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Energy expenditures of environmentally sustainable farms

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Abstract: *Energy expenditures of environmentally sustainable farms.* The work presents energy expenditures in the production process of 15 selected environmentally sustainable farms. The results obtained have been compared with results for 15 farms, which did not meet the criteria of environmental sustainability. It was found that environmentally sustainable farms had higher energy expenditures in comparison with non-sustainable ones, and the statistical analysis conducted showed substantial differences in the energy expenditures of these groups of farms. Also an average positive correlation was found between energy expenditures and human labor expenditures at the environmentally sustainable farms, which is not a typical situation, as usually, increase in the expenditures of objectified labor is associated with reduction of human labor. On the other hand, at non-sustainable farms, a negative average correlation between energy expenditures and human labor was found.

Key words: organic matter balance, expenditures, farms

INTRODUCTION

Technical and technological modernization of farms, implemented in the last decade in Poland, allows for reduction of human labor expenditures while increasing energy expenditures [Sawa et al. 2004, Tabor 2006, Sawa 2008, Kocira 2013]. Increase in energy expenditures and reduction in human labor expenditures in agricultural production, accompanied by a shift in the mode of farming towards more extensive production is associated with increasing (negative) impact on the natural environment. Therefore, in the recent period, various activities have been popularized, aimed at sustainable farming. In sustainable farming, three main components can be distinguished, namely: environmental sustainability, economic sustainability and social sustainability. In order to implement the sustainable farming principles at the farm, it is necessary to start with the environmental sustainability components. The main component of this sustainability is achieving an organic matter balance at least on the positive level at proper crop rotation, and, according to Sawa and Kocira [2010], achieve the appropriate level of intensity of production organization. Therefore, energy expenditures at environmentally sustainable farms were examined and compared with those farms, which fail to meet the sustainability criteria.

MATERIAL AND METHODS

The material used in the study is a part of research conducted in years 2009–2012 throughout the country within the framework of the research project conducted by ITP Branch in Warsaw (NCBiR 1204306/2009), entitled "Technological and ecological modernization of selected households". 30 households were analyzed to selects those, which meet the criteria of environmental sustainability, defined according to Sawa and Kocira [2010] and those, which fail to meet the criteria.

The environmental sustainability criteria include:

- organic matter balance (OMB) of 0.4–1.5 t·ha^{-1} GO;
- farm organization intensity 450–800 points;
- at least three plants in crop rotation.

Environmental expenditures for the farms were calculated as the total expenditure of work performed by tractors and mobile machines, expressed in kWh, and electricity used for the production process.

The statistical analysis was conducted using Statistica 10PL software. Significance of the differences between the farms examined was verified using Tukey's test at $\alpha = 0.05$. Normality of distribution of the variables analyzed was verified using Shapiro–Wilk test. In the work, the balance of organic matter was calculated according to the Code of Good Agricultural Practice [Duer et al. 2004]. The intensity of production organization was calculated using the methodology contained in the work of Kopeć [1987]. The machinery use index was calculated as the ratio of the gross replacement value of the technical means of work to the area of arable land of the farm.

RESULTS AND DISCUSSION

The farms analyzed were characterized by crop structure typical for Polish agriculture. Cereals and corn occupied 64.4% of UAA in the cropping pattern, and in the structure of sown area, cereals and corn had the share of as much as 81.3%, which was higher than the national average, amounting to 73.8% in year 2012 [GUS 2012]. The share of meadows and pastures in the UAA was 20.7% (Fig. 1). Both sustainable and non-sustainable farms cultivated cereals in 50% of their UAA. In environmentally sustainable farms, due to higher livestock density (Table 1) in comparison with other farms, corn was cultivated, mainly for silage.

The average UAA in the two examined groups of farms was similar (Table 1). Livestock density at the environmentally sustainable farms was characterized by low variability and amounted on the average to 1.3 DJP·ha^{-1}. It was more than 0.7 DJP·ha^{-1} greater in comparison with non-sustainable farms. Renewability of organic matter at non-sustainable farms was characterized by extremely high variability, while at the environmentally sustainable farms, the level of variability was average. Intensity of organization of production at the environmentally sustainable farms amounted on the average to 609 points per farm, and in the second group analyzed it was lower, amounting to 386 points per farm. The machinery use index was diversified in the examined groups of farms. Its value was close to the results obtained by Szuk [2009] and Wasag [2014].

In environmentally sustainable farms, the average energy expenditures

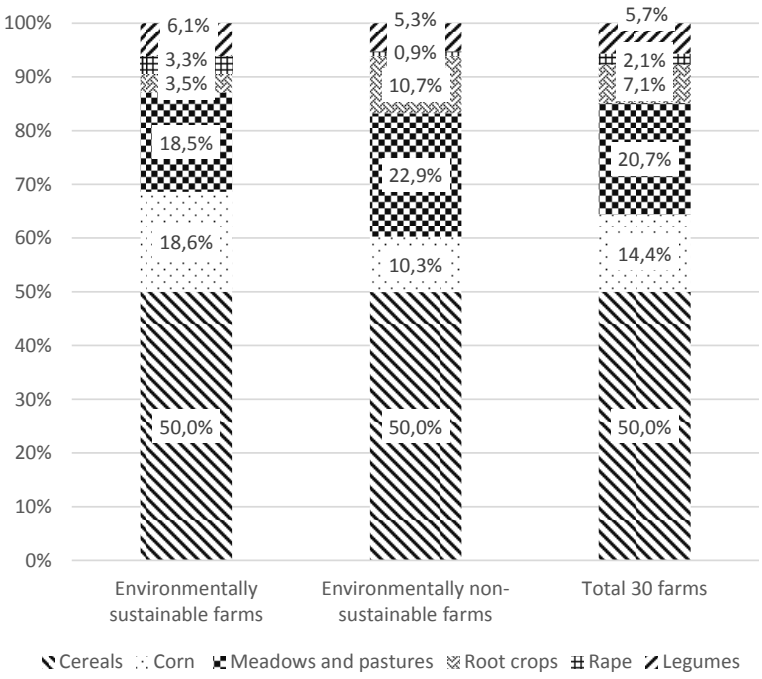

FIGURE 1. The structure of crops at the farms examined

TABLE 1. General characteristics of the farms examined

Specification	Unit	Average		Minimum		Maximum		Variability coefficient [%]	
		Z*	Nz**	Z*	Nz**	Z*	Nz**	Z*	Nz**
UAA	ha	37.98	38.57	12.10	14.87	71.27	85.00	49	49
Livestock density	DJP·ha^{-1}	1.30	0.57	0.59	–	1.49	1.15	18	64
Renewability of organic matter	t·ha^{-1} GO	0.89	–0.03	0.41	–0.59	1.27	0.36	33	998
Intensity of production organization	points·farm^{-1}	609	386	459	117	794	954	15	46
Machine use index	thousand PLN·ha^{-1}	30.379	25.459	17.440	12.885	56.302	38.154	41	27

*Z – environmentally sustainable farms; **Nz – environmentally non-sustainable farms.

amounted to 2246 kWh·ha^{-1}, while at the farms, which failed to meet the criteria of environmental sustainability, they were almost 1/3 lesser, amounting to 1,500 kWh·ha^{-1}. In both groups, this variable was characterized by average variability, amounting to 27% in the group of environmentally sustainable farms and 32% in the group of non-sustainable farms. Similar results were ob-

TABLE 2. Energy and human labor expenditures in the examined groups of farms

Specification	Unit	Average		Minimum		Maximum		Variability coefficient [%]	
		Z*	Nz**	Z*	Nz**	Z*	Nz**	Z*	Nz**
Energy expenditures	kWh·ha^{-1}	2 246	1 500	1 409	611	3 421	2519	27	32
Human labor expenditures	rbh·ha^{-1}	178	145	97	62	348	297	46	45
Work energetic equipment coefficient	kWh·rbh	14.6	13.1	6.3	3.6	27.4	25.4	39	61
Machine use index according to Zaremba	%	72	67	57	42	85	84	10	19

[1]Z – environmentally sustainable farms; [2]Nz – environmentally non-sustainable farms.

tained by Wójcicki et al. [2014] when examining energy expenditures for tractors for 53 family farms, obtaining the value of 1,500 kWh·ha^{-1} in the case of mechanization of work in farmyards and transport. The human labor expenditures per 1 ha of UAA at the environmentally sustainable farms were greater in comparison with the non-sustainable farms. The average value of the work energetic equipment coefficient in the examined groups of farms was at a similar level, however, at the environmentally sustainable farms, the variability coefficient was within the limits of average value, while in the second analyzed group of farms it showed high variability. On the other hand, the machine use index in the examined groups ranged from 42 to 85% and it was characterized by low variability in both groups.

Using Tukey's test, at $\alpha = 0.05$, significant differences were found between energy expenditures for environmentally sustainable farms and non-sustainable farms.

In non-sustainable farms, a negative average correlation between energy expenditures and human labor was found (Fig. 2). In this case, the positive correlation is rather non-typical, as usually, increase in the expenditures of objectified labor is associated with reduction of human labor expenditures (substitution of live labor with objectified labor). This situation may be due to intense animal production of these farms (the average livestock density being 1.3 DJP·ha^{-1}). Analysis of detailed data indicated that animal production at almost all environmentally sustainable farms was focused on breeding of milk cattle.

In the group of non-sustainable farms, a negative average correlation between energy expenditures and human labor was found (Fig. 3). These farms are characterized by classic substitution of live labor with objectified labor.

SUMMARY AND CONCLUSIONS

The analysis of energy expenditures in two groups of farms, differing in terms of fulfillment of criteria of environmental sustainability, showed that at environmentally sustainable farms, there is an average positive correlation between energy expenditures and human labor expenditures. In this case, the positive cor-

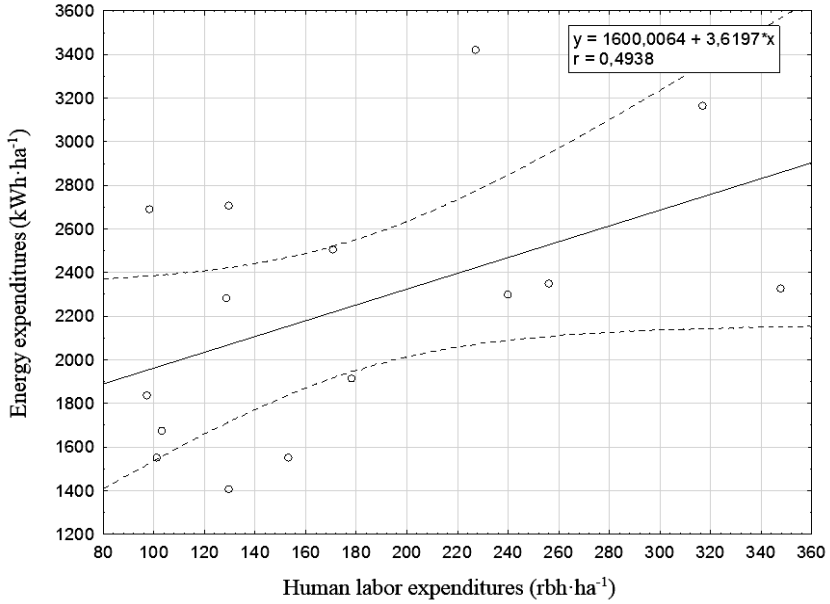

FIGURE 2. Energy expenditures and human labor expenditures at the environmentally sustainable farms

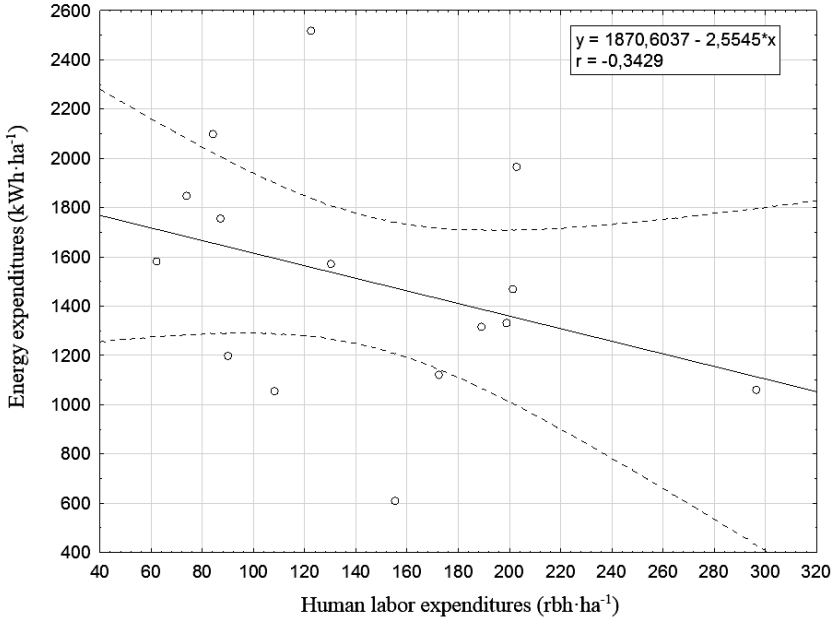

FIGURE 3. Energy expenditures and human labor expenditures at the environmentally non-sustainable farms

relation is rather non-typical, as usually, increase in the expenditures of objectified labor is associated with reduction of human labor expenditures (substitution of live labor with objectified labor).

On the other hand, at non-sustainable farms, a negative average correlation between energy expenditures and human labor was found.

It was also found that environmentally sustainable farms had higher energy expenditures in comparison with non-sustainable ones, and the statistical analysis conducted showed substantial differences in the energy expenditures of these groups of farms.

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Streszczenie: *Nakłady energetyczne w gospodarstwach zrównoważonych środowiskowo*. W pracy przedstawiono nakłady energetyczne ponoszone w procesie produkcyjnym w 15 wybranych gospodarstwach zrównoważonych środowiskowo. Uzyskane wyniki porównano z wynikami z 15 gospodarstw niespełniających kryteriów zrównoważenia środowiskowego. Stwierdzono, że gospodarstwa zrównoważone środowiskowo ponoszą większe nakłady energetyczne od gospodarstw niezrównoważonych środowiskowo, a przeprowadzona analiza statystyczna wykazała istotne różnice w nakładach energetycznych między tymi grupami gospodarstw. Zaobserwowano także przeciętną dodatnią korelacja między nakładami energetycznymi a nakładami pracy ludzkiej w gospodarstwach zrównoważonych środowiskowo, co jest nietypową sytuacją, gdyż najczęściej wzrostowi nakładów pracy uprzedmiotowionej towarzyszy zmniejszenie nakładów pracy ludzkiej. W gospodarstwach niezrównoważonych środowiskowo stwierdzono natomiast ujemną przeciętną korelację między nakładami energetycznymi a nakładami pracy ludzkiej.

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