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SOIL FERTILITY AND ECONOMIC EFFICIENCY – THE CASE OF POLISH AGRICULTURE

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Abstract

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The basis of sustainable agriculture is to maintain a constant, highest possible level of soil fertility, which is one of the main conditions for long-term increasing of agricultural productivity. This condition can be achieved through the use of appropriate agricultural practices, which not only provide ecosystem services, but also are the crucial factor of biodiversity conservation. Agriculture productivity is a multidimensional issue that creates premises to analysis from both environmental and economic efficiency perspective.

The purpose of this article is to assess organisation and efficiency of farms in terms of production and economics, depending on the balance of soil organic matter and agricultural area of the farms. The study covered 1281.9 thousand Polish individual farms with an area of at least 1 ha of agricultural land.

The results indicated that the share of farms with a positive and negative balance of organic matter was similar, both in terms of farms numbers and the level of production factors involved and the standard agricultural output. It is also noted that the maintenance of adequate soil fertility is easier with the increase in area of the farm.

Farms with positive and negative balance of organic matter differed in terms of organisation of plant and animal production. Farms which preserved the productive potential of the soil were characterised by more structure-forming plants. In addition, an important factor in the proper balancing of soil organic matter and the level of economic benefits is the scale and intensity of livestock production. Organic fertilisers are an important determinant of the soil fertility, but too intensive production can disturb the local agro-ecosystem balance.

The results seem to be promising as they indicate positive - desired relationships between environmental and economic objectives at the farm level.

Key words: individual farms, balance of soil organic matter, sustainable agriculture

Introduction

Agriculture plays a key role in sustainable socio-economic development because of its importance in the management of natural resources (especially land) and some peculiarities, which do not allow for the treatment of agricultural production the same as industrial activity or services. First of all, agriculture is one of those few areas of business that use free solar energy for the production of biomass - the real added value of the Earth. This issue is described more broadly by Zegar (2012). Agriculture produces food - a good necessary for human existence, and not having a substitute - and other raw materials. Agricultural production takes place in the natural system, whose important component - the soil, along with a wealth of living organisms, must be maintained in order to continue the process of agricultural production in the future. Additionally, agriculture provides a variety of non-commercial goods and services[1], including social and cultural, and is essential to the vitality of rural areas.

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[1] The environmental services provided by agriculture include: soil fertility, water purification processes, retention of water, control of soil erosion, pollution absorption, landscape, etc. (MEA, 2005; Aisbett and Kragt, 2010; Kumar, 2010). They are part of a wider phenomenon, i.e. the externalities, that is, the processes that go unnoticed by the market mechanism because of the lack of instruments for their valuation (cf. Marshall, 1890; Pigou, 1920).

Meeting the growing needs of man in terms of food[2] depends on many factors but the most important is unquestionably the natural potential of agriculture, especially soil. In view of the limited possibilities of extending the area of land for agricultural purposes, the only solution to the challenges ahead is to increase productivity of agriculture which is the primary source of food. This raises the issue of how to increase agricultural productivity: whether by increasing inputs (business as usual) or by agro-ecological intensification. The first - industrial method - increases production through the promotion of traditional growth factors and the use of genetic modification, nanotechnology, genomics, computerisation (Sage, 2013). The other one is to use nutrient streams from microorganisms and plants to animals and back - better use of virtually unlimited resources - solar energy and seawater, allowing a reduction in demand for agricultural land, fossil energy and fresh water, and at the same time reduction in emissions associated with the consumption of agricultural chemistry products (Spiertz, 2010). Weaknesses of the industrial method are increasingly being mentioned, as are the advantages of the agro-environmental practices. The first case concerns externalities, particularly environmental externalities, and the second concerns increasing agricultural output in an environmentally friendly way - through better seeds, improved agricultural technology, new varieties of crops and animal species (Pretty et al., 2011). In particular, the importance of environmental services for the sustainable development of agriculture has been noted. Among many kinds of these services, soil fertility and pollination are of fundamental importance for food production and maintaining biodiversity.

Due to environmental reasons, the transition to sustainable agriculture is not only necessary but also urgent because of the exceeding of planet's threshold capacity (Rockström et al., 2009). The main requirement for such farming is to preserve the productive potential of the soil through the implementation of proper agricultural practices, in order to at least maintain its fertility. Agricultural practices unsuited to the soil conditions are the cause of soil degradation and fatigue. The increasing threat of soil degradation is noticed in particular in Europe, where it is considered one of the basic problems (Gardi et al., 2009; Creamer et al., 2010; Jones et al., 2012). The main principle to enable agricultural production with respect for natural resources is the skilful use of crop rotation and fertilisation of plants adequately to the condition and type of soil. Proper crop rotation and fertilisation of plants should provide a positive balance of organic matter in the soil[3]. Balance of soil organic matter is considered an important environmental indicator, an important element of the assessment of organisation and crop production and the basic principle of good management in agriculture. Organic matter and its transformation into humus compounds play a vital role in creating and maintaining soil fertility at a high level, i.e. the physical, chemical and biological properties favourable for the growth and yield of crops. The content of humus in the soil results in good quality and high level of crops. Balance of organic matter reflects the state of soil quality, which is in part the result of human activity, conscious or resulting from lack of knowledge and concern about the quality of the basic agricultural production factor. Carefully planned agricultural practices can enhance environmental values, including by stimulating the growth and diversity of agricultural crops and the inclusion of animals in various economic activities (Van Loon et al., 2005). Some traditional agricultural technologies encouraged increased biodiversity, while industrial technologies limited biodiversity. The cyclical interactions indicate the need for the development of agricultural technologies that cooperate with the processes occurring in nature.

The purpose of this article is to assess organisation and efficiency of Polish farms in the terms of production and economics, depending on the balance of soil organic matter and agricultural area of the farm.

Materials and Methods

The analysis used statistical data collected under the Agricultural Census (AC) conducted by the Central Statistical Office (CSO) in 2010. The study covered Polish individual farms with an area of at least 1 ha of agricultural area, which used arable land.

Balance of organic matter was calculated as the difference between the sum of the products of areas of cultivated crops, mass of produced natural fertilisers, mass of straw potentially allotted for ploughing and the corresponding coefficients of reproduction and degradation in relation to the area sown on arable land in the farm (Formula 1, Table 1)[4]. This balance is calculated only for arable land, since under permanent plant cover in grasslands the result always takes positive values (Fotyma and Kuś, 2000). Some important pa-

[2] These needs are growing due to the continued growth of the human population, which is estimated at about 9.5 billion in 2050 and nearly 11 billion in 2100 (United Nations, 2013), which, together with the increasing enrichment of the diet makes it necessary to increase the supply of food by at least 70% by 2050 (FAO, 2006; 2009).

[3] Soil organic matter is a collection of all organic compounds except for undecomposed parts of plants, remains of animals and living microorganisms.

[4] This method is used by the Institute of Soil Science and Plant Cultivation - State Research Institute in Puławy.

rameters (of data) that are not covered by surveys of official statistics have been established. Estimation of missing data related to the production and application of natural and organic fertilisers (straw) on farms. The positive balance of organic matter shows the soil enrichment with humus through decomposition of organic matter in the soil, which guarantees appropriate supply of nutrients throughout the growing period. In contrast, a negative balance – loss of organic matter causes the soil degradation, loss of soil fertility and productivity, particularly when such a balance is maintained for several years. The effect of degradation is the release of large amounts of minerals including nitrogen, leading to contamination of groundwater and surface water.

Table 1
Reproduction (+) or Degradation Coefficients (-) in Tonnes of Organic Matter for Medium Soil (According to Eich and Kindler)

No.	Crops and fertilisers*	Unit	Coefficient
1	Root crops	1 ha	-1.4
2	Maize, vegetables	1 ha	-1.15
3	Cereals, oilseeds, fibre	1 ha	-0.53
4	Pulses	1 ha	0.35
5	Grasses on arable land	1 ha	1.05
6	Legumes	1 ha	1.96
7	Aftercrops for green manure	1 ha	0.7
8	Straw to be ploughed	1 tonne	0.18
9	Manure	1 tonne	0.07

** Classification of crops to these groups: 1. Potatoes, sugar beet, fodder roots; 2 Maize for grain, maize for green fodder, field vegetables; 3 Cereals, rape and turnip rape, other oilseeds, flax, hemp; 4 Pulses for grain, fodder pulses; 5. Grass on arable land for green fodder; 6 Forage legumes on arable land; 7. Crops to be ploughed. Crops not specified in table 1 (resulting from the difference between sowing of arable land and total area under listed groups of plants), were treated as a neutral and were assigned „0"*
Source: (Harasim 2006, p. 67-69).

Formula 1. Balance of soil organic matter

$$SOM = \frac{\sum_{i=1}^{n}(x_i \times w_i) + (y \times w_y) + (z \times w_z)}{\sum_{i=1}^{n} x_i}$$

where:

SOM – balance of soil organic matter (t/ha),

x_i – cultivated area of particular groups of crops (in hectares),

i = 1, 2, 3, …, n,

y – amount of natural fertilisers - manure (tonnes),

z – amount of organic fertilisers - straw (tonnes),

w_i – reproduction rates or degradation rates of organic matter for groups of crops (tonnes),

w_y – reproduction rate for natural fertilisers (tonnes),

w_z – reproduction rate for organic fertilisers (tonnes).

Balance of soil organic matter was used to divide the population of farms into those with positive and negative results. Specified group of farms were characterised also in four area sub-groups, namely: 1-4.99 ha; 5-24.99 ha; 25-49.99 ha; 50 ha and more. The population of farms divided in this manner was characterized taking into account the number of farms, some elements of production and economic potential, organisation of plant and animal production - with particular emphasis on issues related to the environmental sustainability of farms - and their economic efficiency.

The preliminary characterisation of farms took into account their numbers and selected elements of production and economic potential, namely:

- agricultural land (ha),
- labour inputs (expressed in AWU)[5],
- head of livestock (expressed in LU)[6],
- value of standard output (thousand EUR)[7],
- value of standard gross margin (defined in European Size Units - ESU)[8].

[5] 1 AWU (Annual Work Unit) is equivalent to full-time, or 2120 hours of work a year.

[6] 1 LU (Livestock Unit) is a conversion unit of farm animals with a mass of 500 kg. See tables of conversion coefficients for livestock from physical units to livestock units (GUS, 2013).

[7] 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 by the number of hectares or number of animals (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.

[8] Sum of standard gross margins (SGM) - the difference between output and specific costs of all activities conducting on the farm - indicates the economic size of the farm, otherwise the productive potential of the farm. 1 ESU is equivalent to EUR 1200. 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 specific costs necessary to produce (Goraj, 2007).

Environmental sustainability was established through the presentation of average characteristics values of farm groups, namely:

- number of parcels of agricultural land in the farm - a variable indicating the farm land layout,
- share of structure-forming crops in sowings on arable land (%) - a variable indicating the environmental friendliness of crop production,
- share of cereals in sowings on arable land (%) - a variable indicating the diversity of field crops,
- winter crop cover on arable land (%) - a variable that indicates the degree of soil protection against weather, wind and water erosion,
- stocking density on agricultural land (LU/ha of AL) - an indicator of soil loading with manure,
- average balance of nitrogen (kg N/ha of AL) - determinant of proper fertilisation of agricultural crops with nitrogen,
- average balance of organic matter on arable land (t/ha of ArL) - synthetic indicator of proper crop rotation and fertilisation.

Economic efficiency of farms was measured using several criteria, such as:

- standard output per hectare of agricultural land (EUR thousands/ha of AL) - used to assess land productivity,
- standard gross margin for a full-time employee (ESU/AWU) - used to assess the labour profitability,
- source of income (maintenance) of the farm (%) - indicates the socio-economic type of farm,
- market activity of farms (%) - indicates the scale of the farms links with the market.

Economic efficiency of farms can be assessed using different indicators. Unfortunately, there is no single universal measure to evaluate the economic results of the farm. It was considered that it is necessary to use the category of agricultural income, which is the primary economic objective of the farmer, and is important for the quality of life of the farm family. Data resources collected under AC 2010 do not take into account the level of agricultural income. However, the information on the predominant source of income (maintenance) in a farm family enables the farms classification, including farms specification in which the predominant agricultural activity provides a majority income of the family, in other words, the source of livelihood.

The studied population included the following types of socio-economic households with a farm user:

- farmers' holdings - with majority income from agricultural activities,
- part-time holdings - with majority income from agricultural activities and contract work together,
- employees' households - with majority income from contract work,
- entrepreneurs' households - with majority income from non-agricultural activities,
- pensioners' households - with majority income from pension,
- other - with majority income from other sources.

The study also identified market orientation of the analysed groups of farms as an important variable in the assessment of local and market activities. Therefore, the following farms were identified:

- market-oriented farms - selling at least 50% of the generated value of agricultural production to the market,
- subsistence farms - consuming for their own needs more than 50% of the generated value of agricultural production,
- farms oriented on local market - with more than 50% of the production of goods in direct sales, i.e. at markets, own shops, neighbourhood sales.

Research Results

Characteristics and organisation of production in studied groups of farms

The study covered 1 281 thousand individual farms with an area of at least 1 ha of agricultural land, which used arable land. These farms accounted for 12 269 thousand ha of agricultural land, 1697 thousand of labour inputs (AWU) and 6128 thousand livestock units (LU). The surveyed farms accounted for 86.2% of all farms in Poland (engaged in agricultural activities with an area of at least 1 hectare) and 93.1% of agricultural land, 91.9% of labour inputs and 96.7% of livestock units. The value of the standard output generated in these farms stood at EUR 15 557 million, and the standard gross margin was 6046 thousand ESU, which respectively accounted for 94.1% and 95.6% of the total value of these economic and production categories in Poland. The research indicated the importance - scale of production factors involved and the value of agricultural output generated – by farms using arable land, which are the basic fraction of economic entities actively operating in the Polish agriculture.

In the analysed population, the group with a negative balance of organic matter slightly exceeded the group of farms with a positive balance (respectively 693.7 thousand - 54.1% and 588.1 thousand - 45.9% of the total). The same proportion applied to the relation of the factors involved and the value of agricultural production (i.e. labour inputs, livestock units, standard output). Despite the differences in the numbers of the two groups of farms, they had a comparable area of agricultural land and generated a similar value of gross margin (in both cases, the values oscillated around 50%). In the researched farms population with an area of 1-5 ha of agricultural land, the farms with a positive balance accounted for a relatively lower percentage in relation to units degrading the soil (respectively 42% and 58%), also in favour of large farms with an area of 50 hectares and more (their share was 52% and 48% respectively). These figures demonstrate the importance of the area of farms to ensure renewal abilities of the productive potential of the soil.

Farms with positive organic matter balance had better area structure (Figure 1). This group was dominated by farms with an area of 5-25 ha, while very small farms with an area of 1-5 ha dominated among farms with the negative balance. This figure indicates a greater potential for production - measured with area of agricultural land - of farms with a positive organic matter balance.

Farms with reproduction of organic matter were larger in terms of area by 14% compared to the others, and at the same time generated standard gross margin higher by 7% (Table 2). In the case of labour inputs, livestock and standard output, the differences between the two groups differed slightly *in plus* - in the case of farms where is soil degradation. These differences have intensified in the area groups, particularly in the case of the largest farms. Farms with negative balance and an area of at least 50 ha of agricultural land involved 16% more labour inputs, head of animal was larger by 55%, while standard output and standard gross margin were at a higher level - respectively 31% and 24% - against farms with a positive balance of organic matter and comparable in terms of area.

Farms with negative and positive balance of organic matter differed in terms of organisation of plant and animal production (Table 3).There were significantly more structure-forming crops in farms where care was taken to preserve the productive potential of the soil (by 61%, as compared to the others). Also, in these farms most of the crops were cereals and winter plant species (a difference of 10% and 24% in plus in comparison to farms with a negative balance of

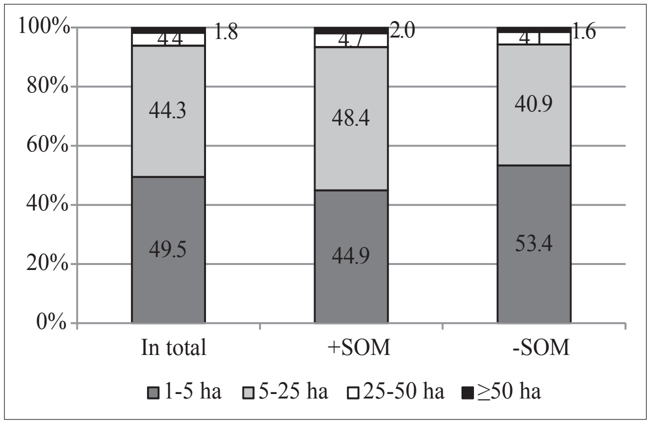

Fig. 1. Area structure of farms: in total and groups with positive (+SOM) and negative (-SOM) balance of soil organic matter

Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

Table 2

Production and Economic Characteristics of Farms (On Average): in Total and Groups with Positive (+SOM) and Negative (-SOM) Balance of Soil Organic Matter

No.	Specification	Agricultural land (ha)	Labour input (AWU)	Livestock (LU)	Standard output (EUR thousand)	Standard gross margin (ESU)
1	In total	9.57	1.32	4.78	12.14	4.72
2	+SOM: in total	10.24	1.28	4.58	12.06	4.89
3	1-5 ha	2.68	0.9	0.64	3.33	1.16
4	5-25 ha	10.65	1.52	5.61	13.08	5.45
5	25-50 ha	33.62	2.03	20.78	43.19	19
6	≥50 ha	114.29	2.42	29.69	109.35	41.57
7	-SOM: in total	9.01	1.36	4.95	12.2	4.57
8	1-5 ha	2.64	1.05	0.94	3.52	1.04
9	5-25 ha	10.58	1.62	6.57	14.7	5.77
10	25-50 ha	33.66	2.14	24.82	48.67	20.14
11	≥50 ha	117.16	2.82	45.67	143.15	51.47

Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

[9] See part of the article dedicated to the research method - table 1 on indices of reproduction and degradation coefficients of organic matter.

Table 3
Characteristics of production Organisation of Farms (On Average): in Total and Groups with Positive (+SOM) and Negative (-SOM) Balance of Soil Organic Matter

No.	Specification	Structure--forming crops (%)*	Cereals (%)*	Winter crop cover (%)*	Number of parcels of AL	Stocking density (LU/ha of AL)	Nitrogen balance (kg N/ha of AL)	Organic matter balance (t/ha)*
1	In total	12.22	75.01	50.3	5.9	0.5	45.6	0.09
2	+SOM: in total	14.94	78.54	55.46	5.67	0.45	48.1	0.59
3	1-5 ha	12.37	83.82	56.71	3.43	0.24	24.8	0.3
4	5-25 ha	12.68	82.03	52.44	6.58	0.53	50.3	0.89
5	25-50 ha	16.53	75.21	54.01	12.14	0.62	47.7	0.35
6	≥50 ha	19.74	71.08	62.01	18.46	0.26	55.6	0.31
7	-SOM: in total	9.28	71.22	44.74	6.09	0.55	43.1	-0.34
8	1-5 ha	5.62	74.3	37.51	4.22	0.36	22.3	-0.39
9	5-25 ha	8.42	74.89	42.04	7.3	0.62	44.5	-0.29
10	25-50 ha	10.58	69.12	47.18	12.66	0.74	43.4	-0.29
11	≥50 ha	12.25	63.45	52.76	20.76	0.39	55	-0.26

**Index refers to arable land. Other indices refer to agricultural land (AL).*
Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

soil organic matter). This crop structure was dictated by the direction and strength of impact of different crops groups on the content of soil organic matter[9]. A significant advantage of farms with a positive balance in terms of structure-forming crops (mainly legumes and pulses) is not surprising, because this crop group provides greater reproduction of organic matter[10].

Slight differences between the groups in terms of cereal crops resulted from the manner of distribution of cereal straw. Despite the negative impact of cereals on the state of the soil, application cereal straw for ploughing is an important factor in offsetting this impact. Specific opportunities in this field are present in farms without livestock, where the entire crop of straw can be used for organic fertiliser. In the case of animal farms keeping livestock in bedding system (this system prevails in Poland), the crop straw surplus of demand for bedding and feed for animals can be used as fertiliser to enrich the soil. Farms without livestock production, but with sustainable crop production - reflected in the structure-forming crops and organic fertiliser management - ensure production sustainability of the natural resource that is soil, although such an approach to the organisation of a one-orientation farm is more difficult. Management of a farm without livestock requires a lot of organisational skills and professional knowledge necessary to provide mitigation measures for the permanent lack of natural fertilisers[11].

In the case of cereal crops, there is the phenomenon of certain complementarity of environmental objectives. On the one hand, cereals degrade the soil - but to a lesser extent than root crops, vegetables or maize - on the other hand they protect it, by enriching it in the form of application organic fertilisers (straw)[12], and to ensure adequate protection of the soil in winter (Table 1). The advantage of cereals is the multitude of species in the form of winter varieties, which allows for sufficient soil protection against erosion (see Table 3, the share of winter crop cover in farms with positive balance of

[10] According to data from AC 2010, farms with at least 3 groups of plants were characterized by positive net balance of organic matter at the level of 0.17 t/ha, whereas in farms with less diversified crop structure, the result was 0.06 t/ha.

[11] AC 2010 results indicate that farms with animals have much higher balance of organic matter: 0.14 t/ha, compared to farms without animals, where the balance takes a negative value: -0.02 t/ha. These data indicate the importance of livestock production in the balancing of soil organic matter. The problem of balancing organic matter in farms without livestock was discussed in the publication of J. Kuś and S. Krasowicz (2008).

[12] AC 2010 results indicated that with such management of straw of cereals, the farms where cereal crops did not exceed 2/3 of arable land had on average lower balance of organic matter than the farms with higher share of cereal crops (respectively -0.14 t/ha and 0.17 t/ha). However, the differences between these groups of farms are possible in the short period due to the side effects of long-term use of cereal straw in a large area as an organic fertiliser.

organic matter was 56%, whereas in those with a negative result it was 45%). Of course, long-term cereal monoculture[13] is not beneficial for the natural environment (soil degradation, weed growth, development of diseases in cereal crops)[14] or for profits (lowers plant productivity).

The data indicate the importance of the level of livestock intensity in the management of soil organic matter and generating economic benefits. The positive effect of organic fertilisers on the physical and chemical properties of the soil is not to be underestimated, but too intensive production can disturb the local agro-ecosystem balance[15]. Natural fertilisers due to humus reproductive properties allow for balancing any loss of organic matter due to the simplification of field crops, but too high head of livestock often entails adverse changes in crop production - far-reaching simplification and detachment from the nutritional needs of farm animals. High concentration of livestock production, as well as organisation of work on the farm (labour factor involved primarily in one direction of production) usually force the unification of crop production and purchase of feed on the market. Such simplifications are associated with the cultivation of plants degrading soil - cultivated primarily in long-term monoculture. In contrast, the external costs of intensive livestock production are the result of e.g. generated surpluses of nitrogen (in soil, water, air), the emission of greenhouse gases (such as carbon dioxide, methane and hydrogen) and reduced aesthetic values of the rural environment (e.g. reduced sensory qualities as a result of storing large amounts of manure and odour emissions). However, the population of such farms in Poland is not large. The differences between comparable groups in the level of stocking density and production and economic categories (standard output and standard gross margin) also indicate that the high scale animal production results in disproportionate economic results. Differences in the level of economic results would have been even greater if calculations had taken into account the significant environmental externalities of intensive animal production. In such an arrangement, the farms which took proper care of the soil fertility would have greater economic benefits.

Table 3 takes into account the farm land layout. The average number of parcels of agricultural land was higher in the case of farms with a negative organic matter balance - a difference of 8%. This number can point to some organisational constraints in crop production resulting from the fragmentation of agricultural land. Fragmentation of agricultural land is undoubtedly valuable in terms of nature - it allows for existence and development of local bird habitats and segetal vegetation - but it also influences the organisation and crops production profitability.

The data indicate the complementarity of environmental objectives at the farm level. In many cases, it is necessary to carry out a multi-faceted analysis of specific agricultural practices in the context of their impact on the natural environment. The principles of sustainable agricultural production indicate multi-species crops, contributing to the increase in soil organic matter (humus). However, simplification of the crop production organisation requires provision of adequate nutrition through proper natural and/or organic fertilisation of soil. The farm land layout is an important element which influences the crop production organisation, which creates conditions for biodiversity conservation in rural areas and also determines the farmer's production decisions.

There was previously mentioned the importance of natural fertilisers in balancing organic matter. The data presented in Tables 3 and 4 indicated, that two thirds of farms engaged in livestock production and their stocking density was 0.50 LU/ha of AL. Farms with a different balance of organic matter differed in this respect, as already indicated by data on their production potential (Table 2). Farms with a positive balance slightly less often engaged in livestock production and stocking density was lower (respectively in farms with positive and negative net balance: 62%, 0.45 LU/ha of AL and 71%, 0.55 LU/ha of AL).

Number of farms with livestock production did not correspond to the number of farms, where natural fertilisers were used. In farms with positive result, natural fertilisers were used more often (64%) - that is an evidence of the purchase of these fertilisers. The situation was different in farms with a negative balance (59%) - there took place the sale of natural

[13] In a period of several years (about 3 years), such crops can be the dominant part of the crops without significant damage to the natural environment.

[14] It should also be noted that too frequent cereal straw ploughing can cause a number of adverse effects, which include: 1) formation of biologically active substances in the soil which inhibit the initial growth of plants; 2) disturbance of the soil nitrogen balance, as cereal straw contains only 0.5% nitrogen, and the ratio of carbon to nitrogen is 80-100 to 1. Microorganisms causing its degradation in the soil must draw nitrogen from other sources, which can cause poor supply of that ingredient to plants; 3) ploughing under the straw, especially winter cereals under winter cereals poses a risk of increased prevalence of certain diseases, which are difficult to combat with chemical plant protection products. Straw of grain maize has the most favourable influence on the soil state, followed by legumes and rape straw (Kuś et al., 2006).

[15] AC 2010 results indicate that farms where stocking density on agricultural land did not exceed 2 LU/ha were characterized by a higher balance of organic matter: 0.13 t/ha; for farms with more intensive stocking density: 0.00 t/ha.

Table 4
Share of Farms with Livestock Production and According to the Means of Production (%): in Total and Groups with Positive (+SOM) and Negative (-SOM) Balance of Soil Organic Matter

No.	Specification	Farms with livestock production	Farms that used:		
			plant protection products	natural fertilisers	calcium fertilisers
1	In total	66.62	18.48	61.15	12.95
2	+SOM: in total	61.92	17.51	63.67	14.07
3	1-5 ha	45.95	26.01	49.48	8.14
4	5-25 ha	75.13	10.75	75.59	17.2
5	25-50 ha	80.02	8.21	79.3	28.53
6	≥50 ha	58.3	12.06	57.33	37.43
7	-SOM: in total	70.6	19.31	59.01	12.01
8	1-5 ha	62.5	26.48	47.51	6.23
9	5-25 ha	79.96	11.76	71.77	16.69
10	25-50 ha	84.98	6.07	80.94	29.48
11	≥50 ha	64.51	7.03	59.65	39.87

Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

fertilizers. These results are justified by a different scale of livestock production in analysed groups of farms.[16]

In addition to organic and natural fertilisers, calcium fertilisers are an important element of fertilisation practices. They are a major source to neutralise the acidity of soil. Taking into account the fact that the bulk of soils in Poland are light soils, it can be assumed that they should be limed every 3-4 years with 1-1.5 tonnes of CaO/ha (Hołubowicz-Kliza, 2006). Farmers who show greater concern for the proper soil pH (hence soil production potential) - as evidenced by the level and frequency of application of calcium fertilisers - have greater organisational capacities in terms of crop production (diverse structure of agricultural crops). Public statistics are used to determine the number of farms in which such practices occurred. On average, only 13% of Polish farms used calcium fertilisers. In farms with positive organic matter balance, calcium fertilisation was more frequent, than in others.

Organisation of agricultural production (crop and livestock) is reflected in the synthetic indicator which is the fertiliser balance, especially nitrogen balance. Nitrogen is the main macroelement that determines plant productivity on the one hand, and threats to the natural environment (water, soil, and atmosphere) on the other. The level of nitrogen fertilisation in farms - with both positive and negative balance of organic matter - was within safe ecosystem limits (respectively, balance of nitrogen was 48 kg N/ha and 43 kg N/ha).

Economic efficiency of surveyed groups of farms

Economic efficiency of farms can be assessed using different indicators - there is no single universal measure to evaluate the farms economic results. In this article, the issue of farms economic efficiency was analysed taking into account the following indicators:

- land productivity (indicating the size of agricultural production per land unit),
- labour profitability (indicating the size of standard gross margin per labour unit - potential payment for work),
- predominant source of income (maintenance) for a farm family (socio-economic types),
- links with the market (market type).

The average land productivity of Polish farm stood at 1.27 thousand EUR/ha of agricultural land (Figure 2). Farms, that degraded soil organic matter were characterised by higher land productivity, than farms with a positive balance (difference between the two was 15%). These differences particularly intensified in the case of the last area group (respectively 28% in favour of farms with a negative balance). The research indicated a higher land productivity of farms where take place depletion of soil organic matter. These results, however, are static - they apply only to 2010. In dynamic/long term perspective and with full economic calculation taking into account the external effects of economic activity, the relationship between the surveyed groups of farms most likely

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[16] The figures refer only to the number of farms trading natural fertilisers. Public statistics do not record the amounts of natural fertilisers which was the subject of trading.

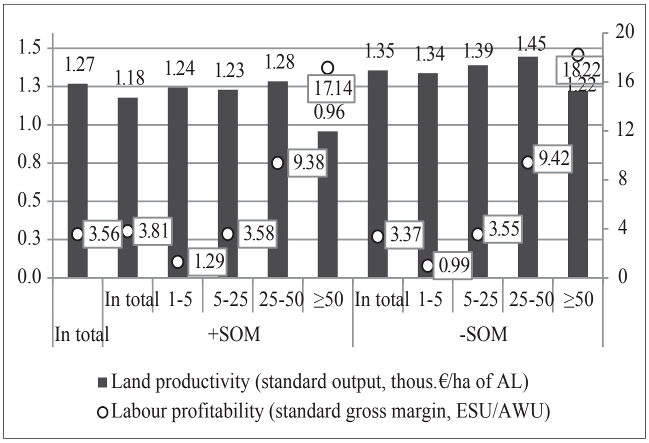

Fig. 2. Selected indicators of farms economic efficiency: in total and groups with positive (+SOM) and negative (-SOM) balance of soil organic matter
Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

would be different - in favour of farms in which agricultural practices ensure the local agro-ecosystem stability. Intensive exploitation of the natural resource which is the soil can be profitable for the farmer, but only in the short term. In the long term, degradation of humus limits the volume of production (unit productivity), thus affecting the income level of agricultural producers.

Short-term relatively higher productivity of agricultural production - usually characterised by intensive organisation and production - encourages agricultural producers to undertake rational action only in microeconomic terms. Macroeconomic perspective on economic activity - and thus the social responsibility - must take into account the value of public goods that do not have a specific price yet. The figures show that, in particular, highly intensive agricultural production is profitable for the farmer; hence the comprehensive valuation of natural resources used in agriculture and the full economic calculation must take into account the high profitability of intensive agricultural production. If agricultural production is conducted in accordance with the principles of sustainable development, it will not be sufficiently competitive in economic terms with high volume (conventional) production degrading natural resources, the producer will act only in accordance with the principles of microeconomic rationality.

The results for the labour profitability present a slightly different picture - more beneficial for farmers who take care of soil organic matter (Figure 2). In this case, the standard gross margin per labour unit distinguished farms with a positive balance - an average of 3.81 ESU/AWU and exceeded the value of farms degrading the soil by 13%[17]. With the increase in the area of farms, those relations were reduced, whereas for the last area group (at least 50 ha), the most favourable results were in case of farms with negative balance (difference of 6%). These data confirm the impact of large-scale (intensive) agricultural production on its economic efficiency.

The assessment of economic efficiency of farms was also based on the income structure of farm families. As indicated in Table 5, the structure of income in farms with both positive and negative balance of organic matter was similar. The largest part of farms is managed by people for whom agricultural activities are not the main source of the income (holdings of entrepreneurs and employees stood out). Agricultural holdings of farmers, and more precisely households with a user of a farm, obtaining majority of the income from own agricultural activity, accounted for over one third of the total number of the analysed population of farms, while the least numerous group were the holdings of pensioners. A similar distribution of the examined groups of farms in socio-economic terms indicates no close relationship between quality of management and the predominant source of income for farming families. However, the distribution of farms by socio-economic type in the area groups allows us to formulate some general but important conclusions. Greater production potential of farms is favourable to economic sustainability, which is indirectly proved by AC 2010 data through the structure of households associated with the user of farm. The results seem to be promising as they demonstrate positive relationships between environmental and economic objectives at the farm level (Wrzaszcz, 2012).

Population of farms with an area of 1-5 ha is dominated by employees' and entrepreneurs' agricultural holdings, followed by households of pensioners. This result is not surprising, since agricultural activity in small farms often constitute complement function with reference to non-agricultural activities. In the case of active pensioners, conducting agricultural activity is a hobby and/or constitute additional source of household income. Also, a significant proportion of farms with a large area (from 25 ha) is managed by entrepreneurs (almost every tenth farm), which indicates the scale of agricultural production po-

[17] Relations between the two groups in terms of the unit standard output and the unit standard gross margin were different. The causes can discern in the amount of subsidies - which increase the value of the gross margin and in the level of specific costs, which are included in the calculation of this category. The level of subsidies to some extent compensates for the alternative benefits of intensive (high volume) agricultural production that degrades the soil. Financial support for agricultural producers should compensate not only the abandonment of operations to further increase the scale of production, but also create some incentive - a financial surplus - to activate agricultural producers towards pro-environmental measures.

Table 5
Structure of Agricultural Holdings by the Socio-Economic Type (%): in Total and Groups with Positive (+SOM) and Negative (-SOM) Balance of Soil Organic Matter

No.	Specification	Farmers'	Part-time	Employees'	Entrepreneurs'	Pensioners', other
1	In total	37	3.2	27.6	8.5	23.7
2	+SOM: in total	38.5	3.1	28.2	8.9	21.4
3	1-5 ha	15.2	3.2	40.4	11.9	29.4
4	5-25 ha	53.6	3.3	20.3	6.7	16
5	25-50 ha	84.7	1.1	4.2	3.8	6.2
6	≥50 ha	84.1	0.9	3	5.5	6.4
7	-SOM: in total	35.7	3.2	27.2	8.1	25.7
8	1-5 ha	14.6	3.6	36.8	10.1	34.9
9	5-25 ha	56	3.1	18	6.2	16.7
10	25-50 ha	88.7	0.8	2.8	2.6	5
11	≥50 ha	86.6	0.6	2.7	4.5	5.5

Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

tential available to people who mainly derive income from outside agriculture. The rationale followed by such entrepreneurs is certainly based on economy, as they can raise additional funds as beneficiaries of a wide range of subsidies targeted at users of agricultural land, and also it is a relatively safe way of owner's equity investment.

An important feature - and at the same time the criterion for the classification of farms - is the distribution of agricultural production. CSO studies isolated three directions of agricultural production distribution, two of which are separate (market and subsistence orientation), and the third is located in both of the preceding and applies to so-called direct sales (local market orientation). The distribution of agricultural production in the studied groups of farms is illustrated in Figure 3.

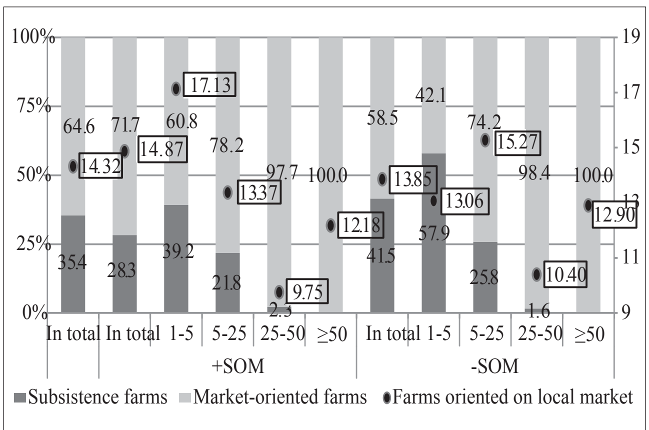

Fig. 3. Share of farms according to their market activity (%): in total and groups with positive (+SOM) and negative (-SOM) balance of soil organic matter
Source: Prepared on the basis of the Central Statistical Office data of the Agricultural Census 2010.

Among the total number of surveyed farms, two thirds produced mainly for the market, while the remainder of farms produced mainly for domestic needs. Farms in which agricultural practices allowed for an increase in soil organic matter were relatively more often oriented on the market, as compared to farms with a negative balance - 72% and 56% respectively. Such relationships can be regarded as a symptom of a higher demand for agricultural products produced under conditions not interfering with environmental sustainability and of higher quality (resulting for example from precise management of organic and natural fertilisers). A growing percentage of market-oriented farms in higher area groups is evident; Figure 3 confirms it.

On average, the local market activity of farms was moderate – this was the case of several percent of farms. Strength of links between farms and the local market, both farms with positive and negative balance, was comparable (respectively 15% and 14% of farms sold more than half of the production volume in the local market). For these two groups of farms, shortening the food chain provides benefits to both the consumer and the producer. On the one hand, the final recipient can directly verify purchased product through the exchange of information with the producer (among others on the quality and characteristics of the product) and have an impact on the price (possible negotiations and subsequent elimination of components of the price of product as a result of shorter food chain). On the other hand, in the case of a producer-farmer, the sale on the local market reduces the risk of potential losses (associated e.g. with transport and storage), and the entire economic surplus goes to the producer.

It is difficult to assess the relationship between the area of farms and their local market activity. Attention is drawn to the relatively higher share of local market farms with area of at least 50 ha (compared to entities with an area of 25-50 ha), including farms pursuing the principles of sustainable agricultural production. The presented summary raises a presumption that on the local market occurred demand for large - uniform batches of agricultural products, which can be provided only by large producers.

Conclusions

A key requirement for the agriculture sustainability is to preserve fertility of the soil, which crucially depends on the regeneration of organic matter. The paper analyses organisation and efficiency of Polish farms in terms of production and economics, taking into account the balance of soil organic matter and area of agricultural land. The analysis used statistical data collected under the Agricultural Census conducted by the Central Statistical Office in 2010. The study covered 1281.9 thousand individual farms with at least 1 ha of agricultural land, which used arable land, i.e. 86.2% of all individual farms in Poland.

Based on the research, the main conclusions are as follow:

- In the researched population, the share of farms with a positive and negative balance of organic matter was similar, both in terms of farms number, the level of production factors involved and standard agricultural output.
- Results of the analysis confirm the importance of the land factor -the farm area - for the functioning and development of sustainable forms of agriculture. With large areas, it is easier to reconcile environmental and economic goals.
- Farms with positive and negative balance of organic matter differed in the organisation of crop production, which can be considered more environmentally friendly in farms that preserve production potential of the soil, mainly due to the high proportion of structure-forming crops and significant winter crop cover.
- The scale and intensity of livestock production is an important factor in the proper balancing of soil organic matter and the level of economic benefits. The positive effect of natural fertilisers on physical and chemical properties of the soil is an important determinant of the positive balance, but too intense production can disturb the local agro-ecosystem. Farms without livestock production, but with sustainable crop production - reflected in the correct structure of crops and organic fertiliser management - ensure the soil fertility, although the proper organisation of a one-orientation farm is more difficult and requires more knowledge and professional skills.
- Complementarity of environmental objectives at farm level justifies the need for a multifaceted analysis of specific agricultural practices in the context of their impact on the natural environment. In applying the principles of sustainable agricultural production, it is possible to cultivate crops that do not contribute to an increase in soil organic matter (humus), but with a simplified crop production organisation it is necessary to provide sufficient nutrition to the soil through proper organic and/or natural fertilisation. Another example is the farm land layout, which creates conditions for biodiversity conservation in rural areas, but also determines the farmer's production decisions.
- Short-term higher land productivity - usually resulting from intensive organisation of agricultural production - encourages agricultural producers to undertake rational action only in microeconomic terms. This approach does not take into account the side effects of agricultural activities in the form of depletion of soil organic matter. In long-term perspective and with full economic calculations based on valuation of externalities of economic activity, the relationship between the researched groups of farms would be different - in favour of farms in which agricultural practices ensure the local agro-ecosystem balance. In the long term, degradation of humus limits the volume of production (unit land productivity), thus affecting the level of agricultural producers income.
- Larger production potential of farms promotes economic sustainability. This is confirmed by the relatively higher percentage of farmers' holdings in comparison with the whole population of analysed farms.
- Farms where agricultural practices allow for an increase in soil organic matter are relatively more market-oriented (they sell most of their agricultural production on the market),as compared to others, that degrade the soil productive potential. In turn, the larger area of farms, the stronger is their market activity. On average, links between farms and the local market are moderate – this is the case of 14% of farms. Agricultural practices that are reflected in the level of soil organic matter do not differentiate farm activity in the local market. It is important to promote this form of activity among agricultural producers, as shortening the food chain provides benefits to both the producer and the consumer. It is difficult to assess the relationship between the area of farms and their links with the local market. However, the relatively higher share of the local market farms with an area of at least 50 ha (compared to those with an area of 25-50 ha) raises a presumption that on the local market occurred demand for large - uniform batches of agricultural products, which can be provided only by major producers.
- Visible trends in crop and livestock production intensify the phenomenon of competitiveness of economic and environ-

mental objectives at farm level. The presented data are the reason for introduction of changes, both in crop and livestock production. On the one hand, in the long-term, the prevalence of cereals in crop structure on arable land, as well as a significant portion of farms without livestock (not using natural fertilizers) will lead to overexploitation of natural resources. On the other hand, major external costs are generated by farms with high-scale livestock production, often unrelated to crop production.
- Taking into account the necessity of sustainable development, the most desirable form of farm management is to combine crop and animal production with a moderate level of intensity.

These assertions suggest that about half of Polish farms provide environmental services concerning the maintenance of soil production potential. The study indicated relatively small differences in the level of land productivity between farms that reproduce and degrade the soil. This gives premises to activate an institutional factor that could offset the economic differences, for example in the form of subsidies. This form of co-financing would be an incentive for agricultural producers who have previously applied practices that generate negative consequences for the natural environment, towards the adoption of sustainable agricultural activities. Broadly defined education (including policy-makers, agricultural producers and food consumers), which would influence environmental awareness of the public, is an important factor in introducing agricultural changes that are beneficial to the ecosystem.

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