

**PRIVATE FARMING DEVELOPMENT
IN THE CONTEXT OF PRESERVATION
OF SOIL ECOSYSTEM SERVICES**

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Abstract

The issue of ecosystem services is a relatively new concept in economic theory. This is the concept considered problematic, due to the difficulty of defining the benefits provided to people by ecosystems and their measurement and valuation. Some of these services are strongly associated with soil. Soil is one of the basic environmental resources necessary to conduct agricultural production. It fulfills many of non-production functions and provides services that are essential to human existence. Based on the crucial classification developed by the United Nations, we attribute providing the following ecosystem services to soil: basic/supporting, provisioning, regulating and cultural. Variety of services which are produced by soil causes the need to pay more attention to its quality, which is to a large extent derived from agricultural practices. The assessment of agriculture in the context of the farms' organization allows to determine whether the present profile of agricultural production is conducive to maintaining environmental services or whether it destabilizes environmental processes. What seems especially important from this perspective is highlighting the changes in agriculture over the years, in the context of their impact on the condition of the natural environment.

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The aim of the paper is to indicate changes taking place in agriculture in Poland relevant to soil ecosystem services. The study was based on public data of 2005, 2007, 2016 from the Statistics Poland (GUS), gathered in the Farms Structure Survey. The research covered all private farms in Poland from 1 ha of agricultural land in good agricultural and environmental conditions. The results have shown the dynamic development of agriculture in Poland after accession to the EU, although many of the observed changes can threaten soil ecosystem services. The progressive crop diversification, including the cultivation of winter species, nitrogen fixing crops and catch crops were assessed positively. Problematic issues were, on the one hand, the process of farms' withdrawal from livestock production, on the other hand, increasing livestock production concentration.

Keywords: private farming, agriculture development, farm, ecosystem services, soil ecosystem services.

JEL: Q01, Q15, Q24, Q57, H4.

Introduction

Ecosystem services are the benefits people obtain from ecosystems (MEA, 2005). In economics, they have the nature of externalities¹. In the era of capitalism and free market economy, ecosystem services are usually overlooked, hence economic activity often weakens the ability of the environment to produce them. This can result in compromising the balance of ecosystems, or even their loss.

Soil is one of the basic resources of the environment, necessary for a human to live. According to the Millennium Ecosystem Assessment classification (MEA, 2005), soil is associated with all types of ecosystem services. The group of supporting services includes processes conditioning life on Earth, which are related to soil structure, its fertility, nutrient cycling and the ability to retain and supply water. This group also includes soil formation. The group of provisioning services includes the production of biomass, and thus the production of food. Soil is also the source of regulating services such as pollution absorption, water purification and climate regulation. Soil also contributes to the creation of cultural services, i.e. services related to proper farming, landscaping or a sense of belonging. The variety of services produced by soil necessitates paying greater attention to its quality, which largely depends on agricultural practices.

¹ "Externalities are unintended consequences of activity carried out by economic entities. An externality occurs where the process of production or consumption of some goods or services, carried out by one entity, has a direct impact on decisions (relating to production or consumption) made by other entities." (Prandecki, Gajos and Buks, 2015, pp. 31-32). This process takes place outside the market mechanism, and externalities are characterised by the absence of monetary valuation of their value. In the case of ecosystem services, we are dealing with benefits for humans, which from an anthropogenic point of view are a side effect of natural processes. These processes have no economic valuation, which means that they meet the criteria of an externality. More information about externalities can be found, e.g. in: Prandecki et al. (2016); Prandecki, Gajos, Jaroszewska, Krzyżanowski and Małażewska (2018); Prandecki, Gajos, Jaroszewska, Wąs and Wrzaszcz (2017).

However, the dependence between soil condition and agricultural production is bidirectional. On the one hand, the organisation of agricultural production translates into soil condition, and on the other, soil condition (physical and chemical properties, quality) determines the agricultural producer's results – land productivity, and thus also profitability. Soil quality is assessed mainly in terms of organic matter content which enables carbon sequestration (Krasowicz et al., 2011). Soil organic matter content depends on the structure and scale of crop and livestock production on a farm. Assessment of agriculture through the prism of production organisation makes it possible to determine whether a given farming method favours the preservation of ecosystem services or compromises environmental processes. In this context, particular attention is required to changes in agriculture over the years, in terms of their impact on the condition of the environment.

The purpose of the paper is to show changes taking place in the Polish agriculture that are relevant to ecosystem services provided by soil. The study was carried out using statistical data regarding the population of private farms in Poland, collected as part of farm structure surveys in 2005, 2007 and 2016. The key environmental sustainability indicators were calculated for particular farms and for the agricultural sector to assess the correctness of farming in terms of ecosystem services.

Ecosystem services – general characteristics

Research into ecosystems began in the 1930s, but it became very popular only in the 60s and 70s due to the growing problem of environmental threats caused by globalisation processes². This resulted from the observation of the growing competitiveness of different ways of using the same type of environmental resource. Initially, this research covered mainly non-renewable resources, i.e. problems related to their depletion or environmental pollution (Hubbert, 1956; Meadows, Meadows, Randers and Behrens III, 1972). Problems relating to renewable resources were secondary and were less frequently raised in the literature, although researchers dealing with this topic pointed to their fundamental importance for the proper functioning of the planet (Carson, 1962).

The identification of environmental problems and increasing public awareness in this area have contributed to the growing interest in economic theories that take into account environmental protection in business, in particular the systemic analysis of the relationship between the environment and the economy, the theory of public goods and externalities (Becla, Czaja and Zielińska, 2012; Famielec, 2010; Fiedor, Czaja, Graczyk and Jakubczyk, 2002; Żylicz, 2004).

Based on the benefits of using resources, it was noticed that processes in the environment can also bring numerous benefits to people. In the early 1980s, these benefits were called ecosystem services (Ehrlich and Ehrlich, 1981). However,

² Cf. U'Thant (1969).

more extensive research aimed at defining this concept as well as identifying services and the basis for their valuation was launched only in the mid-1990s (Costanza et al., 1997; Daily, 1997; Ryszkowski, 1995; Simpson and Christensen, 1997; Toman, 1998; van Wilgen, Cowling and Burgers, 1996).

As a result of this research two approaches to defining ecosystem services were developed. In the first one, services include functions and processes – these concepts are treated as equivalent (e.g. Daily, 1997), while in the other, ecosystem services are the result of functions – these are two separate concepts (e.g. Costanza et al., 1997). In practice, such dichotomy in the approach to ecosystem systems services is present to this day, although some consensus was reached in 2005, by defining ecosystem services as “benefits people obtain from ecosystems” (MEA, 2005). This definition, provided in the report entitled Millennium Ecosystem Assessment, prepared under the UN auspices by a group of about 1,300 scientists, has become the benchmark for most researchers of ecosystem services. At the same time, it is claimed that this definition is too general, which leads to further attempts to make it more specific, and thus the discussion about the place of the environment functions in the context of ecosystem services continues. However, new definitions are not as common in the literature as the MEA definition.

The above-mentioned definition of ecosystem services raises the question about benefits people obtain from ecosystems. They are described in many ways. The most commonly used classification (MEA, 2005) is presented below with examples of different types of services. Services have been grouped as follows:

1. Supporting services – necessary for nature to provide other categories of services required for life on Earth, e.g. photosynthesis, primary production, soil formation and cycling of nutrients and substances essential for life (carbon, oxygen, water).
2. Provisioning services, production services – providing e.g. food, water, wood, fibres and biofuels.
3. Regulating services – e.g. absorption of pollutants, climate regulation, flood wave mitigation, water purification, waste disposal, etc.
4. Cultural services – providing people with intangible benefits relating to e.g. aesthetics, recreation, religion, culture diversity, sense of place, perception of natural and cultural heritage, impact on education, creative inspiration, artistic sense, leisure and nature tourism.

Besides the above-mentioned classification, there are also others worth considering (e.g. Kośmicki, 2005; Daily, 1997; Groot de, Wilson and Boumans, 2002; TEEB, 2010). These include the division used by Michałowski (2012), who divides ecosystem services into material, energy, informative and stabilising. This division is significantly different from the others, as it attempts at adapting the theory of ecosystem services to the methods of their analysis based on elemental or energy flows.

The aforementioned examples of ecosystem services show that this term should be understood as the basic processes that occur in the environment and are associated with the creation of benefits for people. Their importance for life can be considered fundamental, as in many cases they do not have their substitutes. At the same time, due to their prevalence and lack of common recognition, they are not considered valuable. They are degraded as a result of alternative uses of the environment, which is due to e.g. the slow, almost imperceptible, pace of their degradation (people are often not aware of the effects of their activity), as well as an indirect relation between the cause and effect, which is delayed relative to the cause (the effect often occurs years or decades later).

From the economic point of view, the problem with ecosystem services is that they are not reflected in the economic calculation. Processes occurring in the environment are not visible in business activity, because in most cases they are not widely recognised and have no economic valuation. As noted in the 1940s, a service that has no monetary value is ousted and its benefits are lost (cf. Baveye, Baveye and Gowdy, 2016). In the context of ecosystem services, it means that natural processes occurring in the environment, which are vital to human survival, are successively reduced due to anthropogenic environmental pressure. Such ousting results from civilisation changes taking place on a global scale (see Fig. 1). Population growth and technical progress lead to increased global consumption, which in turn translates into an increased demand for natural resources (both non-renewable ones, e.g. minerals, land surface, and renewable ones, e.g. water, wood). The growing demand for resources increases environmental pressure and competitiveness of the ways of using the existing resources, which makes people seek to maintain the availability of resources with a monetary value (e.g. access to raw materials, at least maintaining an adequate level of agricultural output) at the expense of resources that do not have a value expressed in monetary units. As externalities, ecosystem services do not have their value measured in monetary units.



Fig. 1. Humans and ecosystem services.

Source: the authors' own study.

In agriculture, ecosystem services relate not only to the ability of soil to produce food, but also to supporting and regulating services, e.g. the ability to retain and filter water, or to ensuring the proper cycling of elements in nature. Agriculture is linked to all categories of services³, which shows the importance of this sector in ensuring their proper functioning. This relationship has a feedback

³ Cf. Buks and Prandecki (2014).

nature. Agriculture is responsible for the quality and quantity of ecosystem services, but at the same time it is dependent on these services. This means that lack of care for these services may decrease the sector's production capacity. Internationalisation of ecosystem services is, therefore, not only a key element ensuring the sustainability of these services, but also an important element of long-term strategies for agriculture development.

As in the case of the most externalities, the measurement of the value of ecosystem services is very complicated. As Mizgajski (2010) notes, research into ecosystem services should be based on an analysis of ecosystem metabolism, and not on the condition of and changes in natural resources, as is usually the case in research into environmental economics. This approach requires, however, a slightly different attitude to capital, i.e. going beyond environmental capital and extending analyses to cover a broader category, i.e. nature's capital (Poskrobko, 2010). The extended approach to capital and the specific characteristics of ecosystem services require their economic analysis to be based on methods developed through studies of elemental or energy flows. The most recognisable theories based on the use of such flows include the theory of entropy (Georgescu-Roegen, 1971; Odum, 1983) or emergy (Odum, 1995). These theories are difficult to use in practice because they require extremely detailed statistical studies and complex research methods. What makes their use even more difficult is the absence of relevant statistical data, which often prevents the use of theoretically described instruments and determining the condition of ecosystems and their changes. Therefore, despite the dynamic development of theoretical considerations, the implementation of solutions in the field of internalisation of ecosystem services is very difficult.

The authors of this study believe that alternative methods of incorporating externalities in economic calculations should be sought, i.e. solutions similar to those used today. Although such methods will definitely be simplified, they will offer a better chance to assess the situation or implement appropriate instruments in the current market conditions.

Soil ecosystem services

Land (including soil), labour and capital are the basic inputs in the classic approach. The importance of land in production processes has already been emphasised. The works of physiocrats (from the Greek *physiocratie* – dominion of nature) who, as the name of this movement suggests, emphasised a strong link between development and natural factors, are the best example here. In the works of physiocrats, land played a special role, because it was treated as the only source of wealth. In accordance with this theory, farmers and landowners are the only social classes that generate wealth. Others, e.g. craftsmen, only processed wealth generated by land. This approach is most extensively described and presented in the work by Quesnay (cf. Stankiewicz, 1998).

The physiocrats' views were the basis for the classic concept of inputs developed by Smith, which was later further developed by Ricardo and Mill. Over time, this eighteenth and nineteenth century approach has been extended and now these three concepts are treated more as groups of inputs rather than homogeneous variables. Initially, land was considered only in terms of agricultural production and sources of valuable raw materials, e.g. metals or coal. It was not until the 1940s that theorists noticed that land has also other uses (Baveye et al., 2016), e.g. as a surface necessary for human life (e.g. for living, professional, transport and recreational purposes) or as a structural element in construction (aggregate, clay, as the basic material for building houses in a large part of the world, hardener for road construction, etc.). Such use is not marginal – it is estimated that today in about 1/3 of residential buildings in the world land is used as the basic building material. More examples like this can be easily presented, which proves the high value of land as an input in production processes. The multiplicity of land uses means that the competitiveness of using this input increases with an increase in population and economic development. The European Parliament resolution of 13 November 2007 on the Thematic Strategy for Soil Protection (2006/2293(INI)) notes that productive agricultural land is an increasingly scarce global resource. Estimates show that only 13% of the world's agricultural land is of high quality. Different processes result in increased pressure on soil, which, regardless of its properties, is used for non-agricultural purposes to an ever greater extent.

Soil is one of the basic components of the Earth's ecosystem (Szabolcs, 1994) and, at the same time, one of the most complex biomaterials on Earth (Young and Crawford, 2004). Soil is a dynamic three-dimensional regulatory system that performs many functions (Blum, 2005). Soil functions are crucial in the context of ecosystem services. As already mentioned, a great deal of researchers believe that functions and services are tantamount terms, while others claim that services result from functions. Using the available categories of soil functions, including those developed by FAO (2015) and Blum (2005), one can distinguish a dozen or so soil functions that are characterised by benefits for humans, which means that virtually all of them should qualify as ecosystem services. However, only selected ones are presented below as ecosystem services, in accordance with their previously adopted classification. Even a general overview shows that soil-generated ecosystem services are important for humans. Soil ecosystem services include:

- supporting services: related to soil structure, soil fertility, nutrient cycling, water retention and supply as well as soil-forming processes;
- provisioning services: biomass production, and thus the production of food, wood, fibres;
- regulating services: absorption of pollutants, carbon binding, water retention and purification, climate shaping/control;
- cultural services: a means of preserving archaeological heritage.

Soil has been underestimated in the context of ecosystem services for a long time, which is surprising given the importance of the functions it fulfils. A review of the literature shows that even in the case of the initially enormous interest in ecosystem services in the 1990s, the role of soil in this respect was completely neglected. In the work edited by Costanza et al. (1997), considered fundamental for considerations regarding the economic aspects of ecosystem services, soil occurs only indirectly in the context of the phenomena of erosion and soil-forming processes, while its production and regulating services, such as provision of nutrients, carbon binding and water retention and filtration, are completely ignored.

In the aforementioned MEA report, soil ecosystem services were underestimated as well. Although the food production service was distinguished and classified as a provisioning one, a number of other services were omitted. It was only in the mid-2000s that soil was distinguished as an important element of ecosystem services (Barrios, 2007; EC, 2006). As literature in this field became more extensive, it was pointed out that issues relating to soil ecosystem services are somewhat different from the general assumptions regarding ecosystem services, and are thus often overlooked by researchers. For example, analyses of services generated by forest ecosystems, soil services are not distinguished but are treated as a whole. This approach results in ignoring soil services in both economic practice and economic calculation. As ecosystem services are not internationalised, they are not properly protected.

To consider soil ecosystem services, a more detailed approach to the functioning of ecosystems is required. Such refinement necessitates the use of more precise and complex measurement tools. This is particularly important when it comes to soil, since the supply of its services depends on a wide spectrum of soil properties. Their determination is usually a prerequisite for measuring these services and introducing changes in their supply. This is the basis for developing a method of service valuation and internalisation for business practice. The recognition of complex relationships is necessary to precisely determine the value of ecosystem services, which entails the development of an appropriate set of methodological tools.

As noted earlier in the paper, research into ecosystem services should be based on an analysis of their metabolism, because in theory, this solution helps to obtain a precise answer as regards the conditions of ecosystem services. Based on theoretical premises relating to soil, it can be concluded that it is necessary to use methods based on elemental flow studies. However, their practical application requires labour-intensive measurements, which on a larger scale seems to be very difficult and even impracticable at the national level. Most likely, such a detailed approach would also lack economic rationale.

For this reason, it is advisable to look for other solutions, based on cause-and-effect relationships, that would allow for drawing more general conclusions applicable in the agricultural sector and agricultural policy. Their use is particularly sensible in the case of macroeconomic research, where there is no need for a pre-

cise assessment of a single ecosystem service, but their entire basket. Such a general approach to soil ecosystem services requires identifying and analysing relevant relationships between the ecosystem and business operations. In this case, it is a complex relationship between agriculture and soil.

The bidirectional relationship between agriculture and soil ecosystem services is very important (Fig. 2). The organisation of agricultural production (e.g. sowing, livestock, fertilisation method) affects the condition of soil and determines the functions it serves. The basic measures of soil condition include soil organic matter balance, balance of main macronutrients (NPK), as well as pH. Also the condition of soil determines the organisation of production (production capacities), which applies particularly to crop production. The condition of soil and the services it provides determine the productivity of agriculture, and thus also its profitability⁴. These relationships are both direct and indirect. Soil ecosystem services can contribute not only to an increase in yield, but also to e.g. increased water retention, which in turn can lead directly to an increase in yield. Therefore, farmers should be interested in maintaining soil in an adequate condition ensuring the most favourable supply of ecosystem services. This entails both the need to apply advisable agricultural practices and to increase farmers' awareness of the importance of ecosystem services in agricultural production. It seems that action in the latter area can bring about significant progress with relatively little investment.

Given the existence of feedback between agriculture and soil condition (Fig. 2), one can distinguish a number of components of the organisation of agricultural production that affect the supply of ecosystem services. Identification of changes in this area helps to specify the direction of the impact of agricultural production on ecosystem services.



Fig. 2. Relationship between agriculture and soil condition.

Source: the authors' own study.

⁴ On the one hand, the relationship between the production (and, consequently, productivity) of agriculture and soil condition is widely recognised, which is reflected also in land valuation (which depends e.g. on soil quality). On the other hand, soil ecosystem services are classified as externalities and described as services with no monetary valuation. The value of land in monetary units includes only a part of ecosystem services, mainly its direct ability to produce food, assessed e.g. using soil class. Other ecosystem services are not measured and hence not valued. The internalisation of a larger basket of ecosystem services could change the monetary value of land, as well as the way it is used.

Research method

The study was based on the Statistics Poland (Główny Urząd Statystyczny, GUS) data for 2005, 2007 and 2016 (representative data for Poland), which was collected as part of the Farm Structure Survey⁵. The study covered all private farms conducting agricultural activity, with utilised agricultural area maintained in good agricultural and environmental condition, of at least 1 ha of UAA. Adoption of the same criteria for isolating farms for the study in the years indicated above eliminated the impact of the change in the definition of a farm (used in official statistics in that period) on the study results. The wide range of data collected from farms also enabled the assessment of changes taking place in the agricultural sector (farms) in the context of the provision of environmental benefits.

Based on the available statistical data and the relationships between the organisation of agricultural production and soil quality, several areas have been identified in terms of the provision of soil ecosystem services, namely: **agricultural production potential, organisation of agricultural production and environment-friendly practices**. These areas correspond with supporting, regenerating and provisioning ecosystem services provided by soil. Due to the specifics of the paper and the authors' interests, the study did not directly address soil cultural ecosystem services.

The production potential of agriculture, including the number of farms, utilised agricultural area, labour inputs, livestock population and standard results (standard output and standard gross margin)⁶, is the basic determinant of agricultural output and, consequently, food production. Food production is a fundamental element of soil provisioning ecosystem services. As regards regenerating and supporting services, livestock production is of particular importance. This production direction determines the quantities of natural fertilisers supplied to the soil and better opportunities to properly manage soil organic matter. Attention has also been drawn in the paper to non-livestock farms, whose organisation is particularly demanding in terms of ensuring an adequate soil condition (Kopiński and Kuś, 2011).

After identifying changes in the agricultural production potential, including those relating to livestock production, the organisation of crop production was characterised. The coupled relationships between crop production and soil condition are currently gaining importance due to the ever smaller opportunities to use natural fertilisers. The direction of changes in the area and cropping patterns

⁵ For the purposes of the implementation of the Multi-Annual Programme of the Institute of Agricultural and Food Economics – National Research Institute for 2015-2019, cooperation was launched with the Statistical Office in Olsztyn, which provided for, e.g. calculations with the use of separate data from farms, in accordance with the adopted research method.

⁶ To determine the standard results for 2005 and 2016, 2004 SGM and 2013 SO coefficients were used to capture changes in the volume, structure and scale of production. The adoption of fixed coefficients for the analysed years eliminated the impact of changes in prices and unit productivity on the sector's result. The presented values regarding the sector reflected production changes in agriculture, which were the effect of changes in the scale and structure of production in 2005-2016.

of various groups and species of plants indicates potential threats or benefits to soil resulting from the organisation of crop production. Besides market conditions, an important role in the organisation of crop production is played by administrative instruments that impose the conditions for subsidising crop production, including direct payments related to the area covered with plants that have soil structure formation properties (Wrzaszcz, 2017).

The organisation of agricultural production determines the agricultural type of the farm, which reflects its specialisation and production profile. Organisational diversity of farms with different agricultural types determines their level and extent of sustainability (Wrzaszcz, 2012). In this study, farms were classified in accordance with the General Type of Farming classification, determined based on the standard output "SO 2013" (Bocian, Cholewa and Tarasiuk, 2017). In accordance with the adopted classification, the following types of farms were identified: specialised farms with field crops (I), horticulture (II), permanent crops (III), grazing livestock (IV) and granivores (V); mixed farms with a combination of crop products (VI), a combination of livestock products (VII) and a combination of crops and livestock products (VIII). The same SO indicators were used to determine the direction and scale of changes on farms.

The paper contains an assessment of changes occurring on private farms as regards selected important agricultural practices determining the condition of soil and processes occurring in it. Attention was drawn to the following three issues: **organic farming system (certified organic farms were identified), environmental sustainability of the sector and soil liming practices.**

Due to the environmentally friendly functions of the organic farming system, issues relating to the development of organic farming were also discussed. The organic farming system is guided by the principle of cultivating plants in accordance with the standards of good agricultural and environmental culture, with due care for the phytosanitary condition of plants and soil protection. In accordance with legal guidelines, organic farming is a farming system that activates natural production mechanisms through the use of natural, technologically unprocessed resources, thus ensuring sustainable soil fertility and good health of livestock as well as high biological quality of agricultural products. This system is largely independent of external inputs, and soil fertility is a fundamental value (Zegar, 2009).

Environmental sustainability of agriculture is one of the basic research issues related to the impact of agricultural production on the environment. Sustainable agriculture is characterised mainly by the maintenance of the production potential of soil which is an essential element of the natural environment used in agriculture (Krasowicz, 2005). Therefore, what is the basis for the implementation of correct agricultural practices is at least preventing the degradation of organic matter in soil, and ultimately increasing its fertility and maintaining its ability to produce biomass (Harasim 2006, Loon van, Patil and Hugar, 2005). The content of soil organic matter is determined by resources of soil humus, which, apart from being relevant to

soil production functions, is also important for the carbon sequestration process, and, consequently, for reducing the greenhouse effect. The intensive use of soil through monoculture destroys its structure, leads to excessive aeration of habitats and mineralisation of humus as well as release of carbon dioxide into the atmosphere (Bieńkowski and Jankowiak, 2006). Conducting agricultural production with respect for natural resources is possible through skilful crop change and fertilisation, adapted to the fertility and type of soil (Faber, 2001). The above agricultural practices have been comprehensively compiled in the Code of Good Agricultural Practices, which is a set of principles of rational farming. The presented substantive issues were considered as priorities when selecting environmental sustainability indicators for farms. The following criteria were adopted with respect to environmental sustainability of agriculture: the proportion of cereals in the structure of arable land sown, index of arable land cover by vegetation during the winter, stocking density on utilised agricultural area, balance of soil organic matter, gross nitrogen, phosphorus and potassium balance in soil⁷.

Soil liming was the last of the environmentally friendly farming practices considered. This practice is particularly important for ensuring the production and environmental functions of soil, and, consequently, its ability to provide ecosystem services. The consumption of lime fertilisers (CaO) has a direct effect on soil pH. Plants grown on acidic soils give low yields of poor quality, and as soil acidification increases, nutrient uptake by plants is disturbed. Acidification of soil is very closely associated with the limitation and reduction of the activity of microorganisms involved in the processes of organic matter decomposition in soil, reduction of humus content in soil, weakening the intensity of the process of nitrogen uptake (assimilation) from air, both by free-living soil microorganisms (*Azotobacter*) and those living in symbiosis with most papilionaceous plants (Holubowicz-Kliza, 2006).

The presented research method enabled the determination of organisational changes in agricultural production in terms of the provision of soil ecosystem services. However, it cannot be considered universal, but resultant of the conducted theoretical considerations (substantive criteria) and empirical ones, adapted to the available resources of public statistics, showing the condition of the agricultural sector and changes therein.

⁷ Detailed rationale for particular indicators is presented, e.g. in: Wrzaszcz (2012); Toczyński, Wrzaszcz and Zegar (2013). For the purposes of determining nutrient balances, the fertiliser balance calculation method developed by the OECD/Eurostat (OECD, 2006), and commonly used at the Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy, was adapted (Kopiński, 2017). Due to the incomplete scope of data compared to the guidelines regarding the aforementioned method, simplifications were introduced using expert knowledge and available literature on the subject (Wrzaszcz and Kopiński, 2019). The basic premise of the conducted research was the use of a uniform research method, enabling making the calculations in a comparable manner in the analysed period in order to capture changes that occurred in the fertiliser management on private farms.

Results

Production potential of agriculture

Over the past several years, there have been significant changes in the agriculture of Poland. These changes concerned a number of farms, their production potential and profile, as well as their economic potential (Table 1). In 2016, there were 1.4 million private farms with an area of at least 1 ha of UAA maintained in good agricultural and environmental condition. Compared to 2005, the number of these farms decreased by almost 1/5. These significant changes indicate that many farmers have abandoned this type of economic activity either due to their retirement (as they have reached the retirement age) or because they have chosen to transfer their agricultural land to larger farms in exchange for a monthly compensation (applies to farmers in working age), or because they have chosen non-economic activity⁸.

The area of utilised agricultural area maintained in good agricultural and environmental condition was over 13 million ha. Given the percentage changes, it can be concluded that this area did not change significantly over the analysed period. There was, however, an increase in the area of agricultural land in absolute terms by 121 thousand ha, as a result of introduction of conditions for obtaining direct payments for maintaining land in good agricultural and environmental condition. Prior to Poland's accession to the EU, this land was not utilised and part of it was set aside. The legal obligation to restore land utilisation or keep it fallow (i.e. in good agricultural and environmental condition) translated into environmentally friendly agricultural practices pursued by its users. Farmers interested in obtaining direct payments were obliged to implement specific agricultural practices on utilised agricultural land.

⁸ In 2005, all measures provided for in the Rural Development Plan for 2004-2006 to favour transformations in agriculture were launched. Part of them concerned the transfer of farms to young successors. In this case, support addressed to individuals that have chosen to transfer their agricultural land to larger farms in exchange for a monthly compensation (applies to farmers at working age), was of great importance. Simultaneously, administrative measures were proposed to support the development of farms managed by young farmers, which was an additional stimulus to farm succession. Due to the multi-generational model of agricultural families in Poland, the institutional conditions often resulted in the transfer of farms (agricultural land) by the oldest family members to their children, who until then had also dealt with agricultural production (Dudek, 2016).

Furthermore, market conditions related to the creation of jobs outside agriculture prompted working-age farmers to take up economic activity in other sectors of the economy. Opportunities to take up competitive work outside agriculture encouraged some farmers to retrain and cease agricultural activity. Land used by them until then could be let or sold to other agricultural producers, thus increasing the production potential of their farms.

Table 1

Production potential of agriculture

No.	Item	2005	2016	Change in 2016/2005 in:	
				units	%
1	Number of farms (in thousand)	1,723.9	1,398.1	-325.8	-18.9
2	Utilised agricultural area in good agricultural and environmental condition (thousand ha)	13,060.6	13,181.4	120.8	0.9
3	Labour inputs (thousand AWU) ^a	2,035.2	1,617.0	-418.2	-20.5
4	Livestock population (thousand LU)	6,430.3	5,923.5	-506.8	-7.9
5	Number of farms with livestock (in thousand)	1,247.6	712.6	-535.0	-42.9
7	Standard output (EUR million)	20,824.1	21,824.3	1,000.2	4.8
8	Standard gross margin (thousand ESU)	9,963.9	9,283.4	-680.5	-6.8

^a Labour inputs in Annual Work Units (AWU), equivalent to 2,120 hours of work per annum

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2016.

In 2005-2016, the inputs of human labour in agriculture decreased significantly, by as much as 1/5. These changes were due to transformations taking place in agriculture as a result of a decrease in the number of farms and an increase in the average farm area, which allowed for limiting labour inputs and favoured their effective use. Another important factor was the changing technology of agricultural production, resulting from the modernisation of farms (Kusz, 2012; Kutkowska, Berbeka and Pilawka, 2015). The observed substitution of human labour with objectified labour was largely due to the implementation of support schemes for agriculture and rural areas, involving co-financing of costly investments, including improvement of building equipment and purchase of agricultural equipment (Czubak, 2012; Kuś and Matyka, 2014). Costly investments, automated production and improved mechanisation have resulted in changes in agricultural production technology and simplification of the production process.

During the period concerned, the livestock population measured in large units decreased by 8%, from LU 6.4 million to LU 5.9 million. This decrease concerned mainly non-specialised farms with a low livestock population, which were abandoning livestock production⁹. Given the fact that about 43% of farms abandoned livestock production, the livestock population was concentrated on farms enhancing the indicated production profile. A significant increase in the number of non-livestock farms, which currently constitute half of the private farms' population, indicates the simplification and narrowing down of agricultural production, and thus the ongo-

⁹ This issue will be discussed in more detail later.

ing process of farm specialisation towards crop production¹⁰. Agricultural producers' decisions as regards production translate into both the economics of farms and their environmental pressure. Abandoning the diversification of agricultural production narrows down the sources of income, thus increasing the economic risk threatening business activity as well as the environmental risk (Krasowicz et al., 2011).

The maintenance of livestock production is of particular importance in terms of providing supporting and regenerating soil ecosystem services, due to the environmental importance of natural fertilisers. The process of abandoning livestock production by farms has a negative impact on the environment, due to the reduction in the quantity of natural fertilisers of animal origin, and, as a result, the growing dependence of agricultural production on inorganic inputs of agricultural production, such as mineral and chemical fertilisers. The effect of a reduced use of natural fertilisers on non-livestock farms can be measured through a change in the organic matter content in soil. The loss of organic matter can be compensated by cultivating structure-forming plants and using organic fertilisers of plant origin or natural fertilisers purchased from producers dealing with high-volume livestock production. As shown by research, the market for trading in natural fertilisers is negligible and involves only a few per cent of farms, hence solutions based on the reorganisation of crop production are of greater economic importance in this case (Wrzaszcz and Kopiński, 2019).

The provisioning ecosystem services refer to food production, which is a derivative of the economic potential of farms. This potential can be measured using standard output and standard gross margin. The former indicates the potential volume of agricultural output, while the latter includes also direct costs associated with agricultural activity.

In 2005-2016, a slight, nearly 5% increase was recorded in standard output, while the standard gross margin decreased by 7%. The differences between the two categories are due to the significant impact of direct costs of agricultural activity. The increase in direct costs in the analysed period was not offset by proportional changes in the value of agricultural output. This increase was associated in particular with the prices of industrial agricultural inputs, including mineral fertilisers, plant protection products as well as feed and livestock feed additives. In the analysed period, there was also an increase in the dependence of agricultural output on external (industrial) inputs as a result of the widespread decoupling of crop from livestock production on farms, which potentially increases environmental pressure.

¹⁰ Abandoning livestock production results mainly from market conditions determining the profitability of this direction of production. Volatile prices of livestock products and rising costs of livestock maintenance (associated with the purchase of feed and ensuring adequate living conditions) have an adverse effect on the agricultural producer's profitability. Outflow of labour from agriculture and farm transformations related to the simplification of agricultural production made farmers abandon labour-intensive livestock production. Administrative requirements imposing standards of keeping livestock translate into obligations (including financial ones) to be met by agricultural producers. These requirements are particularly acute for "smaller" producers.

Production potential of the average farm

Changes in private agriculture translate into the image of an average farm. As shown in Table 2, the average private farm is small, both in terms of utilised agricultural area (9.4 ha in 2016) and standard output (EUR 15.6 thousand¹¹ in 2016)¹².

Table 2

Production potential of the average farm

No.	Item	2005	2016	Change in 2016/2005 in:	
				units	%
1	Utilised agricultural area (ha)	7.58	9.43	1.85	24.44
2	Labour input (AWU)	1.18	1.16	-0.02	-2.04
3	Average stocking density (LU/ha)	0.49	0.45	-0.04	-8.16
4	Stocking density on livestock farms (LU/ha)	0.61	0.77	0.16	26.23
5	Livestock population on livestock farms (LU)	5.15	8.31	3.16	61.28
6	Standard output (EUR thousand)	12.08	15.61	3.53	29.22
7	Standard gross margin (ESU)	5.78	6.64	0.86	14.88

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2016.

The average stocking density on utilised agricultural area in Poland is low – currently it is 0.45 LU/ha of UAA. During the analysed period, the stocking density decreased by 9%, which was mainly due to a decrease in the livestock population. The results for farms with livestock production are different. On such farms, the stocking density increased by 1/4, from 0.61 LU/ha to 0.77 LU/ha. The average livestock population on farms with livestock increased to over 8 LUs per farm (i.e. by over 60% during the analysed period). These results confirm an increase in the production scale on farms specialising in livestock production.

The presented data indicate that, on the one hand, a decrease was recorded in the livestock population and the number of farms with livestock on which livestock production was not the main production direction in earlier years, and, on the other, there was an increase in the concentration of livestock production and production specialisation on farms pursuing this production direction. These results confirm

¹¹ Farm classification by standard output is presented in Floriańczyk, Osuch and Płonka (2018).

¹² The image of the average farm has changed, but over a dozen or so years. The data shows the ongoing process of farm expansion, both in terms of area and economic activity. During the analysed period, the average farm increased its area by about 1/4, thus increasing its economic potential (by almost 30% in the case of standard output and 15% as regards the standard gross margin), while maintaining comparable labour inputs. Having regard to the area of the average farm, a significant decrease in the input of human labour was recorded in the analysed period, both per unit area and standard results.

the phenomenon of farm polarisation in terms of livestock production¹³. As for environmental issues, both the liquidation of livestock production and the high scale of livestock production have negative environmental effects. The liquidation of livestock is associated with a greater organisational and cost challenge to cover the demand of cultivated plants for the necessary nutrients (purchase of fertilisers, mainly mineral ones, is necessary). On the other hand, high-volume livestock production results in high emissions of gases and odour, as well as the need to manage excessive quantities of natural fertilisers (their storage, transport, sale), inconveniences for the neighbouring environment and it also requires taking action in the market to properly dispose of such fertilisers.

Crop production

The area and structure of sown crops determines the volume of crop production. Crops sown on arable land, next to natural fertilisation, also determine the direction and scale of the impact of crop production on the environment, and thus also the capacity to provide ecosystem services. As regards improving soil quality, special importance is attached to the cultivation of plants such as papilionaceous plants, legumes, grasses on ploughed land as well as mixtures of specific plants. Structure-forming plants can be grown both as a main crop and catch crop, intended for green manure. The share of structure-forming plants in the cropping pattern is an important determinant of the assessment of crop production in environmental terms. Root crops, vegetables, corn, other cereals and industrial crops have degrading properties. Their effect on soil condition is measured with indicators of reproduction and degradation of soil organic matter (Harasim, 2006). As regards soil protection, winter plant cover on arable land, which consists of both winter crops grown in the main crop and catch crops, is particularly important. In accordance with the above classification, sown crops of the indicated plant groups were compiled in Table 3.

In 2016, the sown area of arable land was 9.6 million ha, similarly to 2005. The similar sown area proves stabilisation as regards allocating this type of utilised agricultural area for traditional field production. Both in 2005 and 2016, the cropping pattern was dominated by the cultivation of plants adversely affecting soil condition, nevertheless in the analysed period, there were favourable changes in the area intended for the cultivation of structure-forming plants (binding nitrogen in soil).

Crops were dominated by cereals, whose share in the total crop area was 70% (2016). Cereals were followed by industrial crops (8%), mainly rape and agrimony. Green forage corn covered 6%, whereas root crops covered 5% of the

¹³ Both processes, i.e. abandoning livestock production as well as its high concentration and specialisation, have various economic and environmental effects, affecting also the soil environment. As for economic effects, abandoning livestock production by farms results in the reduction of sources of income from agricultural activity, while an increased volume of livestock production strengthens the producer's market position, thus increasing its revenues from the sale of livestock products and its productivity and profitability (Ziętara, 2014).

total crop area (2016). Crops of soil improving plants, i.e. papilionaceous plants and legumes, covered 9% of sown area dominated by fodder plants. As recommended, plants favourably affecting soil condition should cover 20% of sown area (Harasim, 2006). Adopting this value as a reference, the area covered currently with papilionaceous plants is smaller than that specified in agrotechnical recommendations.

In the analysed period, the cropping pattern on arable land changed significantly, as evidenced by the reduction in the area covered with cereals and root crops, as well as their share in total crops, in favour of industrial crops and legume plants. There was also a significant increase in the area covered with green forage corn. As regards changes in sown area, there was a 9% decrease in cereals and a 44% decrease in root crops, as well as an impressive increase in industrial crops and green forage corn (the area covered with these plants doubled). These plants have a degrading effect on the soil organic matter content.

It is worth emphasising that in the analysed period, the area sown with structure-forming plants (papilionaceous), particularly important for soil-reproducing processes, increased by as much as 51%. The increase in the area sown with structure-forming crops needs to be recognised as a positive process in terms of the provision of soil ecosystem services, as it enhances the diversity of cultivated plants and, consequently, offers greater crop rotation opportunities.

Besides their economic importance and the role in shaping the production potential of soil, crops on arable land also ensure protection against adverse atmospheric phenomena and erosion. In this context, the cultivation of winter crops is particularly important. As indicated by statistical data, a significant area in the cropping pattern was intended for the cultivation of winter crops in the main crop. Both in 2005 and 2016, their share was 44%. Although there was no improvement in this respect, the value of this indicator is high.

The cropping pattern includes an important element, namely catch crops, both spring and winter ones, which are a major source of soil organic matter reproduction and also protect soil. In 2016, catch crops accounted for 12% of the cropping pattern, compared to 3% in 2005, hence the area intended for catch crops increased almost fourfold. This is an example of implementing good agricultural practices beneficial for the soil environment.

Table 3

The area and structure of crops sown on arable land

Item	Area in thousand ha			Share	
	2005	2016	Change (%)	2005	2016
Total sown area	9,670.9	9,614.9	-0.6	100.0	100.0
Root crops	815.8	460.1	-43.6	8.4	4.8
Potatoes	540.2	285.8	-47.1	5.6	3.0
Sugar beets	234.9	167.2	-28.8	2.4	1.7
Forage root crops	40.7	7.1	-82.4	0.4	0.1
Green forage corn and vegetables	455.9	775.3	70.1	4.7	8.1
Green forage crop	258.7	538.0	108.0	2.7	5.6
Ground vegetables, strawberries, wild strawberries	192.6	232.7	20.8	2.0	2.4
Vegetables, strawberries, wide strawberries under covers	4.6	4.6	0.3	0.0	0.0
Cereals and industrial crops	7,841.3	7,548.3	-3.7	81.1	78.5
Cereals	7,442.2	6,772.5	-9.0	77.0	70.4
Oilseed crops	353.1	658.3	86.4	3.7	6.8
Other industrial crops	46.0	117.5	155.5	0.5	1.2
Structure-forming plants	548.1	826.7	50.8	5.7	8.6
Edible legumes for dry forage	29.2	92.8	217.6	0.3	1.0
Cereal-legume forage mixture	35.2	31.1	-11.7	0.4	0.3
Forage legumes	41.3	172.0	316.4	0.4	1.8
Green forage legumes	10.7	32.1	200.2	0.1	0.3
Green forage field grass	316.5	205.1	-35.2	3.3	2.1
Green forage papilionaceous plants	77.0	157.2	104.1	0.8	1.6
Other green forage crops	12.6	60.2	378.9	0.1	0.6
Seed crops	25.6	76.2	198.3	0.3	0.8
Total catch crops	297.8	1,139.6	282.7	3.1	11.9
Spring catch crops	189.3	614.4	224.5	2.0	6.4
Winter catch crops	108.4	525.2	384.2	1.1	5.5
Winter crops in the main crop	4,292.4	4,198.5	-2.2	44.4	43.7
Green manure crops in the main crop	28.3	15.6	-44.8	0.3	0.2

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2016.

The cultivation of plants intended for green manure in the main crop is another important element of the cropping pattern. However, this agricultural practice is not common, and is losing its significance. During the analysed period, the area under these crops decreased by 45%, and their share in the cropping pattern was negligible. Farmers increasingly more often decide to grow plants intended for green manure in catch crops.

To sum up, cereal crops did and do dominate the cropping pattern on arable land. Despite the significant economic importance of cereals, their area has significantly decreased. Thus, the area covered with other plant groups has changed, so has the cropping pattern. These changes concerned the cultivation of less popular plants, constituting a small part of the sown area. The cropping pattern is changing in favour of the environment, which can be seen both as regards the cultivation of plants such as papilionaceous and their mixtures in the main crop, as well as in catch crops. These plants are of particular importance to soil due to their anti-erosion and structure-forming properties. The area sown with root crops that severely degrade soil has decreased. The liquidation of a significant part of the area of their cultivation was required by both changing market conditions and organisational changes in livestock production on farms. There was also a change in the scale of livestock production that determines the demand for feed and the livestock feeding system.

Changes in crop production were introduced with the use of various administrative mechanisms. Instruments implemented in 2005-2016 required or encouraged farmers to diversify their crops. These instruments included agri-environmental programmes, direct support for the cultivation of structure-forming plants, as well as a new greening mechanism. Since 2015, the greening requirement has been applicable to farmers seeking for full direct support. This mechanism has obliged farmers to diversify field crops and to maintain ecological focus areas, which also include areas sown with crops that affect favourably soil conditions (nitrogen-binding crops). This mechanism has obliged farmers to implement indicated agricultural practices, assuming measurable environmental effects of the changed organisation of agricultural production (EP Reg. 1307/2013; EP Reg. 639/2014). As shown by the results of research carried out using the Polish FADN data for 2014-2015, farms bound by the greening requirement introduced significant environment-friendly changes in crop production within the first year after the implementation of this instrument (Wrzaszcz, 2017).

Agricultural type of farms

The agricultural type of farms depends on the organisation of agricultural production they pursue. Research shows that both in 2005 and 2016, most farms specialised in field crops (type I, Figure 3). Currently, more than half of private farms in Poland are specialised entities pursuing traditional field cultivation. Their percentage increased significantly from 41% to 58%. This is the only group of farms that recorded a significant increase.

These farms were followed by non-specialised farms pursuing crop and livestock production (VIII), whose share shrank by almost half, from 31% to 16%.

These changes should be considered unfavourable in terms of potential environmental pressure of agricultural activity and the provision of soil ecosystem services. Combining crop and livestock production at the farm level helps balance nutrients and soil organic matter, as well as diversifies plants cultivated on the farm. A similar decrease was observed also in the case of non-specialised farms with diversified livestock (VII), while the share of farms specialising in livestock production (IV and V) remained unchanged in the analysed period.

To sum up, in the analysed period, the number of non-specialised farms decreased significantly in favour of specialised ones (change by 19 p.p.; in 2005, non-specialised farms accounted in total for 42%, while in 2016 – only 23%). These changes confirm the progressing specialisation of farms, mainly towards crop production. Non-specialised farms are abandoning livestock production, narrowing their production profile. It should be noted that animal husbandry determines the proper functioning of the agro-ecosystem (Tyburski and Żakowska-Biemans, 2007).

The narrowing down of agricultural activity to specialised crop production generally increases the environmental pressure of this activity through an increased risk of worse soil organic matter balance. This situation is particularly unfavourable in the case of farms operating on inferior quality soil and areas with an extremely high risk of drought. Therefore, farm specialisation in crop production is associated with a number of organisational challenges to ensure compensation of the loss of natural fertilisation and adequate reproduction of organic soil matter. This problem can be solved by using organic fertilisers (green manure and straw) and through local cooperation with specialised livestock farms trading in natural fertilisers. These agricultural practices are necessary to ensure the restoration of soil organic matter.

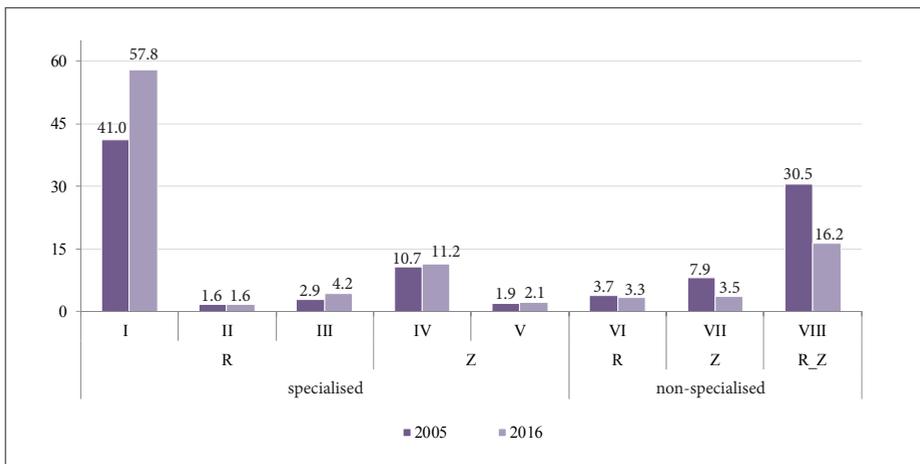


Fig. 3. Structure of private farms by agricultural type.

Note: predominant direction: R – crop production, Z – livestock production. Agricultural types are described in the part concerning the research method.

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2016.

Environment-friendly practices

In order to verify the scale of provided environment-friendly practices that have a favourable impact on soil condition, three main elements were highlighted, namely: organic farming system – a legal form of soil-friendly farming; farm sustainability determinants – relevant production and environmental indicators enabling the assessment of crop and livestock production; and soil liming practices – basic activities regulating soil pH.

Organic farming system

An organic farm should be characterised by a different organisation of agricultural production compared to that of conventional farms. Due to a significant limitation of industrial inputs, organic farms should be based on natural environmental processes and use them in agricultural production. Therefore, as stipulated by law, agricultural production on organic farms should be based on agricultural practices that have favourable effects on soil quality.

Organic farming is recognised as the most environmentally friendly method of agricultural production due to the environmental benefits it provides. This is a very important area of economic activity that requires constant changes in order to increase the share of this farming system in the agricultural sector's output. The development of organic farming is to a large extent a response to the changing structure of market demand. The ecological awareness of the society is constantly increasing, which is reflected in the growing demand for organic products (MRiRW, 2019).

The development of this farming system is determined to a large extent also by significant financial support received by farms under government programmes since 2004. Initially, this support was provided as part of the agri-environmental programme under the Rural Development Plan for 2004-2006, and then under the Rural Development Programme for 2007-2013. Currently, organic farming is covered by a separate measure under the Rural Development Programme 2014-2020. The importance of these subsidies in the operation and development of organic farms is due to the significantly lower productivity and profitability of land used by such farms compared to that used by conventional farms (Wrzaszcz, 2018b).

Global trends show that organic farms have been so far a niche form of agriculture (Stolze and Lampkin, 2009). It is worth noting, however, that their number worldwide has increased rapidly in the last decade. A similar situation is observed in Poland (Figure 4). From 2005, the number of certified organic farms increased rapidly, to reach over 16,000 in 2016, covering 608,000 ha of utilised agricultural area. Their share in the population of private farms was 1.2% and they covered 4.5% in the utilised agricultural area maintained in good agricultural and environmental condition¹⁴.

¹⁴ Detailed results concerning organic farming for 2005 and 2016 were presented in Wrzaszcz (2018b).

The systematic increase in the potential of organic farms in Poland should be deemed a desirable direction in the development of agriculture due to benefits, mainly environmental and social, they offer (Runowski, 2012). The development of organic farming, based on the use of environmental processes, favours the provision of soil ecosystem services. Organic farms are an indispensable part of the future model of agriculture, using renewable resources and friendly to environmental resources (Zegar, 2012).

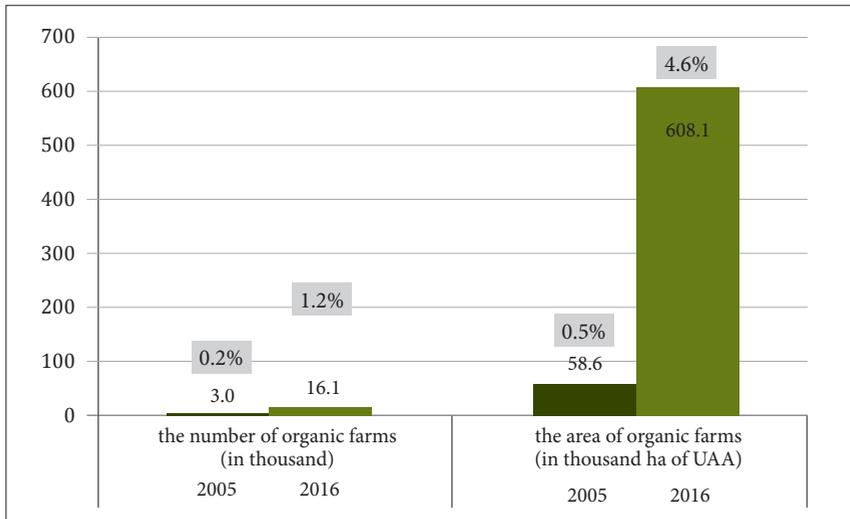


Fig. 4. Certified organic farms – their number, area and share.

Note: the grey boxes give the share of certified organic farms in the total number of private farms and the share of their area in the total utilised agricultural area used by private farms.

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2016.

Environmental sustainability

The concept on sustainable development is based on the protection of the environment, including soil protection. Agricultural practices with a favourably effect on soil condition include crop rotation, the cultivation of plants protecting soil against adverse external conditions, balancing crop and livestock production on the farm as well as balancing organic matter and key nutrients. The average results in this respect for the entire private farm sector are presented in Table 4¹⁵.

As regards anthropogenic factors affecting soil quality, the selection of crops is important. The intensive use of soil, combined with the simplification of crop changes, and the predominance of cereals may lead to a decrease in soil organic matter (Krasowicz et al., 2011). Given the values of indicators regarding crop pro-

¹⁵ More in Wrzaszcz (2018b).

duction, including the share of cereals in the cropping pattern and the share of winter cover on arable land, a significant improvement should be noted. As regards the share of cereals in the cropping pattern, its decrease is tantamount with the cultivation of other crop groups, which confirms an improvement in the diversification of cultivated crops. In 2016, the average share of cereals in the cropping pattern was 70%. Although the value of this indicator is high, it shows a decreasing trend in the analysed period, which should be considered a positive phenomenon in the context of ecosystem processes.

There is also an increase in winter cover on arable land, mainly due to catch crops, which favours soil protection, also against erosion. According to recent statistics, more than half of arable land is covered with plants during winter. As indicated by A. Józefaciuk and C. Józefaciuk (1996), water erosion is a significant threat to soil quality. This phenomenon affects 29% of the Polish territory, including over 20% of utilised agricultural area (mainly arable land). Half of this area is threatened by severe and medium water erosion. Given the current coverage of arable land, a real decrease in the risk of this phenomenon is recorded¹⁶, which is due to an environment-friendly organisation of crop production.

Table 4

Environmental sustainability of agriculture (average values)

No.	Item	2005	2016	Change in 2016/2005 in:	
				Units	%
1	Share of cereals in the cropping pattern (%)	76.95	70.44	-6.51	x
2	Share of winter cover on arable land (%)	49.00	53.00	4.00	x
3	Stocking density (LU/ha of UAA)	0.49	0.45	-0.04	-8.16
4	Organic matter balance (t/ha AL)	0.09	0.23	0.14	155.56
		2007 ^a	2016		
5	Nitrogen balance (N kg/ha of UAA)	43.78	32.97	-10.81	-24.69
6	Phosphorus balance (P kg/ha of UAA)	5.73	-0.38	-6.11	x
7	Potassium balance (K kg/ha of UAA)	8.24	-0.45	-8.69	x

^a Due to the scope of the farm structure survey, the indicators regarding fertiliser management referred to 2007 and 2016.

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2005, 2007 and 2016.

¹⁶ Cf. Krasowicz et al. (2011).

At the same time, the stocking density on private farms is decreasing. Given the low values of this indicator and the demand for natural fertilisation, the current stocking density of 0.45 LU/ha should be considered insufficient relative to the minimum manure application rate (Olko-Bagieńska and Ziętara, 1986). A further decrease in these values will exacerbate the problem of proper balancing of soil organic matter and nutrients, and will also necessitate searching for alternative methods of supplementing soil with organic matter and macro elements. Hence the prevalence of the observed trends, unfavourable for the environment, will create further challenges to ensure environment-friendly farming.

Soil organic matter balance is a comprehensive indicator of the crop and livestock production dependence. Organic matter plays a fundamental role in maintaining the chemical, physical and biological properties of soil at the proper level. It plays an important role in water circulation, soil structure stabilisation, carbon sequestration, shaping biodiversity as well as plant productivity (Krasowicz et al., 2011). Any losses of matter as a result of conducting or discontinuing one production activity should be offset by the proper organisation of other agricultural activities. This is also currently the case with private farming. A loss of organic matter as a result of limited production of natural fertilisers (reduced scale of livestock production) is offset (in the scale of the entire sector) through positive changes in crop production – the cultivation of papilionaceous plants¹⁷. The result of the soil organic matter balance reflects these two basic elements. As the presented data shows, adverse organisational changes in livestock production were offset by environment-friendly crop production (in the scale of the entire sector). In the analysed period, there was an increase in the soil organic matter indicator. In 2016, its value for the agricultural sector was 0.23 t/ha.

What is of great importance in the organisation of crop production is the proper nutrition of cultivated plants. The main nutrients include nitrogen (N), phosphorus (P) and potassium (K). Nitrogen is considered a biogenic component that, if used in excess, results in environmental pollution. Therefore, it is particularly important to balance fertiliser ingredients to ensure that the nutritional requirements of cultivated plants are met, while not creating surpluses dangerous for the environment. As the presented data shows, the nitrogen balance in 2016 was N 33 kg/ha of UAA, and in 2007 – N 44 kg/ha of UAA. Both values do not raise objections in terms of potential environmental pressure, and the observed decrease can be considered significant. The nitrogen balance for the entire sector is relatively low compared to the reference values (Kopiński, 2017). A significant decrease in the balance was mainly due to reduced natural fertilisation (Wrzaszcz and Kopiński, 2019).

A downward trend was recorded also for phosphorus and potassium. However, in the case of these two macronutrients, the balance results are currently too low, which means that cultivated plants must use macronutrient resources accumulated in soil. In 2016, phosphorus and potassium balances were negative and amounted

¹⁷ There are also other exogenous sources of organic matter, including sewage sludge, bottom sediments and digestate (Siebielec S. and Siebielec G., 2019).

to -0.4 P kg/ha of UAA and -0.5 K kg/ha of UAA, respectively. The results of balances of particular macronutrients indicate that fertilisation management in private agriculture is based mainly on nitrogen fertilisers, and much less attention is paid to the nutritional needs of plants satisfied by phosphorus and potassium fertilisers.

To sum up, the presented results showed heterogeneous changes in private agriculture in the context of environmental sustainability of the entire sector. In recent years, an improvement has been observed mainly as regards soil organic matter balancing, and a deterioration in balancing fertiliser components. Increased plant diversification, including the cultivation of plants with soil protective functions, needs to be emphasised.

Liming practices

The right pH of soil largely determines the ability to accumulate organic matter in soil. As research shows, most Polish soils are strongly or moderately acidified, and have low water and nutrient retention capacity and low organic content (Wrzaszcz and Kopiński, 2019). The conditions for agricultural production are even worse due to anthropogenic acidification processes (Filipek, Fotyma and Lipiński, 2006). According to statistics, around 80% of Poland's utilised agricultural area is acidified to varying degrees, with very acidic soils accounting for 29%, acidic soils – 28% and slightly acidic – 24%. Most cultivated plants require slightly acidic to neutral soil, hence the significant need for liming (Krasowicz et al., 2011).

According to Kopiński (2017), the consumption of lime fertilisers collapsed dramatically in the first years of Poland's presence in the EU, but since 2013, it has been slowly increasing with significant fluctuations. In 2016, the consumption of lime fertilisers was 66 kg/ha of UAA (Table 5). Although the average consumption doubled over the analysed period, this result is practically insignificant in terms of a real improvement in soil pH. Given the fact that the majority of soils in Poland are light, it can be assumed that they should be limed every 3-4 years, using 1-1.5 t of CaO/ha of UAA (Hołubowicz-Kliza 2006).

The presented data shows that the number of farms using lime fertilisers is undoubtedly a problem (Table 5). In 2005, 178 thousand farms used lime fertilisers, while in 2016, this figure was 146 thousand. Referring these values to the population of private farms, in both analysed years the population of soil liming farms accounted for only 10% of the total number of surveyed farms. This population is unfortunately not increasing, which – given the deteriorating soil condition in terms of acidification – makes this problem even more acute. In 2016, soil liming farms consumed 347 kg of CaO/ha of UAA. Compared to 2007, this dose increased by almost 90%. The average farm using lime fertilisers has a larger area and is economically stronger compared to the average farm in Poland¹⁸. These results may indicate the importance of the economic factor in agricultural producers' decisions regarding fertilisation.

¹⁸ Owners of larger and economically stronger farms show greater care for soil condition, which is reflected both in the frequency of soil tests carried out to check its pH and in liming practice (Wrzaszcz, 2012).

Based on the results regarding both the number of farms using lime fertilisers and the amount of lime used by them, it can be concluded that current fertilisation practices in this area are insufficient relative to the scale of needs. Moreover, the doubled consumption of lime fertilisers in the analysed period was due to increased fertilisation with this component on farms that had pursued such practices before the surveyed period. Based on the obtained results it can be assumed that the owners of these farms recognised the benefits of using lime fertilisers and the need to use them, and thus continued these agricultural practices.

Table 5

Use of lime fertilisers in private farming^a

No.	Item	2007	2016	Change in 2016/2007 in:	
				units	%
1	Farms having UAA maintained in good agricultural and environmental condition (%)	100	100	x	x
2	Consumption of CaO (kg/ha of total UAA maintained in good agricultural and environmental condition)	31.3	66.2	34.90	111.50
3	Share of farms using lime fertilisers	10.1	10.4	0.32	3.15
4	Area (ha of UAA maintained in good agricultural and environmental condition per farm using CaO)	13.0	17.3	4.30	33.20
5	Consumption of CaO (dt per farm using CaO)	24.2	59.9	35.76	147.90
6	Consumption of CaO (kg/ha of UAA maintained in good agricultural and environmental condition on farms using lime fertilisers)	186.6	347.3	160.69	86.11

^a Due to the scope of the farm structure surveys, the indicators regarding fertiliser management concerned 2007 and 2016.

Source: the authors' own study based on data collected as part of farm structure surveys SGR 2007, 2016.

Another reason for no widespread use of lime fertilisers on the national scale is the farmers' insufficient awareness of the importance of these fertilisers, not only directly for the soil environment, but also for plant productivity (Wrzaszcz, 2012). The right pH also determines the intake of other nutrients (nitrogen, phosphorus and potassium) by cultivated plants. A pH that is not regulated reduces the effectiveness of the use of these components, thus the productivity of plants. Improving soil pH is a basic practice affecting crop yield (Fotyma, Igras and Kopiński, 2009).

In the light of the above results, the initiative to implement a nationwide soil environment regeneration programme, addressed mainly to farms with an area of up to 75 ha (Ministerstwo Środowiska, 2019), should be considered particularly important. This programme aims to support regenerating activities designed for soils acidified as a result of anthropogenic factors. In accordance with the programme assumptions, it is planned to regenerate an area of at least 250 thousand ha in

2019-2023. As indicated in the program, the eligible costs include the costs of purchasing fertiliser lime and liming agent. Financial support for environment-friendly measures should encourage farmers to participate in this initiative, which will bring measurable benefits both to them and the soil environment.

Summary and conclusions

The presented research results concerned changes that have taken place in private farming over the last several years with respect to soil ecosystem services. The research covered farms conducting agricultural activity on an area from 1 ha of UAA maintained in good agricultural and environmental condition. The research used data from official statistics regarding results for the population of private farms in Poland were used. The period adopted for the purpose of the research, i.e. 2005-2016, made it possible to recognise the scale of economic phenomena occurring in agriculture and to evaluate them in the context of favouring and disrupting ecosystem services provided by the soil. Based on the obtained results, the following conclusions were formulated:

1. In the last three decades, despite the growing interest in issues relating to soil ecosystem services, they have not been properly analysed and described yet. Discussion in the literature shows that there is no explicit categorisation of soil functions and soil ecosystem services.
2. The existence of feedback between agriculture and soil ecosystem services is an important premise for promoting agricultural practices that favour quality and maintain soil in the best possible condition.
3. In 2005-2016, there were significant changes in farming, as evidenced by the decrease in the number of farms and labour inputs, the ongoing process of simplifying production and increasing the level of specialisation. These processes are associated with a change in the organisation of agricultural production increasing environmental pressure.
4. At present, agriculture is dominated by farms specialised in field crops, whose population will probably increase in the following years while maintaining current trends in the simplification of production. These processes highlight the need to seek and popularise various organisational solutions to preserve soil ecosystem services.
5. The development of organic farming is a manifestation of the growing interest of agricultural producers in environment-friendly activities, based on the use of natural processes in agricultural activity.
6. The values of productivity indicators confirm the stabilisation as regards the provisioning services provided by soil.
7. The changes in private farming as regards the cropping pattern, i.e. crop diversification and the growing importance of crops with favourable effects on soil condition, need to be recognised as positive.

8. Whereas those regarding livestock production and the level of calcium fertilisation should be considered a problem. Further polarisation of farms can destabilise the supporting and regenerating ecosystem services provided by soil.
9. On the one hand, environmental sustainability of private farming improved over the analysed period, which was a result of favourable changes in crop production (plant diversification, soil protection against erosion, ensuring proper organic matter balance). On the other, changes taking place in livestock production had adverse effects on the results of nutrient balances, which was mainly due to reduced natural fertilisation.
10. Given the processes taking place in agriculture due to its industrialisation, it is necessary to raise public/farmers' awareness of the importance of soil ecosystem services for agricultural productivity and profitability, in particular in the long run.
11. Soil ecosystem services should be considered as one of the priorities in the context of agricultural development support planning to encourage agricultural producers to take action for the environment, also through balancing fertiliser components and organic matter in soil.
12. The proper organisation of the farm involves effective operation ensuring stability of soil ecosystem services.

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ROZWÓJ ROLNICTWA INDYWIDUALNEGO W KONTEKŚCIE ZACHOWANIA USŁUG EKOSYSTEMOWYCH GLEBY

Abstrakt

Zagadnienie usług ekosystemowych jest względnie nowym pojęciem w teorii ekonomii. Jest to pojęcie uznawane za problematyczne ze względu na trudność w definiowaniu świadczeń dostarczanych człowiekowi przez ekosystemy, a dalej na ich pomiar i wycenę. Część tych usług jest silnie powiązana z glebą. Gleba jest jednym z podstawowych zasobów środowiska przyrodniczego niezbędnym do prowadzenia produkcji rolnej. Pełni ona wiele funkcji pozaprodukcyjnych oraz dostarcza szeregu usług, które są niezbędne do egzystencji człowieka. Opierając się na podstawowej klasyfikacji opracowanej przez Organizację Narodów Zjednoczonych, gleba dostarcza następujące usługi ekosystemowe: podstawowe, regenerujące, zaopatrujące oraz kulturowe. Z powodu różnorodności usług wytwarzanych przez glebę konieczne jest zwrócenie większej uwagi na jej jakość, która w znacznej mierze jest pochodną praktyk rolniczych. Ocena rolnictwa przez pryzmat organizacji gospodarstw rolnych pozwala na ustalenie, czy sposób gospodarowania sprzyja zachowaniu usług środowiskowych, czy też może naruszać procesy środowiskowe. W tym świetle szczególnego znaczenia nabiera przedstawienie zmian w rolnictwie na przestrzeni lat, w kontekście ich wpływu na stan środowiska przyrodniczego.

Celem artykułu jest wskazanie zmian zachodzących w rolnictwie w Polsce istotnych dla usług ekosystemowych gleby. W badaniu posłużono się danymi statystyki publicznej GUS z lat 2005, 2007 oraz 2016, pochodzącymi z badania struktury gospodarstw rolnych. Badanie obejmowało wszystkie gospodarstwa indywidualne prowadzące działalność rolniczą od 1 ha użytków rolnych utrzymanych w dobrej kulturze rolnej. Wyniki badań wskazały na dynamiczny rozwój rolnictwa w Polsce po przystąpieniu do UE, aczkolwiek wiele zmian obserwowanych może zagrażać zapewnieniu części usług ekosystemowych gleby. Pozytywnie oceniono postępującą dywersyfikację roślin polowych, uwzględniającą uprawę gatunków ozimych oraz roślin strukturotwórczych, także w formie poplonów. Za kwestie problematyczne uznano z jednej strony postępujący proces wycofywania się gospodarstw z produkcji zwierzęcej, z drugiej zaś rosnącą koncentrację produkcji zwierzęcej.

Słowa kluczowe: rolnictwo indywidualne, rozwój rolnictwa, gospodarstwa rolne, usługi ekosystemowe, usługi ekosystemowe gleby.

Accepted for print: 13.09.2019.

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