USABLE AGRICULTURAL AREA OF FARMS AND THEIR MATERIAL AND ENERGY EXPENDITURE EFFICIENCY

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ARTICLE INFO	ABSTRACT
Article history: Received: January 2020 Received in the revised form: February 2020 Accepted: March 2020 *Key words:* *material expenditure,* *energy expenditure,* *efficiency indexes*	The paper analyzes the efficiency of material and energy expenditure in 679 farms with agricultural production as the main source of income for the years 2013-2015. Six groups of farms were identified according to usable agricultural area (UAA). The aim of the work was to determine the impact of UAA of farms on their material and energy expenditure efficiency. It was found that the area of UAA determines the farms' material and energy expenditure efficiency. It was observed that small farms with UAA of 5 to 10 ha are characterized by the highest material and energy expenditure efficiency. It was proven that the material and energy expenditure efficiency in "Small" farms with UAA (<= 5ha) and "Very large", with UAA (> 50ha) differs significantly from the efficiency determined for other farm groups. Material and energy expenditures were used the least efficiently in the farms with the smallest UAA.

The paper analyzes the efficiency of material and energy expenditure in 679 farms with agricultural production as the main source of income for the years 2013-2015. Six groups of farms were identified according to usable agricultural area (UAA). The aim of the work was to determine the impact of UAA of farms on their material and energy expenditure efficiency. It was found that the area of UAA determines the farms' material and energy expenditure efficiency. It was observed that small farms with UAA of 5 to 10 ha are characterized by the highest material and energy expenditure efficiency. It was proven that the material and energy expenditure efficiency in "Small" farms with UAA (<= 5ha) and "Very large", with UAA (> 50ha) differs significantly from the efficiency determined for other farm groups. Material and energy expenditures were used the least efficiently in the farms with the smallest UAA.

Introduction

The last several years saw an increase in usable agricultural area (UAA) of farms, The process was accompanied by technical and technological modernization, which significantly impacted the amount of material and energy expenditure (Kocira, 2013). The amount of expenditure incurred may indicate the size of the farm and its economic strength. The level of investment expenditure may indicate strong links between the farm and its environment (Cooper et alt., 2007; Gołębiewska, 2007; Mohammadi and Omid, 2010). Material expenditure on agricultural production determine its current total cost, as well as the obtained income and the level of remuneration for the farmer and his family.

An indispensable element of production is direct and indirect energy expenditure. Direct expenditure includes fuel and electricity consumption and energy expenditures related to production of raw materials constitute indirect expenditures (Kocira et al. 2019, Pawlak, 2016). Energy holds a key share in agricultural production expenditure. Changes in the level and

technology of agricultural production, increased prices of energy carriers and a decreasing number of entities that qualify for the category of agricultural holdings have had a significant impact on energy consumption. The development of agricultural production is associated with an increase in energy demand, especially during agrotechnical treatments (Gorzelany, 2010; Gorzelany et al., 2011; Hosseinzadeh-Bandbafha et al., 2018).

The most reliable measure to estimate the condition of the energy economy is the energy expenditure efficiency, expressed by the ratio of the value of production obtained to the expenditure incurred on fuel and electricity. One of the most important factors affecting the efficiency of energy expenditure in agricultural production is the systematically rising prices of the media. Detailed monitoring of changes in this efficiency level is also an important issue (Gorzelany, 2010; Gorzelany et al., 2011). In the case of agriculture in Poland, improving this efficiency is extremely important, primarily due to the competition from Western European farms (Ozkan et al., 2004; Sorensen et al., 2014; Wójcicki and Rudeńska, 2014; Apergis et al., 2015; Komorowska, 2016; Koesling et al., 2017).

However, more extensive studies and analyzes discussing the efficiency of material and energy expenditure on farms with different UAAs are not available. Therefore, it is justified to analyze the impact of UAA on the efficiency of material and energy expenditure to answer the question whether the UAAs of family farms differentiates the efficiency of material and energy expenditure.

Material and methods

The materials used in the work are data obtained under the Polish FADN in 2013, 2014 and 2015 from family farms located in the Lubelskie province. The research used results from 679 farms whose main source of income was agricultural production.

Farms were divided into 6 groups, according to UAA:
– "Very small" farms, with UAA ≤ 5 ha,
– "Small" farms, with UAA ≤ 10 ha,
– "Medium-small" farms, with UAA ≤ 20 ha,
– "Medium-large" farms, with UAA ≤ 30 ha,
– "Large" farms, with UAA ≤ 50 ha,
– "Very large" farms, with UAA ≤ 50 ha.

The analysis of the efficiency of energy and material expenditure was made using 5 indexes.

Efficiency of material and energy expenditure I (E_{NmeI}) − a ratio of total production (P_o) to the sum of material and energy expenditure (N_{me}).

$$E_{NmeI} = \frac{P_o}{N_{me}} \tag{1}$$

where:
P_o –– total production, (PLN)
N_{me} – total material and energy expenditure, (PLN)

Total production is the sum of values of plant, animal and other types of production, e.g. own consumption. It comprises sales, transfer to a household, the farm's own consumption,

a difference in inventory and a difference in the value of animals caused by a change in pricing and reduced by the purchase of animals.

Total expenditure is the sum of human and objectified labor used to produce a specific product or service. They can be measured in natural units or expressed as a value. Total expenditure includes: seeds and seedlings, own seeds and seedlings, fertilizers, plant protection products, feeds for animals kept in the grazing system, feeds for animals fed in the grazing system produced on farms, feeds for granivorous animals produced on farms, electricity.

Efficiency of material and energy expenditure II (E_{NmeII}) - a ratio of gross value added (W_{Db}) to total expenditure (N_{me}).

$$E_{NmeII} = \frac{W_{Db}}{N_{me}}$$ (2)

where:

W_{Db} – gross value added, (PLN)

N_{me} – total material and energy expenditure, (PLN)

Gross value added is the value of total production of the farm minus intermediate consumption (i.e. direct and general economic costs), balance of current payments and taxes.

Efficiency of material and energy expenditure III (E_{NmeIII}) – a ratio of net value added (W_{Dn}) to total expenditure (N_{me}):

$$E_{NmeIII} = \frac{W_{Dn}}{N_{me}}$$ (3)

where:

W_{Dn} – net value added (PLN),

N_{me} – total material and energy expenditure (PLN).

The net value added is the remuneration for work, management and capital used on the farm. It is lower than the gross value by the amount of depreciation charges.

Efficiency of material and energy expenditure IV (E_{NmeIV}) – a ratio of net agricultural income (D_{rn}) to the sum of material and energy expenditure (N_{me}).

$$E_{NmeIV} = \frac{D_{rn}}{N_{me}}$$ (4)

where:

D_{rn} – net agricultural income, (PLN)

N_{me} – total material and energy expenditure, (PLN)

Net agricultural income is a direct surplus minus indirect costs

Material and energy expenditure efficiency V (E_{NmeV}) – a ratio of a farmer's family income (D_{rr}) to total expenditure (N_{me})

$$E_{NmeV} = \frac{D_{Rr}}{N_{me}}$$ (5)

where:

D_{rr} – the farmer's family income, (PLN)

N_{me} – total material and energy expenditure, (PLN)

According to EU agricultural accountancy system FADN, the income of a farmer's family is the value of production (comprising the value of sales, an increase in the value of the herd, the value of productive consumption of own products, the value of private consumption of own products, the value of own product stocks at the end of the year minus the value of own products at the beginning of the year, as well as the value of the purchased animals) minus intermediate consumption.

For each expenditure efficiency index (mean values of the indexes from 2013-2015), the significance of differences between individual groups of farms was analyzed. After determining the significance of differences by the Kruskal-Wallis test at $p < 0.05$, a Mann-Whitney test was performed in order to assess the groups between which there are significant differences.

Results and discussion

The studied farms were characterized by a wide range of UAA, from 2.54 to 95.79 ha in 2013 and 2014, and from 2.54 to 138.67 ha in 2015 (Table 1). The standard deviation calculated for the area of UAA in all three analyzed years was at a similar level. This index remained at 12.36 in 2013, at 11.29 in 2014 and at 13.34 in the last of the analyzed years. The value of the coefficient of variation for all of the analyzed years ranged from 56% to 62%. This would indicate moderate variability in the group of farms divided per UAA.

Stocking density, expressed in LU·ha^{-1} UAA, exhibited an upward trend with each analyzed year, at a constant mean of 0.58 in 2013, and 0.69 and 0.97 in 2014 and 2015, respectively. The high value of the coefficient of variation in all the analyzed years indicated high variability of the stocking density.

The economic size of the studied family farms expressed in EUR was highly diversified, and increased in each of the individual years of research. The average value of their economic size in 2013 was EUR 35,749, and in 2014 and 2015, EUR 38,981 and EUR 53,498, respectively. The minimum level of economic size in each year remained at a similar level. In 2014, farms were characterized by low variability of economic size, while in 2013 and 2015 a moderate variability was noted in this respect.

Labor inputs expressed in mh·ha^{-1} UAA remained at a similar level in all the analyzed years. The average value of labor inputs in 2013 was 319.37 mh·ha^{-1} UAA, while in 2014 and 2015 it was 295.55 and 313.07, respectively. In 2013 and 2014, the farms were characterized by moderate variability of labor inputs, while in 2015 this index demonstrated high variability, at 296%.

In all the analyzed years, total production expressed in PLN·ha^{-1} UAA remained at a similar level, i.e. 11,000 PLN·ha^{-1} UAA. Only in 2013 the farms were characterized by moderate variability of total production, as in all other years, the index was highly variable.

The stocking density in particular groups of farms was highly diversified. The smallest average stocking density per ha of UAA was characteristic for "Very small" and "Very large" farms due to the chosen direction of production. "Very small" farms mainly carried out horticultural production, and "Very large" farms focused mostly on agricultural production. Farms from the "Medium-large" group had the highest stocking density in all the analyzed years. In this group, the stocking density remains at a similar level, from 0.50 to 0.51 LU · ha^{-1} UAA in each year of research.

Table 1.
General characteristics of the studied family farms

Year of research	Specification	UAA (ha)	Animal stocking (LU·ha⁻¹ UAA)	Economic size (€)	Labor input (mh·ha⁻¹ UAA)	Total production (PLN·ha⁻¹ UAA)
	Mean	20.01	0.58	35749	319.37	11255
	Minimum	2.54	0	4571	163.93	2998
2013	Maximum	95.79	2.2	287346	588.44	37474
	Standard deviation	12.36	0.73	23703	228.96	11169
	Coefficient of variation	62%	126%	66%	72%	99%
	Mean	20.17	0.69	38981	295.55	10192
	Minimum	2.54	0	4168	148.68	2050
2014	Maximum	95.79	3.63	355742	561.07	30361
	Standard deviation	11.29	0.92	15406	193.22	11283
	Coefficient of variation	56%	133%	40%	65%	111%
	Mean	23.45	0.97	53498	313.07	11624
	Minimum	2.54	0	4325	95.34	1576
2015	Maximum	138.67	2.58	450653	676.77	38680
	Standard deviation	13.34	1.87	52939	925.81	23852
	Coefficient of variation	57%	193%	99%	296%	205%

The largest economic size was characteristic for farms from the group with the largest UAA in 2015, i.e. "Very large", at EUR 44,890, 45,672 and 48,053 in the years 2013-2015, respectively. Such value of economic size allows classifying them as "Large" farms, according to economic size classes. Due to the fact that "Very Small" farms ran horticultural production, their economic size was comparable to "Medium-large" farms. The smallest economic size was characteristic for farms from the "Small" group. The average economic size of these farms in 2013 and 2015 was EUR 11,704 and 11,690, respectively.

The largest labor input, expressed in mh·ha⁻¹ UAA, were characteristic for farms from the group with the smallest area of UAA and they were almost 40 times larger than the input incurred by farms from the "Very large" group. Such large labor inputs in this group of farms resulted from the horticultural production, which these farms often ran, and which requires a

lot of manual labor. The lowest labor input occurred in the group of "Very large" farms, which is due to the production focus of the farms on agricultural production, which is characterized by a high degree of mechanization of work.

Total production, expressed in PLN per ha of UAA, was different in various groups of the studied farms. Together with the increase in the UAA in farms, the total production per 1 ha of UAA decreased. The highest value of total production was achieved by farms from the "Very small" group. The total production value identified for these farms was almost 20 times higher than on farms from the "Very Large" group, in which the lowest values occurred. In individual years, the total value of production in most groups remained at a similar level. Only in the "Very Small" group of farms a decrease was observed in total production value in 2015 by over 18%, as compared to 2013.

Table 2.
General characteristics of farm groups established per UAA

| Group of farms per UAA UAA6	Year of research	No. of farms in the group	Average UAA (ha)	Animal stocking (LU · ha⁻¹ UAA)	Economic size (EUR)	Work outlays (mh · ha⁻¹ UAA)	Total production (PLN · ha⁻¹ UAA)
Very small (≤ 5 ha)	2013	16	2.39	0.23	27,080	2123	70,346
	2014	15	2.34	0.43	28,429	2043	61,535
	2015	16	2.32	0.23	26,463	1883	57,326
Small (5 ≤ 10 ha)	2013	89	8.10	0.42	11,704	427	7,304
	2014	96	8.17	0.43	11,893	408	6,491
	2015	92	8.10	0.36	11,690	417	7,278
Medium-small (10 ≤ 20 ha)	2013	259	14.59	0.41	16,771	264	5,784
	2014	244	14.65	0.45	17,325	262	5,333
	2015	239	14.55	0.40	16,582	262	5,340
Medium-large (20 ≤ 30 ha)	2013	145	24.48	0.50	26,461	168	5,476
	2014	146	24.55	0.51	27,410	169	5,305
	2015	144	24.25	0.50	27,259	170	5,164
Large (30 ≤ 50 ha)	2013	130	36.57	0.47	37,708	114	5,202
	2014	137	37.10	0.43	37,121	114	4,971
	2015	148	37.91	0.47	39,691	115	3,849
Very large (> 50 ha)	2013	40	62.29	0.13	44,890	64	3,623
	2014	41	64.73	0.12	45,672	60	3,849
	2015	40	66.69	0.11	48,053	57	3,691

The groups of farms, determined according to the area of UAA, were characterized by a large variability of material and energy expenditure efficiency indexes. The highest value of the index E_{NmeI} was obtained by farms from the "Small" group; in the years 2013-2015 it was 2.14, 2.10 and 2.58, respectively (Table 3). Thanks to such material and energy expenditure efficiency, expressed by the index E_{NmeI}, farms from the "Small" group were also characterized by high efficiency, calculated by the ratio of the farmer's family income to material and energy expenditure, expressed as E_{NmeV}, at 0.64-0.94. As a result of production costs incurred, the farms in the "Very small" group were characterized by very low values of the efficiency index E_{NmeV}: 0.03 in 2013, 0.14 in 2014 and 0.09 in 2015, despite the average value of index E_{NmeI}, at 1.57-1.74 (compared to the value of this index in other groups). This situation indicates too high production costs, which generate low income for the farmer's family.

Table 3.

Material and energy expenditure efficiency and the area of UAA in the studied years 2013-2015.

Group of farms per UAA UAA6	Year of research	E_{NmeI}	E_{NmeII}	E_{NmeIII}	E_{NmeIV}	E_{NmeV}
Very small (≤ 5 ha)	2013	1.74	0.65	0.41	0.25	0.03
	2014	1.62	0.75	0.54	0.27	0.14
	2015	1.57	0.68	0.44	0.29	0.09
Small (5 ≤ 10 ha)	2013	2.14	1.55	1.06	0.92	0.78
	2014	2.10	1.43	0.88	0.76	0.64
	2015	2.58	1.91	1.29	1.12	0.94
Medium-small (10 ≤ 20 ha)	2013	1.82	1.26	0.89	0.79	0.71
	2014	1.90	1.25	0.86	0.73	0.62
	2015	2.02	1.38	0.96	0.81	0.70
Medium-large (20 ≤ 30 ha)	2013	1.65	1.06	0.74	0.68	0.65
	2014	1.68	1.07	0.74	0.67	0.63
	2015	1.89	1.23	0.84	0.75	0.69
Large (30 ≤ 50 ha)	2013	1.53	0.95	0.68	0.63	0.60
	2014	1.67	0.97	0.66	0.60	0.55
	2015	1.76	1.07	0.74	0.67	0.62
Very large (>50 ha)	2013	1.74	1.30	0.94	0.90	0.44
	2014	1.68	1.18	0.81	0.78	0.77
	2015	2.16	1.59	1.10	1.02	1.01

The highest three-year mean material and energy expenditure efficiency, expressed as an index E_{NmeI}, were achieved by farms from the "Small" group, and the lowest, from the "Very small" and "Large" group (Fig. 1). Statistically significant differences in the value of this index were identified between farms from the "Small" and "Very small" groups and other farm groups. The lowest efficiency, regardless of the analyzed index, was characteristic for farms from the "Very small" group. However, the highest values of all indexes were obtained in the "Small" group of farms; the values of its indexes differed significantly from the other analyzed farm groups. It was observed that, along with an increase in the area of farms, there is a decrease in material and energy efficiency from "Small" to "Large" groups (Fig. 1).
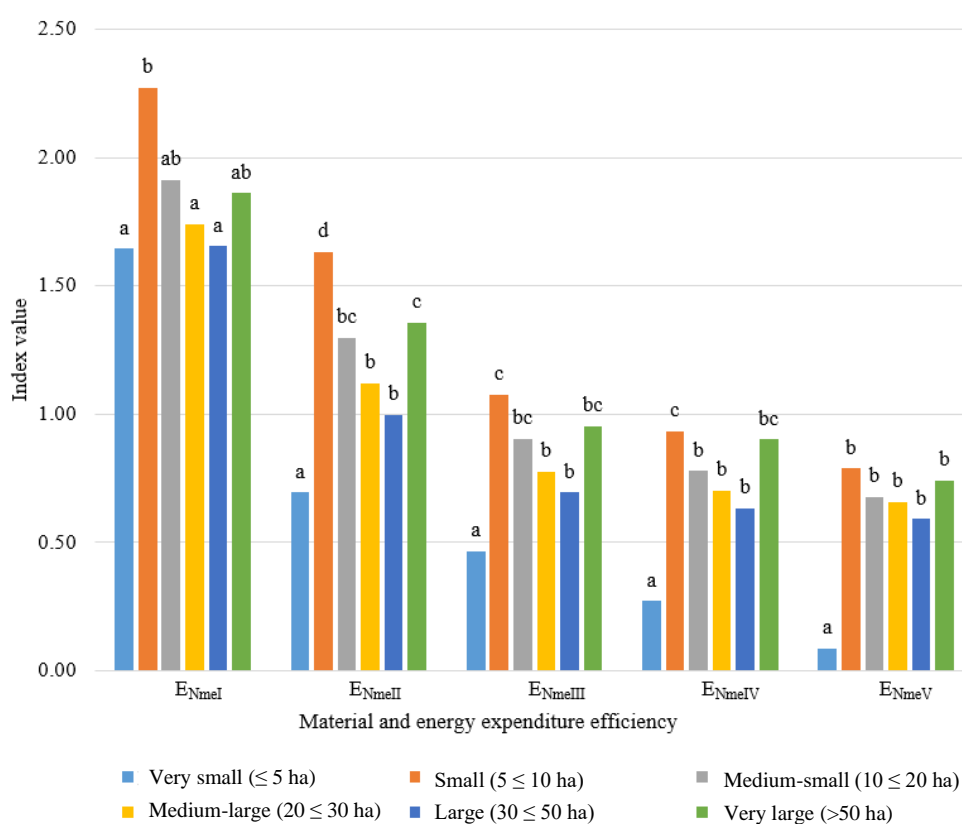
* values of indexes for individual groups of farms marked with the same letter do not differ statistically significantly at p<0.05.

Figure 1. Material and energy expenditure efficiency indexes and the area of UAA - mean values from the years 2013-2015.

The analysis of the results demonstrates that as the UAA increased, the difference between the values of calculated indexes decreased for: "Small", "Medium small", "Medium large" and "Large" farms. Sawa, (2008) observed that high material and energy expenditure in the farms with the smallest area (up to 20 ha of UAA), as well as in larger farms (20-60 ha of UAA), allow the social sustainability of the production process. Energy efficiency in ecological farms grouped by area of UAA was analyzed by Malaga-Toboła et al., (2020), who reported that larger farms use energy expenditure more efficiently. According to Sawa et al., (2004) energy expenditure per ha of UAA increases along with the increasing intensity of production organization, except that in larger farms they are relatively lower than in the smallest ones.

Conclusion

The analysis of the obtained results demonstrated that the area of UAA in farms determines their material and energy expenditure efficiency. It was identified that small farms with UAA of 5 to 10 ha are characterized by the highest material and energy expenditure efficiency. It was observed that the material and energy expenditure efficiency in "Small" farms with UAA (<= 5ha) and "Very large", with UAA (> 50ha) differs significantly from the efficiency determined for other farm groups. Material and energy expenditure is used the least efficiently in the farms with the smallest UAA.

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POWIERZCHNIA UŻYTKÓW ROLNYCH W GOSPODARSTWACH ROLNYCH A EFEKTYWNOŚĆ NAKŁADÓW MATERIAŁOWO-ENERGETYCZNYCH

Streszczenie. W pracy przeprowadzono analizę efektywności nakładów materiałowo-energetycznych w 679 gospodarstw rolnych, których głównym źródłem dochodu była produkcja rolnicza. Analizy dokonano dla lat 2013-2015. Wyodrębniono 6 grup gospodarstw wg powierzchni użytków rolnych (UR). Celem pracy było określenie wpływu powierzchni użytków rolnych w gospodarstwach na efektywność nakładów materiałowo-energetycznych. Stwierdzono, że powierzchnia UR w gospodarstwach rolnych determinuje efektywność nakładów materiałowo-energetycznych. Zaobserwowano, że gospodarstwa małe o powierzchni od 5 do 10 ha UR charakteryzują się największą efektywnością nakładów materiałowo-energetycznych. Dowiedziono, że efektywność nakładów materiałowo-energetycznych w gospodarstwach o powierzchni UR z grup Małe (<=5ha) i Bardzo duże (>50ha) istotnie różni się od efektywności w pozostałych grupach gospodarstw. Najmniej efektywnie nakłady materiałowo-energetyczne wykorzystywane są w gospodarstwach najmniejszych obszarowo.

Słowa kluczowe: nakłady materiałowe, nakłady energetyczne, wskaźniki efektywności