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ASSESSMENT OF ECONOMIC EFFECTS OF GHG EMISSION REDUCTION ON THE EXAMPLE OF FIELD CROP FARMS*

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Abstract

The paper presents economic effects of using GHG emission reduction technologies on model farms. Replacement of traditional tillage with aggregate for direct tillage and seeding (as contractor services) caused increase in annual operation cost of tillage on the model farm by 308.5%. Total annual operation costs of farm machinery on model farm (including costs of contractor services) increased by 25.2% in spite of a decrease in Diesel oil consumption by 26.8%. CO_2 emissions per value unit of production decreased by 22.6%. Replacement of traditional crop production technology with energy-efficient one causes reduction of CO_2 emission per value unit of obtained production by 22.6%. Change of technology, advisable from the ecological point of view, is not realistic because of the increase in the machinery operation costs and decrease in the production value on model farm. This barrier could be overcome with the use of relevant financial support, which however has adequate consequences for the state budget.

Keywords: emission of GHGs, reduction, farm, cost.

JEL codes: C51, O13, O33, Q51.

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Introduction

The biological nature of agriculture makes it strongly dependent on the condition of the environment. One of the factors that affect, and sometimes determine, the crop yield is weather. Adverse weather conditions during winter and the blooming season or during harvest, droughts, hailstorms, downpours and the consequent floods lead to reduction in or even loss of harvest. But then, agriculture affects the environment in many ways. While working, combustion engines used in agricultural production emit to the atmosphere noxious chemical compounds, including the greenhouse gases. Other sources of greenhouses gases include animal production and households. What also has some impact on the environment is the use of fertilisers and plant protection agents, including animal faeces, resulting in pollution of surface and ground water. Heavy equipment and vehicles used in agricultural production cause soil compaction and thus deterioration in vegetation conditions. There is also a need to mention the fact that production of means of production used in agriculture also entails energy input, which in turn leads to environmental impact. In the light of the above facts, it is necessary to ensure sustainable development of agriculture that takes account of the social, economic, energetic and environmental aspects (Pawlak, 2015). A significant reduction in energy input can be achieved through simplified tillage methods (Golka and Ptaszyński, 2014).

Use of appropriately modified agricultural production technologies can decrease the total volume of greenhouse gas emissions by 1/3 (Parton, Del Grosso, Marx and Swan, 2011). The volume of those emissions is affected by the work method on the farm. The research showed that total carbon dioxide emissions per unit produced amounted to: for conventional tillage – 915 $g \cdot kg^{-1}$, for minimum tillage – 817 $g \cdot kg^{-1}$, for no-tillage system – 855 $g \cdot kg^{-1}$. Higher emission per unit of production for the no-tillage system compared to the minimum tillage resulted in the lower crop yield, on average by 10% (Sørensen, Halberg, Oudshoorn, Petersen and Dalgaard, 2014). About 50-60% of GHG emissions results from the mineralisation of organic matter in soil. Therefore, tillage should produce soil conditions limiting mineralisation and oxidation of organic matter.

Direct sowing does not only lead to a reduction in energy input but also to other benefits. Elimination of tillage procedures causing soil to overdry allows soil water balance to improve, especially due to the fact that crop residues left on the surface of a field decrease evaporation. This is particularly important for regions experiencing water deficit. The research carried out in Spain has demonstrated an increase in crop for this reason (Sánchez et al., 2016). Moreover, in undulating terrain exposed to intense movement of air in dry climate, leaving a cover of crop residues effectively protects the soil against wind and water erosion. Elimination of time-consuming tillage procedures, particularly ploughing, also allows the time between the harvest of the forecrop and the catch crop. In a situation of considerable workload, this increases the chance of sowing crops in time and achieving high yield. This is particularly important in the case of winter rape, whose optimum sowing time comes early.

The use of controlled traffic farming reduces excessive soil compaction and formation of ruts. Hence, its use in direct sowing system is gaining more and more importance.

If, due to use of production technologies reducing GHG emissions, crop yield or the efficiency of the input diminish, an economic barrier to their deployment appears. Foreign authors discussing the subject propose financial subsidies to overcome this barrier (Beach et al., 2015; Horovitz and Gotlieb, 2010; Paustian, Antle, Sheehan and Paul, 2006; Parton et al., 2011).

An earlier work published in the Problems of Agricultural Economics (Pawlak, 2017) presents a proposed method for estimating the economic effect of replacement of the conventional plant production technology with a technology reducing greenhouse gas emissions. The aim of this publication is to assess the costs and effects of the application of such method using a model of a farm with 30 ha of agricultural land.

Farm model

The assessment of the economic effects resulting from the use of agricultural production technologies enabling reduction in GHG emissions compared to the conventional technology was done on the basis of a model of a farm with 30 ha of agricultural land producing crops. This area approximates the average area of industrial farms in the field crop type that kept accounts for the Polish FADN in 2015, which equalled 29.1 ha (Polski FADN, 2017). This justifies the selection of the model farm area.

It was assumed that the farm cultivates only cereals and similar industrial crops on six rectangular fields, each sized 167x300 m, which gives 5 ha. The following crop rotation pattern is used:

– winter wheat,
– pea,
– winter rape,
– winter wheat,
– buckwheat,
– pea.

The plants with the greatest percentage in the cropping pattern are wheat and pea (33% each). High percentage of pea as a plant that, due to its symbiosis with the Rhizobia bacteria is capable of fixing free nitrogen, is beneficial for the environment due to the reduced demand for nitrogen fertilisers. Aside from this, pea is a very good forecrop for rape and wheat, which are also present in the crop rotation pattern.

Two production technology variants were compared: the conventional and an energy efficient (no-tillage) system, which results in the reduced GHG emissions. Most of results of fieldwork done in various countries around the world show that direct sowing causes a decrease in crop yield. Studies carried out in Iran have demonstrated wheat yield drop by 21.6% (Akbarnia and Fahrani, 2014), and Turkish research showed a decrease in the harvest of maize for silage by 14% (Barut, Ertekin and Karaaga, 2011). A similar phenomenon is confirmed by results of research done in Poland. According to Biskupski, Sekutowski, Włodek, Smagacz and Owsiak (2014), in the case of direct sowing, maize yield was in most instances lower than for the conventional tillage (on average by 11.8%) depending on the type of forecrop and weather conditions in the given year. Żyłowski (2017) found the yield to be 9.9% lower, but also that additional measures related to production technology can reduce the drop to as low as 2.5%. In this work, it was assumed that in the case of no-tillage systems crop yields drop by 10%. The same value for the Danish conditions is adopted by Sørensen et al. (2014). Process sheets, enclosed hereto (Tables 5-12), were prepared for both technological variants.

The energy-efficient variant provides for a higher number of plant protection procedures due to the higher risk of weed or pest infestation, volunteers, and plant diseases carried by crop residues remaining on the surface of the field. In order to reduce obstacles related to burying crop residues in the conventional technological variants and to direct sowing in the energy-efficient variant, the combine harvester used in both of them is equipped with a straw chopper. Soil compaction during work on fields of the model farm is reduced through the application of controlled traffic, which also facilitates topdressing, and crop treatment and protection during vegetation.

It was assumed that the average daily working time is eight hours for all procedures.

All the transport work consists of: loading, transporting the cargo to its destination, unloading, and return. In the case of transporting harvest products, the sequence is reversed. For this work, it was assumed that the average distance to the centre of a field on a model farm is equal to 400 m, and the average speed of a tractor aggregate with a trailer is equal to 10 km·h^{-1}. If trailer capacity is used to the full, the operating efficiency during the ride in both directions is equal to 12,5 t·h^{-1}.

Operating performances during transport activities to the mass of transported products were differentiated. The time that transport activities take depends primarily on the distance, speed and the number of rides. It was assumed that the average distance and speed during transport activities on the model farm are constant. Where the cargo fits a trailer of 5 tonnes capacity, operating efficiency W07 referenced to a tonne of cargo depends on the mass that is carried, and it is the highest when the mass is equal to the trailer capacity. Where the mass of the cargo is smaller than the trailer capacity, the efficiency was calculated using the following formula:

$$Wt = \frac{Wp \cdot Bc}{Wp \cdot Ł} \tag{1}$$

where:

Wt – operating efficiency during the tth type of transport activity (t·h^{-1});
Wp – operating efficiency where the mass of the cargo is equal to trailer capacity (t·h^{-1});
Bc – cargo mass (*t*);
Ł – trailer capacity (*t*).

Where the mass of the cargo exceeds the trailer capacity, the number of rides is equal to the ratio between that mass and the trailer capacity:

$$np = \frac{Bc}{Wp \cdot Ł} \tag{2}$$

where:
np – number of rides (total value).

Where the cargo to be transported exceeds trailer capacity, the average cargo mass is calculated by dividing the total mass of the cargo by the number of rides, and the result is applied to formula (1) as the basis for determining the operating efficiency.

The operating time of the trailer is equal to the sum of loading time, travel time and time of stoppage (due to organisational reasons) in the field during fertiliser spreading and sowing. On the other hand, for transport of crop harvest products, it was assumed that the operating time of the trailer is equal to the operating time of a combine harvester, and this assumption was taken into consideration while calculating the operating efficiency of the trailer.

The process sheet data was used as a basis for calculating the annual operating time of specific pieces of mechanical equipment in the production of the four crop species on the model farm. The results of these calculations are the basis for estimating depreciation costs. Tractor and transport equipment are also used in general farm work and various activities in the animal pen. Therefore, while calculating unit depreciation costs for the said equipment, its use was increased by an overhead, which in the case of the tractor amounted to 20%. While determining the annual operating cost of the mechanical equipment, the unit operating cost in PLN per hour were multiplied by the number of hours of annual operating time calculated on the basis of process sheets, i.e. without the overhead.

It was assumed that in both technological variants and during sowing in the energy-efficient variant, the farm uses services. Insufficient operating times of a combine harvester (37 hours for the conventional option, and 33 hours for the energy-efficient one) and 120 kW tractor with tillage and sowing equipment with the operating width of 3 m (30 hours) do not justify the possession of such expensive machines on a farm.

Depreciation costs were calculated using the following formula:

$$Ka_m = \frac{C_m}{Wr_m \cdot T_m} \tag{3}$$

where:
Ka_m – depreciation costs of the mth piece of mechanical equipment (PLN),
C_m – retail price of the m^{th} piece of mechanical equipment (PLN),
Wr_m – annual operating time of the m^{th} piece of mechanical equipment (hours·year^{-1}),
T_m – lifetime of the m^{th} piece of mechanical equipment (years).

For service providers' equipment, it is assumed that their annual operating time guarantees that they are operated for the number of hours equal to the service potential during their lifetime. In such case, depreciation costs was calculated using the following formula:

$$Ka_m = \frac{C_m}{Tr_m} \tag{4}$$

where:
Tr_m – service potential of the mth piece of mechanical equipment (hours).

Formula (4) was also used to calculate the depreciation costs for the sprayer in the energy-efficient variant because the product of the operating time of the machine in a year (in hours) and the number of years in its lifetime exceeds the service potential.

The maximum number of years in the lifetime of mechanical equipment, their service potential and the repair cost to price rations were adopted from Muzalewski (2010).

The change of production technology on a farm is related to ceasing to use a certain number of pieces of mechanical equipment, whose service potential and the number of years in a economically reasonable lifetime were not achieved. This equipment was not, therefore, fully depreciated. According to the previously published methodology (Pawlak, 2017), the loss due to incomplete depreciation has to be added to the value of investment spending related to the change of technology. The loss is calculated according to the formula:

$$Ws = \sum_{m=1}^{k} C_m \cdot \frac{(T_m - Wm)}{T_m} \tag{5}$$

where:
Ws – value of the service potential that was not used due to the cessation of use of the piece of mechanical equipment as a result of the change of crop production technology on the model farm (PLN);
Wm – age of the piece of mechanical equipment ceased to be used (years).

If there are no additional investments on the farm, and the activities related to the application of the energy-efficient technological variant are done by external service providers, the price of the machine used to provide the specific service is increased by adding the said loss. The revenue from the sales of the unnecessary equipment is deducted from the loss, and if there are no potential buyers, the deducted amount is equal to the value of scrap metal calculated as a product of the mass of scrapped pieces of mechanical equipment and the unit price of scrap metal.

Results and analysis

Due to the change of production technology, the model farm ceased to use: grain drill (11 years old), three-furrow mouldboard plough (8 years old), five-furrow stubble plough, five-row spike harrow and weeder (10 years each), and a tillage aggregate (5 years old). The said equipment was not fully depreciated. Due to the absence of potential buyers, the loss due to incomplete depreciation should be added to the value of investment spending related to the change of technology. However, due to the lack of additional investment on the farm, the loss was added to the price of the tillage and direct sowing equipment, which is the basis for the calculation of its operating costs.

The estimated loss due to the incomplete use of the capacity of the mechanical equipment that ceased to be used on the model farm due to the change of production technology was shown in Table 1.

Table 1

Economic effects of incomplete use of the pieces of mechanical equipment that have been ceased to use on the model farm

Machine or tool				Number of past operating hours (h)			Disused value (PLN)
Name	price (PLN)	age (years)	lifetime (years)	per year ($h \cdot year^{-1}$)	to date (h)	potentially (h)	
Stubble plough	5,350	10	20	47	470	940	2,675
Spike harrow	2,310	10	20	66	660	1,320	1,155
Three-furrow plough	5,000	8	20	72	576	1,440	3,000
Tillage aggregate	8,496	5	20	12	60	240	6,372
Grain drill	21,290	11	20	30	180	600	9,581
Weeder	3,000	10	15	5	50	75	1,000
Total							23,783

Source: own calculation.

On the model farm, which is the subject of this study, there is no additional investment related to the use of the energy-efficient technology, and the related activities are done by external service providers. Therefore, while calculating costs, the price of tillage and direct sowing equipment used to provide the service is increased by adding the loss due to the unused service potential of equipment that is no longer needed on the farm after the change of technology. It was assumed that due to the absence of potential buyers for that equipment, the value provided in Table 1 is decreased by the value of scrap metal. The value of scrap metal from the discarded equipment whose total mass amounts to 2,500 kg is PLN 1,600. After this amount was deducted from the total value of the unused service potential for the equipment mentioned in Table 1, the price of the tillage and direct sowing equipment in Tables 9-12 was increased by PLN 22,183 and the relevant value (PLN 391,183) provided in Table 3, as the basis for calculating its operating costs.

The calculation results of the annual operating time of the mechanical equipment and energy carrier consumption on the model farm was used for calculating operating costs of tractors, machines, tools and devices on that farm. The operating costs of that equipment for the conventional crop production technology are shown in Table 2, and for the energy-efficient technology – in Table 3.

Tables 2 and 3 show the agricultural machinery at the disposal of the model farm before and after the modernisation aimed at reducing greenhouse gas emissions. Moreover, they also provide the basic technical specifications (engine power and operating width) and the maximum lifetime in years and the service potential (the number of hours that is possible to operate the specific piece of mechanical equipment throughout its lifetime). These values served as the basis for calculating depreciation costs. In the case of low annual operating time, the service potential was not used to the full, while the annual operating time was high – the actual number of years was lower than the number provided in the Tables.

Due to the change of the crop production technology on the model farm, the tractor operating time decreased by 31.5%. On the one hand, this resulted in increased unit operating cost of that tractor (in PLN·h^{-1}) by 23.2%, and on the other, decrease in its annual operating costs by 23.3%. However, due to the increase in the annual operating time of the sprayer by 265.7%, the unit operating cost decreased by 47.5%, but the annual operating costs grew by 92.0%.

Replacement of conventional tillage with the use of a tillage and direct sowing aggregate (in the form of an external service) resulted in the increase in annual operating costs of the equipment used for these activities on the model farm by 308.5%.

Due to the drop in crop yield, the annual cost of harvest using a combine harvester in the form of an external service was reduced by 8.3%. For the same reason, the operating time of the trailer decreased by 1.6%, which resulted in an increase in its unit operating cost by 1.6% with simultaneous drop in annual operating costs during work directly related to crop cultivation on the model farm by 1.0%.

The total operating cost of agricultural machinery on the model farm (including the equipment used by external service providers) grew by 25.2% per annum despite the reduction in diesel fuel consumption by 26.8%.

Table 2

Operating cost of agricultural machinery on the model farm – conventional technology

Specification	Power (kW)	Operating width (m)	Price (PLN)	Annual operating time (h)		Lifetime (years)	Service potential (h)	Repair cost coefficient k_n	Unit operating cost (PLN·h^{-1})				Annual operating cost (PLN·farm^{-1})
				total	including on the farm				depreciation	repair	energy	total	
Tractor	37		107,900	435	435	20	12,000	0.9	12.40	11.16	23.10	46.66	16,939.17
Self-propeller loader	36		70,000	73	73	16	4,800	0.7	59.93	41.95	23.56	125.45	250.89
Trailer			31,100	190	190	20	6,000	0.9	8.18	7.37		15.55	1,834.90
Five-furrow stubble plough		1.5	5,350	47	47	20	2,000	0.8	5.69	4.55		10.24	481.50
Five-row spike harrow		5.2	2,310	66	66	20	1,900	0.9	1.75	1.58		3.33	219.45
Three-furrow plough		1.2	5,000	72	72	20	2,000	1.0	3.47	3.47		6.94	500.00
Tillage aggregate		3	8,496	12	12	20	1,600	0.8	35.40	28.32		63.72	764.64
Fertiliser spreader		12	5,790	46	46	15	1,000	1.1	8.39	9.23		17.62	810.60
Seed treatment machine	1.4		4,450	3	3	15	1,000	1.1	98.89	108.78	0.90	208.56	625.69
Seed drill		3	21,290	30	30	20	1,400	1.0	35.48	35.48		70.97	2,129.00
Weeder		3	3,000	5	5	15	840	1.0	40.00	40.00		80.00	400.00
Sprayer with a 400 l tank		12	5,750	35	35	15	1,000	0.6	10.95	6.57		17.52	613.33
Combine harvester of 4.2 m	99	4.2	476,030	300	36	20	3,000	0.8	158.68	126.94	73.92	359.54	12,943.37
Screw conveyor	3.0		3,630	50	50	16	1,500	0.7	4.54	3.18	1.92	9.63	57.80
Total													38,570.34

Source: own study.

Table 3

Operating cost of agricultural machinery on the model farm – energy-efficient technology

Specification	Power (kW)	Operating width (m)	Price (PLN)	Annual operating time (h)		Lifetime (years)	Service potential (h)	Repair cost coefficient k_n	Unit operating cost (PLN·h^{-1})				Annual operating cost (PLN·farm^{-1})
				total	including on the farm				depreciation	repair	energy	total	
Tractor	37		107,900	298	298	20	12,000	0.9	18.10	16.29	23.10	57.50	12,994.47
Tractor	120		270,000	1,200	30	20	12,000	0.9	22.50	20.25	23.10	65.85	1,975.50
Self-propelled loader	36		70,000	73	73	16	4,800	0.7	59.93	41.95	23.56	125.45	250.89
Trailer			31,100	187	187	20	6,000	0.9	8.32	7.48		15.80	1,816.94
Fertiliser spreader		12	5,790	46	46	15	1,000	1.1	8.39	9.23		17.62	810.60
Seed treatment machine	1.4		4,450	3	3	15	1,000	1.1	98.89	108.78	0.90	208.56	625.69
Tillage and direct sowing aggregate		3	391,183	140	30	10	1,400	1.0	279.42	279.42		558.83	16,764.99
Sprayer with a 400 l tank		12	5,750	128	128	15	1,000	0.6	5.75	3.45		9.20	1,177.60
Combine harvester	99	4.2	47,6030	300	33	20	3,000	0.8	158.68	126.94	73.92	359.54	11,864.75
Screw conveyor	3.0		3,630	50	50	16	1,500	0.7	4.54	3.18	1.92	9.63	57.80
Total													48,339.23

Source: own study.

Use of the energy-efficient technology on the model farm decreased CO_2 emissions due to a reduction in the diesel fuel consumption from 6.0 to 4.2 tonnes, i.e. by 30%. Lithuanian research showed that use of various forms of simplified tillage lead to a decrease in CO_2 emissions related to mechanisation by 12-58% (Šarauskis et al., 2014). At the same time, the value of production based on 2016 buying-in prices according to GUS (2017) decreased by nearly 10% on the model farm (Table 4).

Table 4

Crop production output on the model farm based on 2016 prices

Product type	Buying-in price (PLN/t)	Harvest (t) for:		Production value (PLN) for:	
		conventional tillage	energy-efficient tillage	conventional tillage	energy-efficient tillage
wheat	620.2	50	45	31,010	27,909
pea	1,080.8	28	25	30,262.4	27,020
rape	1,616.7	17.5	16	28,292.25	25,867.2
buckwheat	1,586.7	11.5	10.5	18,247.05	16,660.35
Total				107,811.7	97,456.55

Source: own study.

Despite the drop in production due to the replacement of the conventional crop production technology with the energy-efficient one on the model farm, CO_2 emissions resulting from the energy carrier consumption during the work related to crop production per unit of value of production achieved decreased by 22.6%. From the perspective of environmental production, the technological change was justified. From the farm's perspective, however, it is not so. As a consequence of the drop in crop yield, the value of produced crop decreased by PLN 10,355, which was accompanied by the simultaneous rise in operating costs of agricultural machinery by PLN 9,769. In conjunction with the unchanged cost of fertilisation and seed material, this means a decrease in the farmer's annual income by PLN 20,124, i.e. by PLN 670.80 per hectare of agricultural land. Therefore, from the economic point of view such a change is not justified. The farmer could be persuaded to switch to the energy-efficient technology if the loss was adequately compensated for.

Conclusion

Replacement of conventional tillage with the use of a tillage and direct sowing aggregate (in the form of an external service) resulted in the increase in annual operating costs of the equipment used for these activities on the model farm by 309.4%.

The total operating cost of agricultural machinery on the model farm (including the equipment used by external service providers) grew by 25.3% per annum despite the reduction in diesel fuel consumption by 26.8%.

The economic calculation of the effects of reduction in greenhouse gas emissions in agricultural production considers the unused service potential of agricultural machinery used in the conventional production technology.

On the model farm, the replacement of the conventional production technology variant with the energy-efficient one results in the decrease of CO_2 emissions per unit produced by 22.6%.

The technological change, which is reasonable from the perspective of environmental protection, is not feasible due to the increased operating costs of mechanical equipment and the drop in the value of produced crop on the model farm. Overcoming this barrier would require adequate financial aid that would entail relevant consequences for the State budget.

In such a situation, economically viable opportunities to reduce GHG emissions should in practice be sought primarily in the popularisation of crop production practices optimising use of synthetic fertilisers containing nitrogen. This means e.g. to the implementation of the precision agriculture system, which allows changing habitat conditions to be taken into account. This gives rise to the need to assess the economic and environmental effects of the use of mechanical equipment adjusted to the requirements of precision agriculture, which is another research problem to be solved.

The example of the use of the method described in the previous publication confirms its usefulness for the assessment of economic and environmental impact of the crop production technology reducing CO_2 emissions.

References

Akbarnia, A., Fahrani, F. (2014). Study of fuel consumption in three tillage methods. *Research in Agricultural Engineering*, vol. 60, no. 4, pp. 142-147.

Barut, Z.B., Ertekin, C., Karaagac, H.A. (2011). Tillage effects on energy use for corn silage in Mediterranean Coastal of Turkey. *Energy*, vol. 36. issue 9, pp. 5466-5475.

Beach, R.H., Creason, J., Ohrel, S.B., Ragnauth, S., Ogle, S., Li, C., Ingraham, P., Salas, W. (2015). Global mitigation potential and costs of reducing agricultural non-CO_2 greenhouse gas emissions through 2030. *Journal of Integrative Environmental Sciences*, vol. 12, issue sup. 1, pp. 87-105.

Biskupski, A., Sekutowski, T.R., Włodek, S., Smagacz, J., Owsiak, Z. (2014). Wpływ międzyplonów oraz różnych technologii uprawy roli na plonowanie kukurydzy. *Inżynieria Ekologiczna*, nr 38, pp. 7-16.

Golka, W., Ptaszyński, S. (2014). Nakłady na uprawę roli w technologii zachowawczej i tradycyjnej. *Problemy Inżynierii Rolniczej, nr 3*(86), pp. 31-47.

GUS (2017). *Ceny w gospodarce narodowej w 2017 r.* Warszawa: GUS.

Horovitz, J., Gottlieb, J. (2010). The role of agriculture in reducing greenhouse gas emissions. *Economic Brief*, no. 15. USDA Economic Research Service, Washington DC, p. 8.

Muzalewski, A. (2010). *Koszty eksploatacji*. Falenty-Warszawa: ITP

Parton, W.J., Del Grosso, S.J., Marx, E., Swan, A.L. (2011). Agriculture's role in cutting greenhouse gas emissions. *Issues in Science and Technology*, vol. 27, no. 4, pp. 29-32.

Paustian, K., Antle, J.M., Sheehan, J., Paul, E.A. (2006). *Agriculture's role in greenhouse gas mitigation*. PEW Center on Global Climate Change.

Pawlak, J. (2015). Rolnictwo a środowisko naturalne. *Problemy Inżynierii Rolniczej, nr 1*(87), pp. 17-28.

Pawlak, J. (2017). Założenia metodyczne do oceny ekonomicznych skutków redukcji emisji gazów cieplarnianych w rolnictwie. *Zagadnienia Ekonomiki Rolnej, nr 2*(351), pp. 138-151.

Polski FADN (2017). *Wyniki Standardowe Polskiego FADN* (rok obrachunkowy 2015). Warszawa: IERiGŻ-PIB. Retrieved from: http://fadn.pl/wp-content/uploads/2017/01/WS-R2015-WS.pdf (acsess date: 10.01.2018).

Sánchez, B., Iglesias, A., McVittie, A., Álvaro-Fuentes, J., Ingram, J., Mills, J., Lesschenj J.P., Kuikman, P.J. (2016). Management of agricultural soils for greenhouse gas mitigation: Learning from a case study in NE Spain. *Journal of Environmental Management*, vol. 170, pp. 37-49.

Sørensen, C.G., Halberg, N., Oudshoorn, F.W., Petersen, B.M., Dalgaard, R. (2014). Energy inputs and GHG emissions of tillage systems. *Biosystems Engineering*, vol. 120, pp. 2-14.

Šarauskis, E., Buragiene, S., Masilionyte, L., Romaneckas, K., Avizienyte, D., Sakalauskas, A. (2014). Energy balance, costs and CO_2 analysis of tillage technologies in maize cultivation. *Energy*, vol. 69, pp. 227-235.

Żyłowski, T. (2017). Efektywność środowiskowa i ekonomiczna rolnictwa konserwującego. *Studia i Raporty IUNG-PIB*, vol. 52, z. 6, pp. 119-138.

Table 5

Process sheet for production of winter wheat in a field with medium quality soil (2x5 ha, grain yield: 5 t·ha^{-1}, forecrop: winter rape, pea) conventional technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Stubble ploughing	10		Five-furrow stubble plough	5,350	1	Tractor	37	107,900	1	1	0.65	Jul,2–Aug,1	5
Spike harrowing	30		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Jul,1–Sep,2	5
Mouldboard ploughing	10		Three-furrow plough	5,000	1	Tractor	37	107,900	1	1	0.42	Sep,1-2	10
Fertiliser loading		7.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Sep,1-2	10
Fertiliser transport		7.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Sep,1-2	10
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Sep,1–2	10
Seed treatment		1.6	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Sep, 3	6
Seed loading		1.6	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Sep, 3	5
Seed transport		1.6	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Sep, 3	5
Wheat sowing	10		Grain drill, 3 m operating width	21,290	1	Tractor	37	107,900	1	1	1.00	Sep, 3	5
Post-sowing harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Sep, 3	5
Spraying	10		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–Apr,1	6
Fertiliser loading		2.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	6
Fertiliser transport		2.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	6
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	6
Crop care harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar,3–Apr,2	6
Spraying	10		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	May,2	4
Grain harvest	10		4.2 m combine harvester with a straw chopper	4,76030	1	Engine	99			1	0.90	Aug,1-2	6
Grain transport		50	Self-unloading agricultural trailer	3,1100	1	Tractor	37	107,900	1	1	4.50	Aug,1-2	6
Grain loading		50	Screw conveyor	3,630	1	Engine	3			1	20.00	Aug,1-2	6
Grain storage		50	Grain silo, 57 t capacity	12,100	1								

Key: u.m. – unit of measurement.
Source: own study.

Table 6

Process sheet for production of pea in a field with medium quality soil
(2x5 ha, grain yield: 2.8 t·ha^{-1}, forecrop: winter wheat, buckwheat) conventional technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Stubble ploughing	10		Five-furrow stubble plough, spike harrow	5,350	1	Tractor	37	107,900	1	1	0.65	Aug,1–Sep,2	6
Spike harrowing	20		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Aug,3–Sep,2	15
Fertiliser loading		4.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Oct, 1-3	20
Fertiliser transport		4.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Oct, 1-3	20
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Oct, 1-3	20
Mouldboard ploughing	10		Three-furrow plough	5,000	1	Tractor	37	107,900	1	1	0.42	Oct, 1-3	20
Spike harrowing	20		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar, 2-3	55
Fertiliser loading		1.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	5
Fertiliser transport		1.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	5
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	5
Pre-sowing tillage	10		Tillage aggregate	8,496	1	Tractor	37	107,900	1	1	1.30	Mar,3–Apr,1	5
Seed treatment		2.0	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Mar,3–Apr,1	5
Seed loading		2.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	5
Seed transport		2.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Mar,3–Apr,1	5
Pea sowing	10		Grain drill, 3 m operating width	21,290	1	Tractor	37	107,900	1	1	1.00	Mar,3–Apr,1	5
Post-sowing harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar,3–Apr,1	5
Spraying	10		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–Apr,1	5
Crop care harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Apr, 1-3	5
Spraying	30		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Apr,2–Jul,1	8
Seed harvest	10		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.90	Jul, 2-3	
Grain transport		28	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.52	Jul, 2-3	6

Key: u.m. – unit of measurement.
Source: own study.

Table 7

Process sheet for production of winter rape in a field with medium quality soil (5 ha, grain yield: 3.5 t·ha^{-1}, forecrop: pea) conventional technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Stubble ploughing	5		Five-furrow stubble plough	5,350	1	Tractor	37	107,900	1	1	0.65	Jul,2-3	5
Spike harrowing	15		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Jul,2-Aug,3	5
Mouldboard ploughing	5		Three-furrow plough	5,000	1	Tractor	37	107,900	1	1	0.42	Jul,3–Aug,1	6
Fertiliser loading		5.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Jul,3–Aug,1	6
Fertiliser transport		5.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Jul,3–Aug,1	6
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Jul,3–Aug,1	6
Seed treatment		0.4	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Aug,1-3	6
Seed loading		0.4	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Aug,1-3	5
Seed transport		0.4	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Aug,1-3	5
Rape sowing	5		Grain drill, 3 m operating width	21,290	1	Tractor	37	107,900	1	1	1.00	Aug,1-3	5
Post-sowing harrowing	5		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Aug,1-3	5
Interrow tillage	5		Weeder	3,000	1	Tractor	37	107,900	1	1	1.00	Sep,3–Oct,1	12
Fertiliser loading		3.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	6
Fertiliser transport		3.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	6
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	6
Crop care harrowing	5		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar,3–Apr,1	6
Spraying	10		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Apr,3–May,1	6
Crop care harrowing	5		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar,3–Apr,1	6
Crop desiccation	5		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Jul, 1	5
Grain harvest	5		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.59	Jul, 1-2	5
Grain transport		17.5	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.06	Jul, 1-2	5

Key: u.m. – unit of measurement.
Source: own study.

Table 8

Process sheet for production of buckwheat in a field with medium quality soil (5 ha, grain yield: 2.3 t·ha^{-1}, forecrop: winter wheat) conventional technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Stubble ploughing	5		Five-furrow stubble plough, spike harrow	5,350	1	Tractor	37	107,900	1	1	0.65	Aug,1–2	6
Spike harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Aug,3–Sep,3	15
Fertiliser loading		3.5	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Oct, 1-3	20
Fertiliser transport		3.5	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Oct, 1-3	20
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Oct, 1-3	20
Mouldboard ploughing	5		Three-furrow plough	5,000	1	Tractor	37	107,900	1	1	0.42	Oct, 1-3	20
Spike harrowing	10		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Mar, 2-3	55
Fertiliser loading		1.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–May,1	5
Fertiliser transport		1.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–May,1	5
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–May,1	5
Pre-sowing tillage	5		Tillage aggregate	8,496	1	Tractor	37	107,900	1	1	1.30	May,1-2	5
Seed treatment		0.34	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	May,2-3	5
Seed loading		0.34	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	May,2-3	5
Seed transport		0.34	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	May,2-3	5
Buckwheat sowing	5		Grain drill, 3 m operating width	21,290	1	Tractor	37	107,900	1	1	1.00	May,2-3	5
Post-sowing harrowing	5		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	May,2-3	5
Crop care harrowing	5		Five-row spike harrow	2,310	1	Tractor	37	107,900	1	1	2.60	Jun, 1-3	5
Crop desiccation	5		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Sep, 1	6
Grain harvest	5		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.90	Sep, 2	6
Grain transport		11.5	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.07	Sep, 2	6

Key: u.m. – unit of measurement.
Source: own study.

Table 9

Process sheet for production of winter wheat in a field with medium quality soil (2x5 ha, grain yield: 4.5 t·ha^{-1}, forecrop: winter rape, pea) energy-efficient technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Spraying	20		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Jul,1–Sep,2	20
Fertiliser loading		7.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Sep,1-2	10
Fertiliser transport		7.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Sep,1-2	10
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Sep,1–2	10
Seed treatment		1.6	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Sep, 3	6
Seed loading		1.6	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Sep, 3	5
Seed transport		1.6	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Sep, 3	5
Wheat sowing	10		Tillage and direct sowing aggregate	369,000	1	Tractor	120	319,800	1	1	1.00	Sep, 3	4
Spraying	20		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–Apr,1	3
Fertiliser loading		2.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	6
Fertiliser transport		2.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	6
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	6
Spraying	20		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Apr,3–May,2	6
Grain harvest	10		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	1.00	Aug,1-2	6
Grain transport		45	5 t self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.50	Aug,1-2	6
Grain loading		45	Screw conveyor	3,630	1	Engine	3			1	20.00	Aug,1-2	6
Grain storage		45	Grain silo, 57 t capacity	12,100	1								

Key: u.m. – unit of measurement.
Source: own study.

Table 10

Process sheet for production of pea in a field with medium quality soil
(2x5 ha, grain yield: 2.5 t·ha^{-1}, forecrop: winter wheat, buckwheat) energy-efficient technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Spraying	30		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Aug,1–Sep,3	16
Fertiliser loading		4.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Oct, 1-3	20
Fertiliser transport		4.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Oct, 1-3	20
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Oct, 1-3	20
Fertiliser loading		1.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	5
Fertiliser transport		1.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	5
Fertiliser spreading	10		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	5
Seed treatment		2.0	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Mar,3–Apr,1	5
Seed loading		2.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	5
Seed transport		2.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Mar,3–Apr,1	5
Pea sowing	10		Tillage and direct sowing aggregate	369,000	1	Tractor	120	319,800	1	1	1.00	Mar,3–Apr,1	5
Spraying	20		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–Apr,1	5
Spraying	30		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Apr,2–Jul,1	8
Grain harvest	10		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.99	Jul, 2-3	6
Grain transport		25.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.48	Jul, 2-3	6

Key: u.m. – unit of measurement.
Source: own study.

Table 11

Process sheet for production of winter rape in a field with medium quality soil (5 ha, grain yield: 3.2 t·ha^{-1}, forecrop: pea) energy-efficient technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Spraying	15		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Jul,2-Aug,3	5
Fertiliser loading		5.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Jul,3–Aug,1	20
Fertiliser transport		5.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Jul,3–Aug,1	20
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Jul,3–Aug,1	20
Seed treatment		0.4	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	Aug,1-3	5
Seed loading		0.4	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Aug,1-3	5
Seed transport		0.4	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	Aug,1-3	5
Rape sowing	5		Tillage and direct sowing aggregate	369,000	1	Tractor	120	319800	1	1	1.00	Aug,1-3	5
Spraying	20		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–May,1	5
Fertiliser loading		3.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–Apr,1	5
Fertiliser transport		3.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–Apr,1	5
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–Apr,1	5
Crop desiccation	5		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Jul, 1	5
Grain harvest	5		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.65	Jul, 1-2	5
Grain transport		16	5 t self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.08	Jul, 1-2	5

Key: u.m. – unit of measurement.
Source: own study.

Table 12

Process sheet for production of buckwheat in a field with medium quality soil
(5 ha, grain yield: 2.1 t·ha^{-1}, forecrop: winter wheat) energy-efficient technology

Activities	to be carried out (u.m.)		Machine, tool or device			Power source				Crew (no. of people)	Efficiency W_{07} (u.m.·h^{-1})	Season	
	(ha)	(t)	Name	Price (PLN)	(pieces)	Name	Power (kW)	Price (PLN)	(pieces)			month, decade	(days)
Spraying	15		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Aug,1–Sep,3	16
Fertiliser loading		3.5	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Oct, 1-3	20
Fertiliser transport		3.5	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	8.75	Oct, 1-3	20
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.25	Oct, 1-3	20
Spraying	5		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Mar,3–Apr,1	10
Fertiliser loading		1.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	Mar,3–May,1	5
Fertiliser transport		1.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	5.00	Mar,3–May,1	5
Fertiliser spreading	5		Suspended fertiliser spreader	5,790	1	Tractor	37	107,900	1	1	1.40	Mar,3–May,1	5
Seed treatment		2.0	Seed treatment machine	4,450	1	Engine	1.4			1	2.00	May,2-3	5
Seed loading		2.0	Self-propelled loader, trailer	70,000	1	Engine	36			1	25.00	May,2-3	5
Seed transport		2.0	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	4.00	May,2-3	5
Buckwheat sowing	5		Tillage and direct sowing aggregate	369,000	1	Tractor	120	319,800	1	1	1.00	May,2-3	5
Crop desiccation	5		12 m sprayer with a 400 l tank	5,750	1	Tractor	37	107,900	1	1	1.45	Jun,3–Jul,1	8
Grain harvest	5		4.2 m combine harvester with a straw chopper	476,030	1	Engine	99			1	0.99	Jul, 1-2	6
Grain transport		10.5	Self-unloading agricultural trailer	31,100	1	Tractor	37	107,900	1	1	2.07	Jul, 1-2	6

Key: u.m. – unit of measurement.
Source: own study.

OCENA EKONOMICZNYCH SKUTKÓW REDUKCJI EMISJI GAZÓW CIEPLARNIANYCH NA PRZYKŁADZIE GOSPODARSTW SPECJALIZUJĄCYCH SIĘ W UPRAWACH POLOWYCH

Abstrakt

W artykule przedstawiono ekonomiczne skutki zastosowania w modelowym gospodarstwie rolnym technologii powodującej redukcję emisji gazów cieplarnianych do atmosfery. Zastąpienie tradycyjnej uprawy zastosowaniem agregatu do uprawy i siewu bezpośredniego (w formie usługi) spowodowało zwiększenie rocznych kosztów eksploatacji w modelowym gospodarstwie rolnym o 308,5%. Łączne koszty eksploatacji środków mechanizacji rolnictwa w modelowym gospodarstwie rolnym (z uwzględnieniem sprzętu zaangażowanego w formie usług) zwiększyły się o 25,2% w skali roku, mimo zmniejszenia zużycia oleju napędowego o 26,8%. Zastąpienie tradycyjnego wariantu technologii produkcji roślinnej energooszczędnym powoduje zmniejszenie emisji CO_2 *w przeliczeniu na jednostkę wartości uzyskanej produkcji o 22,6%. Zmiana technologii, uzasadniona z punktu widzenia ochrony środowiska, nie jest wykonalna z uwagi na zwiększenie kosztów eksploatacji środków mechanizacji i zmniejszenie wartości uzyskiwanej produkcji roślinnej w modelowym gospodarstwie rolnym. Przezwyciężenie tej bariery wymagałoby zastosowania odpowiedniego wsparcia finansowego, z odpowiednimi konsekwencjami dla budżetu państwa.*

Słowa kluczowe: emisja gazów cieplarnianych, redukcja, gospodarstwo rolne, koszt.

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