 data.

lar farmers who were also simultaneously engaged in some other economic activity. Economic conditions outside of agriculture, in other sectors of the economy, were relatively favorable, which encouraged some farmers or potential farms' successors to take up economic activity in another sector.

The area of utilized agricultural land in good agricultural condition was more than 13 million ha. The area of agricultural land in absolute terms increased by 121 thousand ha, which was the result of a new program of direct payments for maintaining land in good agricultural condition. Before Poland's accession to the EU, this land was not used and was partially set aside. The legal obligation to restore land use or to maintain it in a form of fallow land (i.e., land maintained in good agricultural condition) has been translated into the environmental-oriented agricultural practices of their users. Farmers interested in receiving direct payments were required to follow certain agricultural practices on agricultural land in the payment program.

In the analyzed period, there were significant changes in the production and economic structure of farms (Figure 2a). Taking into account the area of agricultural land used on the farm, the share of the smallest farms with an area of 1-5 ha decreased, while it substantially increased in the case of medium and large farms with an area of 25 ha or more, particularly those with an area of 50 ha or more. These confirmed the thesis of the process of progressive land concentration in large and very large farms, which gradually increases their production potential. In the analyzed period, average farm area increased by 24%, to 9.4 ha.

At the same time, human labor inputs in agriculture have been significantly reduced, by one-fifth. These changes resulted from reduction in the number of farms and an increase in average farm area. Another important factor was the changing agricultural production technology, resulting from modernization of farms (Kusz, 2012; Kutkowska, Berbeka, & Pilawka, 2015; Zegar, 2012). The observed substitution of human labor on farms with objectified labor (costly investments or changes in agri-

Table 2. Structure of farm types.

Year	Types of farming							
	I	II	III	IV	V	VI	VII	VIII
	Specialized in:					Not specialized with:		
	Crops		Livestock			Crops	Livestock	Crop & livestock
2005	40.97	1.61	2.86	10.66	1.90	3.67	7.89	30.45
2016	57.81	1.63	4.20	11.21	2.13	3.30	3.53	16.18
Difference in percentage points	16.84	0.03	1.34	0.55	0.23	-0.36	-4.36	-14.27
			19.00				-19.00	
		18.21		0.79				

Source: Prepared on the basis of FSS 2005 and 2016 data.

cultural production technology by simplification, automation, and mechanization) stemmed, to a significant extent, from the support for agriculture under rural development programs covering co-financing of costly investments (including improvements in buildings and the purchase of agricultural equipment; Czubak, 2012, 2013; Kuś & Matyka, 2014; Wigier, 2009; Wójcicki & Szeptycki, 2016). With regard to an average farm statistics (Table 1), human labor input in 2005 and 2016 were comparable.

In the analyzed period, an 8% decrease in the livestock population was observed. Simultaneously, farms specializing in the livestock production showed a 60% increase in scale, confirming the progressive specialization of livestock farms and livestock concentration.

Farm economic potential is measured by standard output and standard gross margin. In the analyzed period, standard output reportedly increased by nearly 5%, while standard gross margin decreased by 7%. Discrepancies between these categories result from a significant impact on the direct costs of agricultural activity. This increase was particularly related to the prices of industrial means of agricultural production, including mineral fertilizers, plant protection products, animal feedstuffs, and feed additives. In addition, in the analyzed period the dependence of agricultural production on external (industrial) means of production increased, as a consequence of the more and more common separation between the crop production and livestock production on farms.

The structure of the economic potential of farms has also changed considerably (Figure 2b). Similar trends appeared in the distribution of farms by standard gross margin and standard output. The share of the smallest farms (those generating standard gross margin of up to 4 ESU, as well as producing less than EUR 8,000) increased, which indirectly relates to farms with the lowest economic potential resigning from agricultural

production. At the same time, the share of medium farms decreased in favor of large farms. The biggest changes applied to very large farms, which accounted for only 1% of farms' population in 2005, while their share increased to more than 2% in 2016. The presented farm structures point to an increase in farms with greater production and economic potential. In the analyzed period, the average farm significantly increased its area, which resulted in an improvement of almost 30% in standard output and 14% in standard gross margin.

Presented values indicate an improvement in farms' economic sustainability in the analyzed period, especially regarding labor efficiency (about 17%). This decrease in potential labor costs was not only the effect of standard gross margin improvement, but also, or even mostly, resulted from a significant decrease in labor input, the effect of farm reorganization towards agricultural production simplification and specialization (Tłuczak, 2016; Ziętara, 2014).

Changes in Agricultural Production Direction and Farming Types

During the period there have been significant changes in the structure of agricultural production (Table 2). Many farms resigned from livestock production; the number of farms with livestock decreased by 43% in Poland (from 1,247,600 farms in 2005 to 712,600 in 2016). Livestock production is a section of agricultural production that requires significant labor inputs, a large involvement of the farmer in daily on-farm duties, and investment connected with buildings and animal welfare. The outflow of labor force from agriculture and the transformation of farms related to the simplification of agricultural production contributed to the trend away from the labor-intensive and demanding livestock production. This process has had a negative environmental impact, due to a reduction in the amount of natural fertilizers of livestock origin and the progressive depen-

dence of agricultural production on mineral and chemical fertilizers. The measurable effect of reducing the amount of natural fertilizers in non-livestock farms is also a change in the balance of soil organic matter, which may be reduced partly by reorganizing agricultural production towards increasing structure-forming crops or purchasing natural fertilizers from producers involved in large-scale livestock production.

Presented changes in agricultural production direction are reflected in farms' typology. According to *General Types of Farming*, both in 2005 and in 2016, farms specialized in field crops (Type I) dominated, and their share strongly increased during this period. It should be added that this is the only farm group that so greatly increased their numbers. Non-specialized farms with crop and livestock (VIII) were in second place, and their percentage decreased by half in the research period. These changes can be considered as disadvantages in terms of farms' environmental sustainability. Narrow specialization in crop production requires significant organizational activities to ensure the indicated level of environmental sustainability (e.g., the use of straw as organic fertilizer or the increasing share of cultivated plants that build soil structure and organic matter). Simultaneously, a significant decrease in numbers was visible in the case of non-specialized agricultural holdings with mixed livestock (VII). At the same time, the comparable share of farms specialized in livestock production, precisely in cattle and rearing granivores (IV and V), remained in the analyzed period.

Presented numbers indicated that in the last decade the process of farm specialization was observed; the number of specialized agricultural holdings significantly increased (mainly specialized in field crops), at the expense of those with mixed production, especially mixed livestock and crop production. A significant portion of non-specialized farms ceased livestock production during the period, solely or mainly in favor of field crops.

Changes in Crop Structure Organization

The structure of crops, next to natural fertilizers, determines a farm's environmental sustainability. In this case, the area under cultivation of soil improving crops, including legumes, grasses, as well as their mixes, gains particular importance. This study allowed us to verify the change in this dimension. Table 3 shows the land area devoted to various main and catch crops, including winter vegetation cover.

In Table 3, cultivated crops are grouped according to their impact on the content of soil organic matter. Based on the values of the coefficients of land reproduction and degradation, the largest negative impact comes from root crops, then vegetables and maize, and finally cereals and industrial plants. In contrast, crops that improve soil structure are classified as legumes and grasses. Winter vegetable cover crops, as well catch crops, are of particular importance in soil protection. As Harasim (2006) indicated, the share of crops that increase soil fertility, including catch crops, are useful indicators to evaluate the structure of sowings. In 2016, crops adversely affecting soil condition occupied the dominant area of arable land (the predominance of cereals, industrial crops, and corn for fodder). Subsequently, approximately 9% of the area is allocated for crops improving soil fertility. This share is significantly smaller than recommended, since crops that improve soil condition should occupy 20% of sown area (Harasim, 2006), while the root crops take up only 5%.

The changes that have taken place in the area and the sowing structure over the years 2005-2016 should be recognized as beneficial in terms of soil condition improvement. In this period, share of area of cereals and root crops decreased, but there has been a significant increase in the area of maize for livestock feed, which belongs to the plants that degrade soil. Underlining the fact that the area of soil improving crops has increased by 51%, hence their share in the structure of sown area increased from 6% to 9% over the analysis period. Despite the favorable direction of change and its dynamics, further progress in this area is necessary to create wider opportunities for the application of crop rotation. A significant proportion of cultivated main crops formed winter vegetation cover. Winter species accounted for 44%, both in 2005 and 2016. This percentage must be regarded as sufficient because, on average, spring crops are cultivated interchangeably with winter crop species.

Important elements of the sown area are both spring and winter catch crops, which have a beneficial impact on organic matter content, and serve to protect against soil erosion. In 2016, their share amounted to 12%, while in 2005, it was only 3%. In the studied period, catch crops area increased nearly four times, which deserves emphasis.

Presented changes in the crop structure are moving towards greater protection of soil on the level of farms. An important cause of this process is governmental support of farmers that implement different pro-environmental agricultural practices and generally undertake

Table 3. Crops on arable land—The area and crop structure.

Specification ^a	Area in thousand ha		Change in percentage ^b	Percentage		Change in percentage points
	2005	2016		2005	2016	
Crops on arable land	9,670.9	9,614.9	-0.6	100.0	100.0	x
Root crops	815.8	460.1	-43.6	8.4	4.8	-3.6
Potatoes	540.2	285.8	-47.1	5.6	2.9	-2.7
Sugar beet	234.9	167.2	-28.8	2.4	1.7	-0.7
Fodder root crops	40.7	7.2	-82.4	0.4	0.1	-0.3
Fodder corn, vegetable, strawberries	455.9	775.3	70.1	4.7	8.1	3.4
Fodder corn	258.7	538.0	107.9	2.7	5.6	2.9
Field vegetable, strawberries	192.6	232.7	20.8	1.9	2.4	0.5
Greenhouse vegetable, strawberries	4.6	4.6	0.3	0.1	0.1	0.0
Cereal and industrial crops	7,841.3	7,548.3	-3.7	81.1	78.5	-2.6
Cereal	7,442.3	6,772.5	-9.0	76.9	70.4	-6.5
Oil crops for grain	353.1	658.3	86.5	3.7	6.9	3.2
Other industrial crops	46.0	117.5	155.5	0.5	1.2	0.7
Soil-improving crops	548.1	826.7	50.8	5.7	8.6	2.9
Pulses for grain: edible	29.2	92.8	217.6	0.3	0.9	0.6
Cereal and pulses mixes for grain	35.2	31.1	-11.7	0.4	0.3	-0.01
Pulses for grain: Fodder	41.3	172.0	316.4	0.4	1.8	1.4
Fodder crops: Pulses	10.7	32.1	200.2	0.1	0.3	0.2
Fodder crops: Grasses	316.5	205.1	-35.2	3.3	2.1	-1.2
Fodder crops: Papilionaceous	77.0	157.2	104.1	0.8	1.6	0.8
Fodder crops: Other	12.6	60.2	378.9	0.1	0.6	0.5
Fodder crops: Seed crops	25.6	76.2	198.3	0.3	0.8	0.5
Catch crops	297.8	1 139.6	282.7	3.1	11.9	8.8
Spring	189.3	614.4	224.6	1.9	6.4	4.5
Winter	108.5	525.2	384.3	1.1	5.5	4.4
Winter main crops	4,292.4	4,198.5	-2.2	44.4	43.7	-0.7
Green manure in main crops	28.3	15.6	-44.8	0.3	0.2	-0.1

^a Presented groups take into account the crop classification available in official statistics. More precise division was not possible. According FSS classification, cereals include corn for grain.

^b “-”decrease.

Source: Prepared on the basis of FSS 2005 and 2016 data.

more environmentally friendly farm organization. The period of 2005-2016 was involving with the implementation of the various governmental instruments that obliged or encouraged farmers to diversify crop structure, including agri-environment programs, direct subsidies to soil improving crops, and the greening mechanism. Greening, implemented in 2015, obligated beneficiaries of direct payments to institute crop diversification and maintenance of Ecological Focus Areas (which included nitrogen fixing crops) on their farms. Because greening is a requirement for obtaining full support in the form of direct payments, this mechanism should bring measurable effects in environmental changes of crop structure (EP reg. 1307/2013; EP reg.

639/2014; EC, 2017). Studies carried out on the population of FADN farms, divided according to obligation and exemption from greening rules, have shown significant changes in the structure of sowing area on farms obligated to greening in 2015—the first year of the mechanism implementation. Farmers have adjusted to a wide range of legal requirements in the first year of application of these rules (crop diversification, ecological focus areas maintenance, including catch crops cultivation)—conditioning the level of financial support within the framework of the direct payments (Wrzaszcz, 2017).

Table 4. Percentage of farms according to environmental sustainability.

No.	Specification	2005	2007	2016	Change in percentage points
Farms' percentage according to fulfilment of environmental sustainability criteria^a					
1	Winter vegetation cover	65.3	63.4	61.1	-4.2
2	Cereals in crop structure	27.7	27.7	29.9	2.3
3	Cultivated crop groups	37.3	34.2	19.8	-17.5
4	Livestock density	98.7	98.6	97.8	-0.9
5	Soil organic matter balance	55.1	55.3	71.8	16.7
6	Nitrogen balance (N)	X	8.5	5.5	-3.0
7	Phosphorus balance (P)	X	9.7	7.1	-2.6
8	Potassium balance (K)	X	3.7	2.5	-1.2
Farms' percentage according to environmental sustainability degree (criteria number)^b					
9	One criteria	10.9	10.7	7.5	-3.4
10	Two criteria	27.4	26.5	26.4	-1.0
11	Three criteria	35.7	35.6	44.2	8.5
12	Fourth criteria	18.6	18.9	16.5	-2.1
13	Five criteria	7.4	7.6	5.1	-2.3
14	Six criteria	x	0.7	0.3	-0.4

^a Farms with crops on arable land—100%. Threshold values for specified indicators: 1. 33% min. in crop structure; 2. 66% max. in crop structure; 3. 3 crop groups min. cultivated on the farm; 4. 2 LU/ha max. on the farm; 5. At least 0 t/ha on the farm; 6-8. Optimal balance diverse according to NUTS 2 level (Kopiński, 2017).

^b There were considered from No. 1 to No. 6 criteria, presented above in the Table 4.

Source: Prepared on the basis of FSS 2005, 2007 and 2016 data.

Indicators of Farms' Environmental Sustainability

The organization of crop and livestock production results in the level and scope of farm environmental sustainability. The sustainability indicator values reflect the changes in sowing structure and the direction of trends in agricultural production (Table 4).

Based on the percentage of farms²¹ that met the threshold values for each of the sustainability criteria, it can be concluded that analyzed criteria varied in terms of difficulty level in their fulfilment. Most farms met the criterion of livestock density (in 2016 r., 98% of farms had livestock density up to 2 LU/ha), the balance of soil organic matter (a positive result characterized 72% of farms), and winter vegetation cover (in this case, 61% farms have a winter cover that took up at least 1/3 of the sown surface). As the research results indicated, appropriate crop diversification was the most difficult criterion for farms to meet, which provided the relatively low percentage of farms with the desired crop structure (at least 3 different plant groups were cultivated by the

fifth analyzed farm, while in the case of 30% of farms, cereals covered less than two-thirds of cultivated land).

In the case of fertilizer balance, evaluating the state of the main macronutrients, nitrogen (N), phosphorus (P) and potassium (K), is more complex. The balance result of the individual components may be understated, optimal, or overstated relative to the recommended level. The balance result is dictated by local circumstances, including the soil content of specific macronutrients, the quantity of supplied ingredients to the soil in the form of various fertilizers (natural, organic and mineral), and the amount of components taken up by cultivated crops. The most difficult issue is to ensure an optimum recommended result, to not create an excessive surplus of components in the soil, which may be a hazard to natural environment. Also, the result may not be very low, which can lead to macronutrients depletion from soil requiring restoration during the next years (Kopiński, 2017). 2016 data indicates that less than 6% of farms have the desired balance of nitrogen and only 7% have the proper phosphorus balance. The least beneficial situation applies to potassium, as only 3% of farms actually balance this component.

Based on the percentage of farms with the recommended level of sustainability indicators in 2005 and 2016, it can be concluded that there was progress in

21. Presented indicators were calculated for farms with crops on arable land.

terms of organic matter balance and the cereal criterion. Average soil organic matter balance increased from 0.09 to 0.23 t/ha. This was the result of increasing the area of soil improving crops, especially legumes. At the same time, the percentage of livestock farms decreased significantly, indicating that natural fertilizers were compensated by organic fertilizers and cultivation of soil improving crops. In these years, the average livestock density dropped from 0.49 to 0.45 (about 9%). In parallel, however, animal production increased on specialized livestock farms, and average livestock density increased by 25%, from 0.61 LU/ha to 0.77 LU/ha. These data confirmed the overlapping of two processes: on the one hand, farms not specialized or with a small scale of livestock production eliminated this agricultural activity, and on the other hand, farms with a higher level of livestock specialization increased the scale and concentration of this production profile.

At the same time, a high share of farms remained within recommended livestock density levels (in 2005, 99% and in 2016, 98% of farms had a livestock density below 2 LU/ha), indicating a stable state and only a small percentage of intensive livestock farms in Poland with stocking density above 2 LU/ha.

During the period, the proportion of farms with recommended winter vegetation cover slightly decreased, although it still may be considered as high (respectively, 65% and 61% of farms were characterized by the desired value of the winter cover on 1/3 sown area). The biggest problem, however, is connected with the NPK balance results, as fewer and fewer farms properly balance their content in the soil.

To sum up, the presented results indicate heterogeneous changes in farm environmental sustainability. The last years have indicated both improvement (mainly in the case of soil organic matter) and deterioration (as regards macronutrient balancing and crop plant diversity) in farm environmental sustainability. In reference to the last point, the diversity of crops increased on the farm level, but mostly within one plant group, especially those that improve the state of the soil.

Another research issue was the degree of environmental sustainability of farms. The degree of farm environmental sustainability allows for a unit prioritization according to their impact on natural environment. This degree has been calculated on the basis of the number of completed environmental sustainability criteria, assigning farms to specific groups characterized by the recommended level of environmental indicators (Table 4). In both 2005 and 2016, the analyzed farm population (with crop cultivation on arable land) was dominated by those

units with an average level of environmental sustainability (3 sustainability indicators at the recommended level), and the size of this group increased from 36% to 44% in the analyzed population. At the same time, farms with low/very low and high/very high levels of environmental sustainability significantly decreased. It can be concluded that farms became a more homogeneous group in terms their degree of environmental sustainability.

Conclusions

The article presents a proposal for measuring the environmental sustainability of farms in Poland using the data from the Farm Structure Surveys in 2005, 2007, and 2016. The analysis includes individual farms with an area of at least 1 ha of agricultural land. Results indicated the direction of farm development in Poland in the context of environmental sustainability. Based on the research, the main conclusions are as follows:

- Statistical data collected under Farm Structure Survey 2005, 2007, and 2016, which are in possession of national statistical offices of EU members and EUROSTAT allow a multifaceted assessment of farm environmental sustainability.
- Between 2005-2016 significant changes were observed in individual agriculture in Poland, which concerned a reduction in number of farms and labor input, an increase in average farm production and economic potential, and a simplification of agricultural production at the farm level. Institutional considerations connected with Poland's accession to the EU were an important factor in this case.
- In Polish agriculture, we observed a process of agricultural production simplification (significant increase in the population of farms without livestock) and specialization, especially in plant production. Those processes potentially bring environmental costs.
- Due to the high share of farms specialized in field crops in the Polish agriculture, their organization and applied agricultural practices will mainly contribute to the environmental sustainability of the agricultural sector.
- In the analyzed period, there were favorable changes in the structure of sowings, as evidenced by the increase in area and share of crops that improve soil fertility and protect the soil. Further intensification

of such activities is desirable, including governmental programs that lead farmers to soil protection and pro-environmental crop rotation.

- Farms' environmental sustainability includes various issues related to crop and animal production. Studies have indicated that the sustainability criteria considered here differ in their level of difficulty.
- Farms' environmental sustainability in Poland partly improved, which essentially resulted from an increase in soil organic matter balance and improvement of crop structure.
- In the context of farms' environmental sustainability, there is still a problem with insufficient crop diversification and a decrease in intensive livestock production, which is reflected in the macroelement balance.
- Changes in the field of environmental sustainability can be considered promising in the context of bioeconomy development in Poland. However, there is still much to be done for bioeconomy to be not only a theoretical concept, but also a widespread pro-environment human activity, including farmers' activity—the main users of environmental resources.
- The accession of Poland to the EU has helped to improve the environmental sustainability of farms as a result of the implementation of rural development programs and conditional subsidizing as direct payments (including greening). Still, the present state of farms is not sufficient. Thus additional governmental incentives are desirable to move forward with environmental sustainability.

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