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Analysis of Fuel Consumption Costs in Dairy and Beef Farms

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As opposed to the energy needs of the country and non-agricultural parts of rural areas, energy needs of agricultural farms will be decreasing despite the expected increase in the final agricultural production by 2030. Energy intensity of agricultural production decreases and will decrease along with changes in the agrarian structure and intensification of production in family farms (Wójcicki, 2010). As compared to the status of 2014, the total diesel fuel consumption in 2015 was 2.83% lower. It was caused, among others, by the decrease in the number of farms (by 4.6% in 2016 as compared to 2012). In addition, relatively high prices of energy carriers forced the introduction of saving solutions.

In the individual farms, the unit consumption of diesel oil is strongly diversified depending on the structure of agricultural land, orientation, intensity and production technology as well as natural conditions. Therefore, it depends on many factors, including, among others:

- share of mechanical sources of tractive force in the production technology used;
- farm production orientation;
- level of cultivated plant crops;
- the amount of work to be done with tractors and internal combustion engines;
- working conditions, including the type and condition of soils, terrain, area and shape of fields, distances in internal and external transport and the condition of roads;
- technical conditions of tractors and internal combustion engines as well as auxiliary machines and tools;
- qualifications of personnel handling motorised equipment and work organisation (Pawlak, 2017).

The consideration of the majority of the factors listed above in the estimates of diesel oil consumption in the voivodship scale is, however, practically impossible due to the huge regional diversification. Nevertheless, the application of a simplified method, which is the estimate based on the area of cultivated plants, the yields obtained from them and the unitary consumption of this fuel per hectare of each cultivated plant, taking into account the level of yield, allowed the estimate of the used amount of diesel oil.

The purpose of this work was to estimate the costs of fuel consumption in farms maintaining dairy and beef cattle. The scope of the problem analysis included the costs of unit diesel oil consumption (ON) per 1 hectare of arable land (UAA) and 1 livestock unit (LSU) of cattle and determination of the share of fuel costs in the total economy costs of the business.

Materials and methods

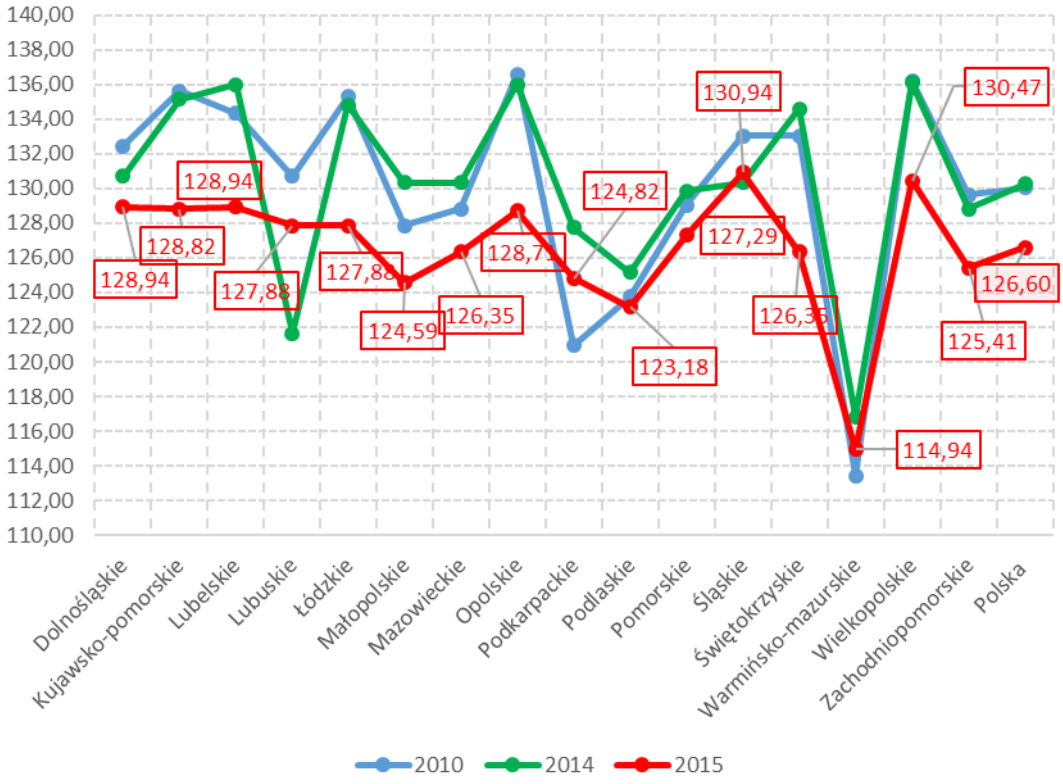
The analysis carried out in this research consists of two parts. The first discusses statistical indicators of diesel oil consumption based on the data of the Central Statistical Office (GUS), and in the second, the actual unit expenditures and costs obtained in own research. GUS statistical data and literature are tabulated in global terms and divided into voivodships, taking into account the carried

out activities. Throughout the study, fuel consumption per 1 ha of UAA in good culture was taken as a starting point. For calculations aimed at determining the consumption of diesel fuel used in cattle breeding, 0.75 ha of forage area per 1 LSU cattle was assumed.

Own research was carried out in south-western and north-eastern Poland in 132 farms maintaining dairy cows and 60 maintaining beef cattle. Data used for calculations were collected directly on farms using the direct interview method based on a questionnaire. During the interview, actual data on inputs and costs were collected as well as data declared by the farmers. The direct interviews were conducted in 2016 and 2017. The researched objects were compiled in regionally differentiated groups and based on the share of grassland included in the farms' resources. On the basis of the obtained data, the area structure of farms, the type and amount of animals owned, technical resources and economic indicators were analysed, among others, such as direct and indirect costs. A descriptive statistics method was used to analyse the results, and the results were presented in a tabular form.

The results and their discussion

On the basis of the subject-related literature and GUS data, the estimated unit diesel consumption in agriculture in the voivodship system was determined.



Source: authors' own elaboration based on data from Pawlak (2017); UR – utilized agricultural area.

Fig 1. Diesel fuel consumption per ha of UAA maintained in good agricultural condition (l/ha of UAA)

The data presented in fig. 1 in individual voivodships confirmed that unit ON consumption is strongly diversified depending on the structure of agricultural land, the orientation, the intensity and the production technology, the area structure of farms and natural conditions. The ON consumption on arable lands was generally higher, and on permanent grassland lower than the average, while on arable lands - the production of vegetables or root crops required higher fuel inputs than cereal production (tab. 1). With the same type of production, energy expenditure incurred in cultivation was higher on heavy soils than on light soils. The considerable diversification of agriculture and the conditions of its functioning in the geographical aspect suggests that the unit consumption of ON per hectare of UAA varies in individual voivodships and differs from the average result in the country scale (Pawlak, 2012 b).

In 2016, diesel oil consumption in Polish agriculture reached 1650 thousand ton according to the Central Statistical Office (2017 a). The area of arable land in Poland was 14,490,077 ha (GUS, 2017 b) at that time. The average ON consumption in agriculture per 1 ha of UAA in good culture was therefore 113.87 kg, or about 136.37 litres.

Table 1. Diesel fuel (DF) consumption in plant production

Type of crop	DF consumption	
	kg/ha	l/ha
Cereals, yield 3.5 t·ha	107	127
Winter rape, yield 2.5 t·ha	101	121
Potatoes, yield 20 t·ha	149	177
Sugar beet, yield 50 t·ha	255	304
Silage maize, yield 60 t·ha	154	183
Fodder roots, yield 40 t·ha	171	204
Fodder legumes (hay), yield 5.5 t·ha	80	95
Meadows (hay), yield 5.0 t·ha	64	76
Pastures	28	33

Source: Pawlak (2012 a).

This problem is also a subject of research conducted by the Department of Management and Law of the University of Life Sciences in Poznan. They indicate a strong level of diversification of the tractive effort incurred, for example, on the production of green fodder per unit area. These differences reached over 100%. After recalculation per 1 ton of green fodder, this differences exceeded 300%. The differences in expenditure on cereal production in individual farms were even higher and amounted to 427%.

The intensification of plant and animal production in small family and large farms requires the use of modern technologies with an increasing share of energy resources that use liquid fuels (field and transport works) and technical devices that use electricity (animal production). The increasing quality requirements and technological standards in animal production also contribute to the increase in the demand for energy carriers for heating, lighting or machine and equipment drives (Kowalski and Malaga-Toboła, 2006). A determinant of the intensity of animal production organisation is the stocking of animals, and an indicator of the efficiency of feed economy - the basic forage area per 1 LSU. It is one of the indicators of the feed economy assessment. The level of this indicator depends on the productivity of the forage area and the structure of livestock (Bojarszczuk and Księżak, 2011).

Based on the literature on the subject, there is a clear regional variation in the size of the indicator i.e. the fodder area per 1 LSU. According to Księżak (2008), in Poland, the average forage area per 1 cattle was 0.76 ha, although in the Lublin province - 0.71 ha. This author adds that the largest forage area per 1 LSU was recorded in the West Pomeranian Voivodeship (about 2 ha), and the smallest (about 0.50 ha) in Wielkopolskie and Kuyavian-Pomeranian Voivodships). It was also found that the regional differentiation of the fodder area in relation to 1 cattle is determined by natural, economic and organisational conditions. In table 2, based on the calculations, the demand for diesel oil per 1 LSU cattle in the amount of 95.18 was determined. The values in individual provinces were similar.

On the basis of the data collected from individual years, a decrease in the demand for diesel oil was observed. However, this was related to the fact that for all the provinces and individual years the same indicator was adopted (0.75 ha / LSU). Production or maintenance systems are not included here.

Table 2. Diesel fuel (DF) consumption in cattle farming and breeding per LU

Voivodeship	Diesel fuel consumption in l per LSU					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Dolnośląskie	99,60	98,98	100,40	99,25	98,28	96,95
Kujawsko-pomorskie	101,99	100,66	103,49	101,37	101,64	96,86
Lubelskie	101,02	99,34	102,17	102,26	102,26	96,95
Lubuskie	98,28	94,12	94,38	94,29	91,46	96,15
Łódzkie	101,72	99,51	101,72	102,17	101,37	96,15
Małopolskie	96,15	92,79	94,83	98,10	98,01	93,68
Mazowieckie	96,86	94,91	98,10	96,95	98,01	95,00
Opolskie	102,70	103,49	104,64	103,76	102,26	96,77
Podkarpackie	90,93	89,43	93,85	93,41	96,06	93,85
Podlaskie	93,06	92,17	94,21	94,74	94,12	92,61
Pomorskie	97,04	95,98	100,04	97,57	97,66	95,71
Śląskie	100,04	94,47	99,51	100,57	98,01	98,45
Świętokrzyskie	100,04	98,28	97,48	101,46	101,19	95,00
Warmińsko-mazurskie	85,27	83,95	87,66	84,12	87,84	86,42
Wielkopolskie	102,43	101,55	103,94	102,34	102,34	98,10
Zachodniopomorskie	97,48	97,21	98,98	96,51	96,86	94,29
Poland	**97,79**	**96,05**	**98,46**	**98,05**	**97,96**	**95,18**

Source: authors' own elaboration based on GUS data, Pawlak (2017)

Based on the research conducted by the National Research Institute of Animal Production PIB on individual farms maintaining dairy cows, ON consumption per 1 LSU of dairy cattle was determined (tab. 3 and 4). The share (%) of grassland in these farms in relation to the area of arable land was about 32%, which is why the alcove system of keeping animals prevailed here, which indicated nutrition based mainly on roughage obtained from arable land without pastures. Depending on the share of grassland in the agrarian structure, fuel consumption per 1 ha of UAA ranged from 68 l in facilities with the highest share (84%) of grassland to 116 l on farms with an average of 13% of grasslands. It was related to higher work expenses and, thus, the consumption of ON. This problem is presented in the same way as in table 3 presenting the farms with a high share of grasslands intentionally selected for research. The argument explaining this dependence is grazing animals in the pasture, which significantly reduces the involvement of agricultural equipment and allows obtaining lower costs of animal maintenance.

It should be noted that the research carried out by the National Research Institute PIB and the literature on the subject are aimed at the same conclusions that cultivation of cereals is more energy-intensive. Nevertheless, it cannot be generalised because there are many factors determining the amount of fuel used

on the farm - for instance, the technical condition of the owned machinery park, the size of the farm or the size of the basic herd – and, thus, the diesel oil consumption per LSU.

In the case of ON consumption per 1 LSU, it was observed that with the increase in the share of grasslands, the fuel consumption increased, but until the arable area was balanced with the grasslands on the farm. Noteworthy is the fact that these farms with up to 50% of grassland (in the range of 0-50%) along with their larger area increased their production area. In this case, it was also observed that with the decrease in the share of grasslands in the farm's area, the number of the herd was increasing, and, thus, the expenditure on the means of production increased. This is understandable if we consider the productivity of biomass (e.g. silage maize) with arable lands as compared to permanent grasslands. It should be emphasised that the largest consumption of ON was observed by farms with a balanced in terms of arable land and permanent grasslands structure (tab. 4). These are objects where nutrition is based on pasture and on feed from the arable land.

Based on research carried out by the National Research Institute BIP (tab. 5 and 6) in individual farms maintaining meat cattle, the consumption and costs of diesel oil per 1 LSU cattle were determined depending on the region and the area of grassland owned. On the basis of the obtained results, the average diesel consumption was estimated, amounting to 82 l per 1 ha of UAA and approximately 92 litres per 1 LSU. Comparing the region of south-west and north-eastern Poland, similar results of ON consumption per 1 ha of UAA were found while there was a large variation in fuel consumption per 1 LSU, amounting to almost 100%. However, this resulted from the land resources owned, i.e. from the size of the farm, and hence from the expenses incurred for the maintenance and management of agricultural land. On average, farms in south-western Poland were larger by around 130%. The analysis of ON consumption, depending on the area of grassland, showed that with the increase of their share in the area of the farm, fuel consumption decreased. This is the same as in the case of dairy cows from the grazing maintenance of this species of animals. The highest indicators of ON consumption were found in farms with around 12% of grasslands while farms with over 80% of grasslands in their resources consumed only 54 l / ha.

On the basis of the analysis of the costs of diesel fuel purchase, it was established that in the case of dairy cattle (tab. 3 and 4) fluctuated from 341.61 PLN / ha of arable land on farms having more than 60% of grassland to 589.40 PLN / ha of arable land on farms with the predominant area of arable land. Slightly lower costs were recorded in farms producing beef livestock (tab. 5 and 6). On average, they amounted to PLN 414.21 / ha of arable land and their diversity within the regions was insignificant, as it amounted to approximately PLN 30 / ha of arable land. The analysis of the costs incurred in terms of the share of grasslands in the area of the farm showed a large variation, amounting to approximately 170%. The cost of fuel in holdings with over 60% of UAA amounted to PLN 270.73 / ha of arable land while in those in which production was based mainly on arable land - PLN 471.11 / ha. On the basis of the obtained results, the share of fuel purchase costs in the total economy costs of the conducted activity was also determined, which on average for all analysed farms was around 20%. Both in the case of dairy cattle and meat cattle, this share increased along with the increase in the share of grassland in the farm area. The growth tendency was maintained at the level of 60% of grasslands, and then, with their further increase, it began to decline.

Table 3. Diesel fuel consumption and costs in dairy farms – with predominant grasslands

Scope	Cattle, total	incl. cows	LU per farm	Farm area (ha)	% grass-lands to farm size	Area in ha per LU	DF con-sumption per ha of UAA culti-vated (l)	DF con-sumption per LU	DF purchase costs per LU (zloty)	DF costs per ha of UAA cultivated (zloty)	Proportion of fuel costs in indirect milk production costs (%)
Mean	30,42	18,72	26,08	24,19	65,01	0,98	67,65	53,84	**230,42**	**341,62**	**26,93**
Max.	71,00	40,00	63,90	60,07	99,37	2,17	259,70	179,03	685,21	1 311,48	78,08

Source: Elżbieta Sowula Skrzyńska's own elaboration; LU – livestock unit; DF – diesel fuel; UAA – utilized agricultural area.

Table 4. Diesel fuel consumption and costs in dairy farms – with predominant arable land

Groups of farms depending on grassland percentage	Scope	Cattle, total (head)	Incl. cows (head)	LU per farm	Farm area (ha)	% grasslands to UAA	Area in ha per LU	DF consumption per ha of UAA cultivated (l)	DF consumption per LU (l/LU)	DF purchase costs per LU (zloty)	DF costs per ha of UAA cultivated (zloty)	Proportion of fuel costs in indirect milk production costs (%)
TOTAL	mean	80,95	41,36	62,86	66,59	31,93	**1,15**	**110,15**	**118,90**	**595,33**	**556,26**	**19,70**
	max.	636,00	301,00	550,99	504,30	91,61	2,96	412,40	286,21	1 445,35	2 082,63	49,25
0,0–25,0	mean	93,27	44,54	70,47	72,57	13,43	**1,11**	**116,71**	**120,93**	**597,97**	**589,40**	**19,25**
	max.	410,00	165,00	300,45	457,22	24,77	2,96	412,40	266,87	1 347,71	2 082,63	38,12
25,1–50,0	mean	80,76	42,53	64,05	68,85	36,94	**1,17**	**109,51**	**121,91**	**615,66**	**553,05**	**20,34**
	max.	636,00	301,00	550,99	504,30	49,05	2,07	338,33	286,21	1 445,35	1 708,54	49,25
50,1–80,0	mean	54,92	32,42	43,98	47,21	58,29	**1,13**	**108,22**	**115,87**	**585,15**	**546,51**	**21,85**
	max.	105,00	67,00	84,10	70,00	72,83	1,97	198,02	256,01	1 292,86	1 000,00	43,14
Above 80.1	mean	36,00	23,83	29,63	38,18	84,69	**1,30**	**68,00**	**83,53**	**421,84**	**343,39**	**13,74**
	max.	46,00	30,00	38,20	50,37	91,61	1,67	129,03	134,19	677,64	651,60	18,61

Source: Elżbieta Sowula-Skrzyńska's own elaboration; for explanations, see Table 3.

Table 5. Diesel fuel consumption and costs in beef farms, by region

Groups		Cattle – total (head)	Incl. cows (head)	LU per farm	Farm area (ha)	% grass-lands to UAA	Area in ha per LU	consumption per ha of UAA culti-vated (l)	DF con-sumption per LU	DF costs per ha of UAA cultivated (zloty)	DF pur-chase costs per LU (zloty)	Proportion of fuel costs in indirect milk pro-duction costs (%)
Farms – total	mean	58,67	21,97	51,33	57,56	**33,49**	1,13	**82,02**	**91,96**	**414,21**	**464,39**	**19,20**
	max.	150,00	77,00	134,00	220,00	98,76	2,84	190,45	450,05	961,75	2 272,73	41,37
South-West Poland	mean	58,13	25,42	51,59	79,26	**37,73**	1,47	**79,23**	**122,76**	**400,11**	**619,96**	**17,62**
	max.	148,00	77,00	130,20	220,00	98,76	2,84	158,73	450,05	801,60	2 272,73	41,06
North-East Poland	mean	59,24	18,28	51,05	34,36	**28,96**	0,77	**85,01**	**59,03**	**429,28**	**298,10**	**20,88**
	max.	150,00	70,00	134,00	67,65	58,06	2,14	190,45	136,00	961,75	686,81	41,37

Source: Elżbieta Sowula-Skrzyńska's own elaboration; for explanations, see Table 3.

Table 6. Diesel fuel consumption and costs in beef farms depending on grassland area

% of grasslands		Cattle, total (head)	Incl. cows (head)	LU per farm	Farm area (ha)	% grass-lands to UAA	Area in ha per LU	DF consumption per ha of UAA cultivated (l)	DF con-sump-tion per LU	DF costs per ha of UAA cultivated (zloty)	DF pur-chase costs per LU (zloty)	Proportion of fuel costs in indirect milk pro-duction costs (%)
Total	mean	58,67	21,97	51,33	57,56	**33,49**	1,13	**82,02**	**91,96**	**414,21**	**464,39**	**19,20**
	max.	150,00	77,00	134,00	220,00	98,76	2,84	190,45	450,05	961,75	2 272,73	41,37
0%–20%	mean	60,63	21,53	52,81	70,73	**12,44**	1,34	**93,29**	**137,02**	**471,11**	**691,97**	**18,25**
	max.	130,00	60,00	116,00	220,00	19,82	2,84	158,73	450,05	801,60	2 272,73	41,06
20%–40%	mean	57,86	18,33	49,95	49,55	**28,25**	0,97	**76,05**	**70,29**	**384,03**	**354,96**	**17,31**
	max.	148,00	59,00	130,20	204,47	39,04	2,24	148,80	158,21	751,43	798,97	37,79
40%–60%	mean	63,14	28,93	56,30	57,75	**47,49**	0,95	**87,87**	**70,14**	**443,75**	**354,20**	**20,47**
	max.	150,00	77,00	134,00	213,38	58,06	2,31	190,45	128,71	961,75	650,00	41,37
Above 60%	mean	44,83	19,83	39,83	43,43	**85,83**	1,45	**53,61**	**76,01**	**270,73**	**383,83**	**25,80**
	max.	117,00	36,00	100,80	69,34	98,76	2,24	77,28	145,60	390,24	735,29	36,41

Source: Elżbieta Sowula-Skrzyńska's own elaboration; for explanations, see Table 3.

Summary

To summarise, it should be emphasised that the average consumption of ON in agriculture according to the Central Statistical Office (2017 a) per 1 ha of arable land in good culture in 2016 amounted to 113.87 kg, or about 136.37 litres (in 2015 - 126.60 litres) / ha arable land), and the average demand for diesel per 1 LSU of cattle was 95,18 l. However, the results obtained on the basis of own research indicate a slightly lower demand for ON per 1 ha of arable land in the analysed farms. It resulted from the direction of the activities carried out by the entities covered by the research. Livestock production inherently requires an increased share of grasslands, and, hence, the lower input and costs for production as compared to farms with a predominant share of arable land, for example, producing grain.

The analysis showed the comparability of the results of the IZ PIB research with the Central Statistical Office data referring to ON consumption in Poland per 1 LSU. In the farms producing beef livestock, this indicator was, on average, 91.96 l / LSU. In the case of farms producing milk, the demand for ON was, on average, 118.90 l / LSU and was slightly higher than indicated by the Central Statistical Office. The studies also showed a significant impact of diesel oil costs on the profitability of milk and beef production. Their share in indirect costs of the business activity was about 20%. This share was dependent on the area of owned grasslands.

In summary, the obtained results may be helpful in determining the current average rate of excise tax refund (currently amounting to 86 l / ha of arable land) in the price of diesel oil (ON) used for agricultural production when the surface of agricultural land is assumed as a reference value.

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ANALYSIS OF FUEL CONSUMPTION COSTS IN DAIRY AND BEEF FARMS

Summary

The aim of the study was to estimate fuel consumption costs in dairy and beef farms. The scope of the research included calculating unit diesel fuel (DF) consumption costs per ha of utilized agricultural area (UAA) and per livestock unit (LSU), and determining the share of fuel costs in farming overheads. According to the Central Statistical Office (GUS, 2017), in 2016 DF consumption in agriculture, per ha of UAA maintained in good agricultural condition, averaged 113.87 kg or around 136.37 l, and the average DF requirement per LU was 95.18 l. The results obtained in the present study indicate that the DF requirement per ha of UAA in the analysed farms was slightly lower, but this was due to the direction of activity conducted by the studied holdings. The analysis showed that the results of the study conducted by the National Research Institute of Animal Production are comparable with GUS data concerning DF consumption per LSU in Poland.

The effect of diesel fuel costs on profitability of milk and beef cattle production was also estimated. Their contribution to indirect costs was considerable at around 20%.

Key words: diesel fuel, costs, beef cattle, dairy cows