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# A REGIONAL ANALYSIS OF THE USE OF TRACTORS ON MODEL FARMS PRODUCING ENERGY CROPS*

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**Abstract.** The potential area of energy crops in Poland is estimated at 1.0–4.5 million ha. The decrease in the prices of energy reduces the high pressure to cut the costs of biomass production. The aim of this study is an analysis of the use of tractors on model farms producing energy crops, which have different areas, intensity of production and quality of soils from different regions of Poland. The use of tractors increased along with the farm area, the soil quality and production intensity. The use of tractors on the smallest farms is low, so they should buy old tractors. A large share of crops for biogas leads to the situation where it takes 20–30 years of work for tractors to achieve full wear of 12,000 hours on farms with 130 ha of farmland, whereas it takes only 8–14 years on farms with 600 and 1500 ha of farmland. Regional differences in the use of tractors increased along with the farm area from 4.7–5.7% on the smallest farms to 10.1–14.8% on the largest farms.

**Key words:** energy crops, model of farms, regions, input, tractors

## INTRODUCTION

Directive 2009/28/EC adopted by the EU assumes that by 2020 the EU countries will have achieved a 20% share of energy from renewable sources. However, Poland should achieve a lower level, i.e. 15% (Baum et al., 2013). Among many sources of renewable energy agricultural and forest biomass has high significance. It may be used for co-incineration in power plants, for the production of biogas or biofuels. Analyses and estimates indicate that from 1.0 to 4.5 million ha of farmland may be used for the production of biomass in Poland (Van Velthuizen, 2003; Wiesenthal et al., 2006; Kuś and Faber, 2009; Matyka, 2011; Baum, 2012). The potential area of energy crops in Poland is 1.7 million ha, where 0.5 million ha of rapeseeds may be used for the production of biodiesel, 0.6 million ha of crops (chiefly cereals) may be used for the production of bioethanol and 0.6 million ha - for the production of solid biomass. The agricultural biogas plant development programme assumes the production of 2 billion $m^3$ of biogas, so it is necessary to use up to 0.7 million ha as the area for energy crops (Matyka, 2011). However, the area of energy crops is still small (Kuś, 2008).

Biomass may be produced all over Poland. However, there are considerable differences in natural and economic conditions in different regions of the country. This strongly affects the yield volume and the use of machinery for harvesting and crop transport.

Prices of electricity are still very important to the cost-effectiveness of production of biomass energy. Those prices are much lower than the costs of energy

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from most renewable sources and much lower than the price of Tradable Renewable Energy Certificates. This situation forces the EU countries to subsidies this production. In consequence, in the long run this will considerably increase the risk of investments in renewable sources of energy, because an administrative decision may abolish or considerably reduce the subsidy. The decrease in the prices of energy that has been observed in recent years deteriorates the cost-effectiveness of production of energy from renewable sources. As a result, there is higher pressure to reduce the costs of biomass production. The costs of machinery are the most important source of costs in plant production. They may range from 30% on large-area farms to 50% (Muzalewski, 2007) or even 70% (Karwowski, 1998) on smaller farms. As far as the structure of the costs of use of farming machinery is concerned, maintenance costs (depreciation, storage, insurance) make about 60% (Muzalewski and Olszewski, 2000). Fixed costs (maintenance costs) may increase even up to 70–73% of operating costs on farms with excessive amounts of machinery (Muzalewski, 2007). Because the share of fixed costs are significantly dependent on working time tractors, it's important to make the best use.

The aim of this study was to analyses the use of tractors on model farms of different sizes and production intensity, with different quality of soils, producing energy crops in 5 macroregions in Poland.

## MATERIAL AND METHODS

Model process charts were developed on the basis of the technologies used in experimental plots and implemented as part of the research project POIG.01.03.01-00-132/08, financed by the European Regional Development Fund under the 'Innovative Economy' Operational Programme. The implementation of the project started in 2009 and will continue until 2015. The series of works and treatments includes all types of field work, the purchase of means of production and the sales of products generated. The charts were prepared for farms without animal production. Their areas are as follows:

- up to 20 ha, where an area of 15 ha of farmland was assumed,
- 20–50 ha, where an area of 35 ha of farmland was assumed,
- 50–200 ha, where an area of 130 ha of farmland was assumed,
- 200–1000 ha, where an area of 600 ha of farmland was assumed,
- over 1000 ha, where an area of 1500 ha of farmland was assumed.

The following types of soils can be found on the farms:

- light soils,
- medium soils,
- heavy soils.

There are three intensity levels, expressed with different levels of nitrogen fertilization and crop.

Poland was divided into 5 macroregions:

- central – with kujawsko-pomorskie i wielkopolskie voivodeships,
- south-western – with dolnośląskie i opolskie voivodeships,
- south-eastern – with lubelskie, małopolskie, podkarpackie, śląskie i świętokrzyskie, voivodeships,
- north-western – with lubuskie, pomorskie i zachodnio-pomorskie voivodeships,
- north-eastern – with łódzkie, mazowieckie, podlaskie and warmińsko-mazurskie voivodeships.

There were differences in the expected yield volume in individual macroregions, because it was estimated with the expert method based on the average yield of crops in individual voivodeships, according to the data provided by the Central Statistical Office. The average yield of crops in a particular macroregion was calculated as weighted averages of the yield from 2001 to 2012. The yield obtained in this way was the base yield for extensive farms with the area up to 20 ha, with light soils. Wheat, sugar beets and rapeseed were the exceptions, because their base yield came from extensive farms with the area up to 20 ha, with medium soils. The expert method was applied to determine corrections in the yield volume related with the increase in the farm area, intensity and improvement in the soil quality. Corrections of the machinery efficiency were estimated on the basis of the Katalog norm i normatywów (1991).

Model farms grew 5–6 crops, where cereals had 40–50% share of farmland and each crop occupied one fifth or one sixth of farmland. We assumed that the following crops would be grown:

- on light soils: maize for silage, triticale, rye and Virginia mallow,

- on medium soils: sugar beets, maize for silage, winter wheat, rapeseed, triticale and Virginia mallow,
- on heavy soils: sugar beets, maize for silage, winter wheat, rapeseed, triticale and reed canary grass.

In order to compare the yield in individual macroregions the synthetic yield volume index (WWP) was calculated. It shows the yield volume of all crops grown on a particular farm in relation to the average yield in Poland or selected region. The index was calculated according to the following formula:

$$WWP = \frac{P_b}{P_t} \cdot 100\%$$

where:

$P_b$ = base area of crops for average yield in Poland,

$P_t$ = the area which is necessary to achieve the average yield in Poland if there is the average yield in the macroregion.

The result which is greater than 100% indicates that the yield obtained in an enterprise under investigation is greater than the average yield in the region. If the result is lower than 100%, the farm achieves lower yield than the average yield in the region (Baum et al., 2009).

## RESEARCH RESULTS

The yield volume index in individual regions is relatively diversified. As far as extensive farming on light soils on farms with an area of 15 ha of farmland is concerned, the yield volume index ranged from 95.8% in north-western Poland to 105.1% in south-western Poland. In central Poland the yield was 2.7% higher than the average yield in Poland, whereas in eastern and north-eastern Poland the yield was respectively 0.2% and 1.2% lower than the average yield in Poland (Fig. 1). On farms with better soils and applying more intensive technology a higher yield was assumed, so the yield volume index on heavy soils with intensive production ranged from 128.1% in south-eastern Poland to 145.8% in central Poland.

We assumed that the yield volume increased along with the increase in the farm area. This resulted in the increase in the yield volume index, which ranged from 106.8% to 117.1% on farms with light soils and extensive production and from 142.7% to 162.5% on farms with heavy soils and intensive production (Fig. 2).

The number and power of tractors used on farms was the same in all the macroregions. However, the number

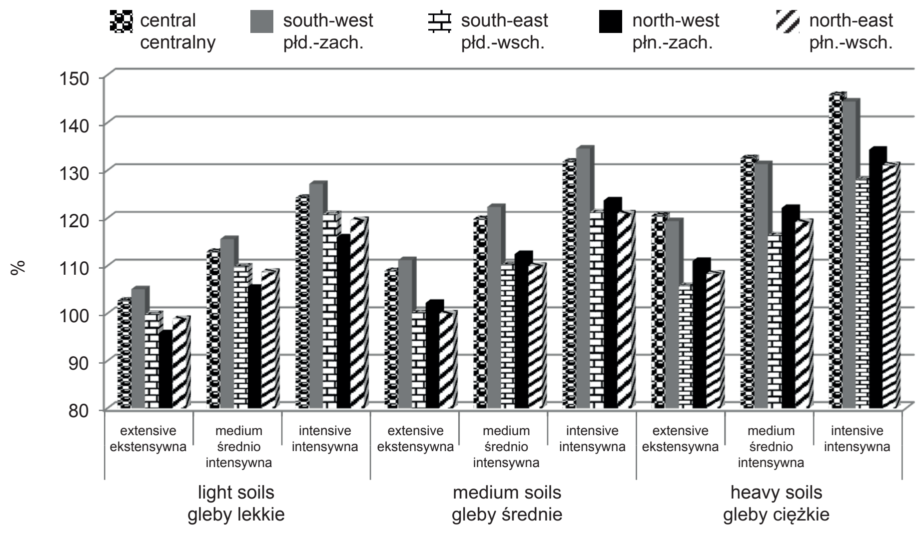


**Fig. 1.** Yield volume index on model farms with 15 ha of farmland
Source: own elaboration.
**Rys. 1.** Wskaźnik wysokości plonów w modelowych gospodarstwach o powierzchni 15 ha UR
Źródło: opracowanie własne.

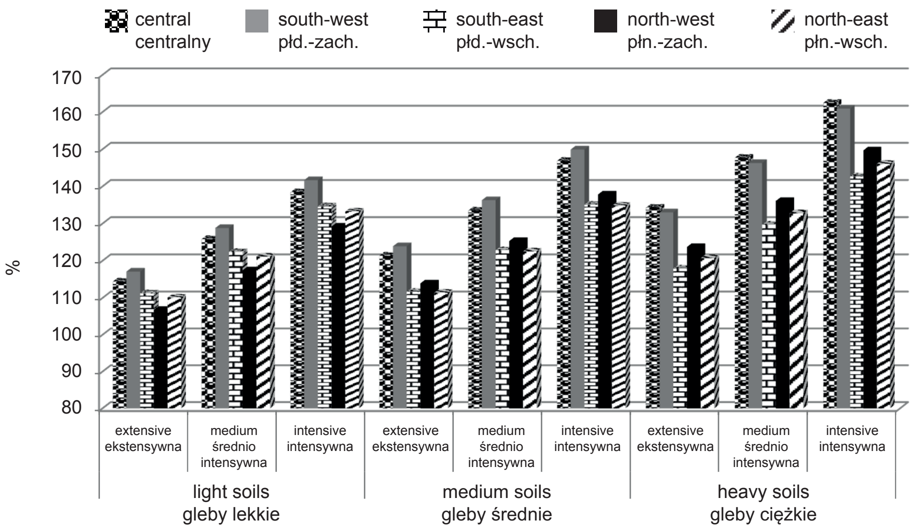


**Fig. 2.** Yield volume index on model farms with 1500 ha of farmland
Source: own elaboration.
**Rys. 2.** Wskaźnik wysokości plonów w modelowych gospodarstwach o powierzchni 1500 ha UR
Źródło: opracowanie własne.

and average power of tractors increased along with the increase in the farm area. On the other hand, the number and total power of tractors decreased when it was calculated per 100 ha of farmland (Fig. 3 and 4).

There are two tractors on farms with 15 ha of farmland and 35 ha of farmland, whereas there are as many as eight tractors on the largest farms. However, there are more than 13.3 tractors per 100 ha of farmland on the smallest farms. On farms with 600 ha and 1500 ha of farmland this ratio drops down below 1.0 and amounts to 0.83 and 0.53 tractors per 100 ha of farmland, respectively. On average there are 10 tractors per 100 ha of farmland in Poland (GUS, 2014). Therefore, the plan to increase machinery on farms is justified.

The average power of a tractor on the smallest farms was planned for about 30 kW on the smallest farms, 46 kW on the farms with an area up to 35 ha, 70 kW on the farms with an area of 130 ha, 106 kW on the farms with an area of 600 ha, 125 kW on the farms with an area of 1500 ha. As far as the farms with an area up to 130 ha are concerned, the planned power of tractors is similar to the power of tractors on model developing farms in Wielkopolska region (Pepliński et al., 2011). The analysis of the total power of the engines installed

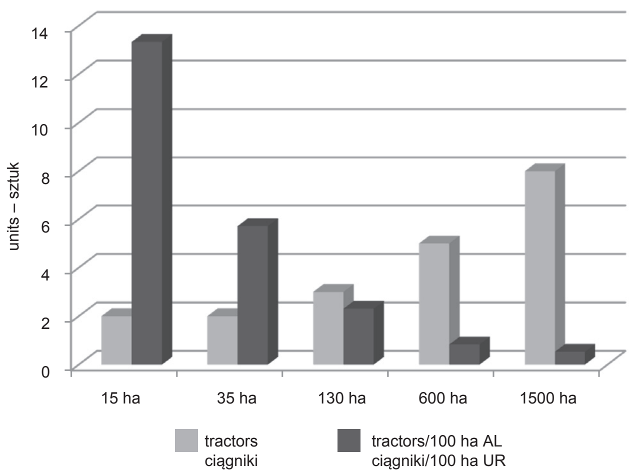


**Fig. 3.** Number of tractors on model farms and the number of tractors per 100 ha of farmland
Source: own elaboration.
**Rys. 3.** Liczba ciągników w modelowych gospodarstwach w sztukach i na 100 ha UR
Źródło: opracowanie własne.

in tractors per 100 ha of farmland revealed that on farms with an area up to 15 ha of farmland there was only

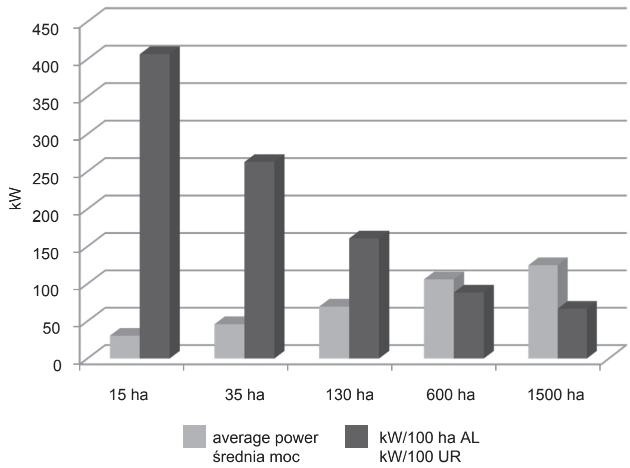


**Fig. 4.** The average and total tractive force on model farms
Source: own elaboration.
**Rys. 4.** Przeciętna i łączna moc ciągników w modelowych gospodarstwach
Źródło: opracowanie własne.

61 kW installed (23 kW and 38 kW tractors), but when the amount was calculated per 100 ha of farmland, it gave the value of 407 kW. On the other hand, on the largest farms, when 1000 kW installed in 8 tractors (1040 kW on farms with the heaviest soils) was calculated per 100 ha of farmland, it gave the value of 67 kW only. In Poland the average power of the engines installed in tractors per 100 ha of farmland is about 425 kW (GUS, 2014). The planned power of tractors in kW per 100 ha of farmland is also smaller than the power of tractors on developing farms (cf. Baum et al., 2011; Wielicki et al., 2002).

Regardless of the region of Poland, the average use of tractors on farms with 15 ha of farmland was highly insufficient, because it ranged from 117 h to 180 h only (Fig. 5). The lowest use was observed on the farms with light soils and extensive production. In individual regions of Poland the differences were minimal and they ranged from 117 h in north-eastern Poland to 123 h in south-eastern Poland. The use of tractors was the highest on the farms with heavy soils and intensive production. It ranged from 171 h in south-eastern Poland to 180 h a year in central Poland. When the expected use of about 12,000 h is planned (Muzalewski 2010), on average tractors would have to work from 67 to 100 years, whereas tractors with the engine power of 23 kW, which work from 55 to 85 h, would have to work from 150 to

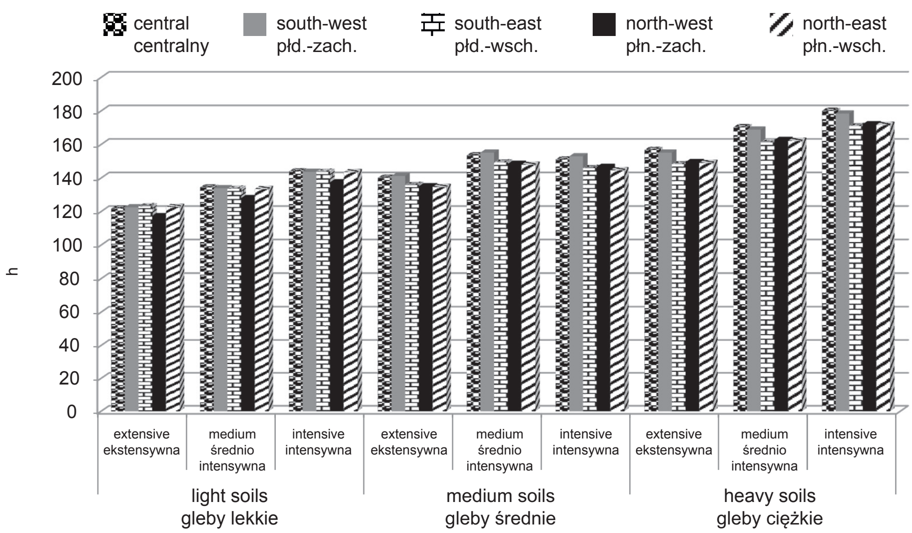


**Fig. 5.** Use of tractors on model farms with 15 ha of farmland
Source: own elaboration.
**Rys. 5.** Wykorzystanie ciągników w modelowych gospodarstwach o powierzchni 15 ha UR
Źródło: opracowanie własne.

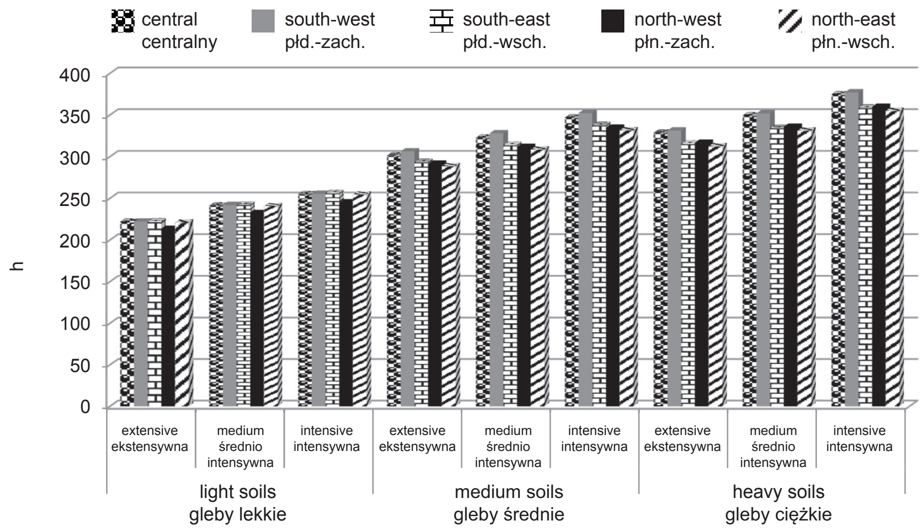


**Fig. 6.** Use of tractors on model farms with 35 ha of farmland
Source: own elaboration.
**Rys. 6.** Wykorzystanie ciągników w modelowych gospodarstwach o powierzchni 35 ha UR
Źródło: opracowanie własne.

200 years, which is unrealistic. In view of this situation those farms have to use used tractors with a considerable degree of wear.

The average use of tractors on farms with 35 ha of farmland is also highly insufficient in all regions of Poland, because it ranges only from 213 h to 377 h (Fig. 6). Again, the lowest use was observed on the farms with light soils and extensive production. In individual regions of Poland the differences were minimal and they ranged from 213 h in north-eastern Poland to 123.3 h in south-eastern Poland. The use of tractors was 60–70% higher on the farms with heavy soils and intensive production than on light soils and extensive production and it ranged from 354 h in north-eastern Poland to 377 h in south-western Poland. The expected working time of tractors reaches from 32 to 56 years, on average. In this case it is also recommended for farms to use used tractors. The suggested machinery stock enabled more equal use of tractors with smaller and greater power on farms with 15 ha of farmland, where the difference in their use was two times greater.

Only the farms with 600 ha of farmland guarantee relatively good use of tractors. As far as extensive production on light soils is concerned, the yearly use of tractors reaches almost 400 h, which means that tractors will achieve full wear after 30 years (Fig. 6). As far as intensive production on those soils is concerned, the yearly use increases to 450–480 h, which shortens the optimal time of wear to about 25 years. Again, the best use can be observed on heavy soils and intensive production, where the yearly use of tractors increased to 580–610 h. This reduces the time of optimal use of tractors to about 21–20 years and enables farmers to have relatively modern farming machinery.

As far as light soils are concerned, tractors are best used in the south-eastern macroregion, whereas they are worst used in the south-western macroregion. On other soils tractors are best used in south-western Poland, whereas they are worst used in north-eastern Poland. Similarly to smaller areas, regional differences in a particular type of farms range from about 4% to 7.5%.

Tractors are used very well only on farms with 600 ha and 1500 ha of farmland (Fig. 8 and 9, respectively). In the former type of farms the use of tractors ranges from 860 h to 1300 h, which means that tractors will achieve fully wear after 14–9 years. This period enables farms to purchase new and very modern tractors. The cost-effectiveness of purchasing one's own equipment to harvest green forage results in a situation where owing to the high percentage of

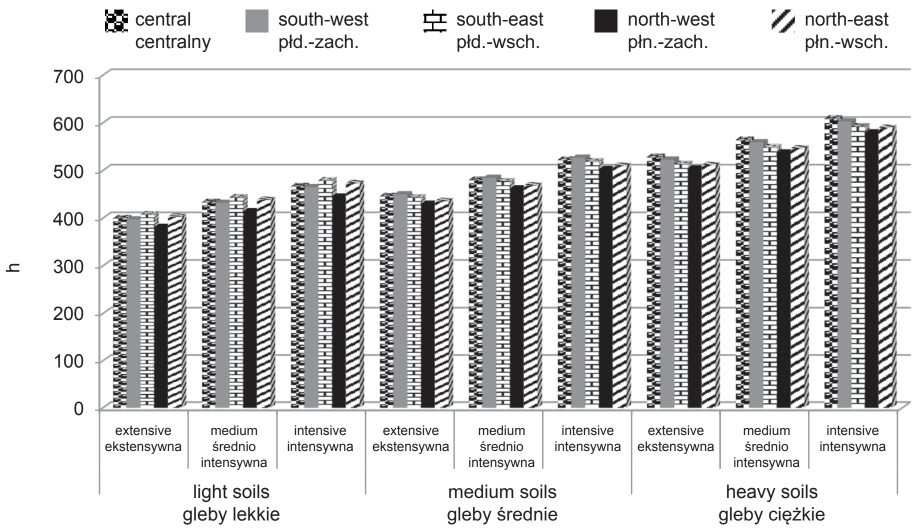


**Fig. 7.** Use of tractors on model farms with 130 ha of farmland
Source: own elaboration.
**Rys. 7.** Wykorzystanie ciągników w modelowych gospodarstwach o powierzchni 130 ha UR
Źródło: opracowanie własne.

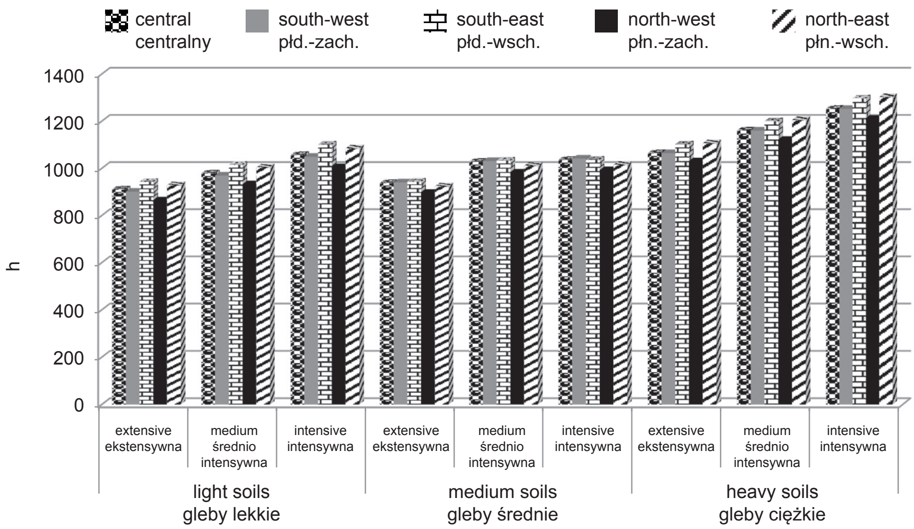


**Fig. 8.** Use of tractors on model farms with 600 ha of farmland
Source: own elaboration.
**Rys. 8.** Wykorzystanie ciągników w modelowych gospodarstwach o powierzchni 600 ha UR
Źródło: opracowanie własne.

silage crops the use of tractors on light soils is on average higher than on medium soils and it ranges from 860 h to 1080 h a year, whereas it ranges from 895 h to 1040 h on medium soils. The use of tractors on heavy soils was a highest and ranges from 1030 to 1300 h.

In all types of farms the lowest use of tractors is observed in the north-western macroregion, whereas the

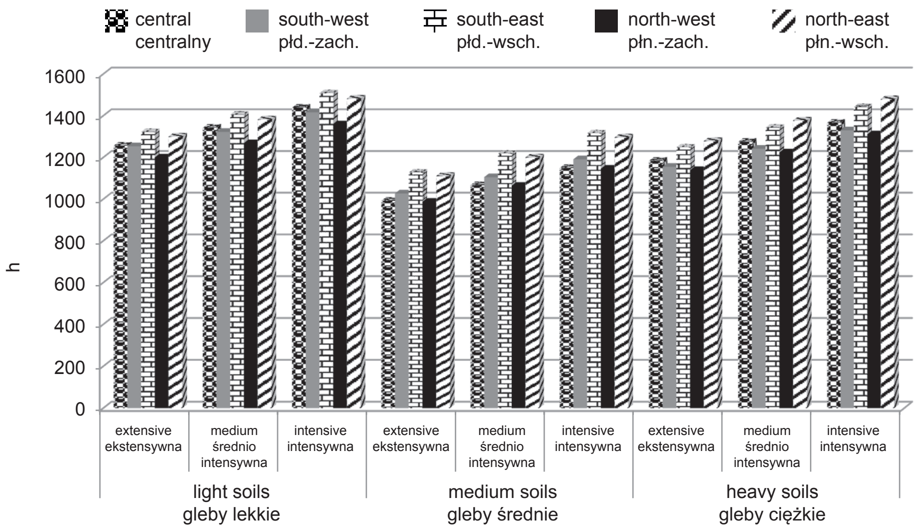


**Fig. 9.** Use of tractors on model farms with 1500 ha of farmland
Source: own elaboration.
**Rys. 9.** Wykorzystanie ciągników w modelowych gospodarstwach o powierzchni 1500 ha UR
Źródło: opracowanie własne.

highest use can be observed in the south-eastern macroregion. There are considerable differences between those regions, because they range from 4.9% to 9.6%, depending on the farm type.

The lowest use of tractors on the largest farms is also observed on medium soils, whereas the best use can be seen on light soils. This chiefly results from the fact that there is high outlay on the transport of silage to biogas plants, which is done with farmers' own equipment, whereas cereals and beets are sold by means of external transport. The use of tractors on medium soils ranges from 990 h to 1310 h, whereas on light soils it ranges from 1200 h to 1510 h. The full wear of a tractor working 12,000 h will be possible after 8–12 years. As far as tractors with very powerful engines are concerned, where the expected use reaches 10,000 h, the equipment could be exchanged as soon as after 7–10 years. Similarly to the farms with 600 ha of farmland, the lowest use of tractors can be observed in the north-western macroregion, whereas the highest use can be observed in the south-eastern macroregion, except for heavy soils, where the highest use can be seen in the north-eastern macroregion. However, there are the greatest disproportions between individual macroregions in this farm type, because they range from 10.1% to 14.8%.

## CONCLUSIONS

The analysis led to the following conclusions:

1. There is relatively high diversification in the yield between the macroregions. The measurement with the synthetic yield volume index gave the value of 9–14%.
2. The use of tractors was higher along with the farm area. When the farm area was the same, the use of tractors mostly depended on the soil quality and production intensity.
3. Regional differences in the use of tractors increased along with the farm area. On the smallest farms the tractor working time in the regions with the lowest use of tractors was 4.7–5.7% shorter than in the regions with the highest use of tractors in a particular farm model. On the other hand, these differences ranged from 10.1% to 14.7% on the largest farms.
4. A large share of crops for biogas leads to the situation where it takes 20–30 years of work for tractors to achieve full wear of 12,000 hours on farms with 130 ha of farmland, whereas it takes only 8–14 years on farms

with 600 and 1500 ha of farmland and in consequence, the costs of production can be optimized.

5. The assumption that farms will use their own means of transport to deliver silage to biogas plants considerably improved the use of tractors and trailers, because this work takes from 15 to 30% of the tractor working time.

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# REGIONALNA ANALIZA WYKORZYSTANIA CIĄGNIKÓW W MODELOWYCH GOSPODARSTWACH ROLNYCH PRODUKUJĄCYCH ROŚLINY ENERGETYCZNE

**Streszczenie.** Produkcja biomasy może być prowadzona na terenie całego kraju na powierzchni od 1,0 do 4,5 mln ha, ale uwarunkowania przyrodnicze i ekonomiczne w różnych regionach znacząco się różnią. Wpływa to na poziom osiąganych plonów, a także na wykorzystanie maszyn, głównie do zbioru i transportu płodów rolnych. Celem pracy jest ocena wykorzystania ciągników w modelowych gospodarstwach rolnych różnej wielkości, o zróżnicowanej intensywności produkcji i jakości gleb, na których uprawia się rośliny energetyczne. Zostały one opracowane dla pięciu makroregionów w Polsce. Poprawie wykorzystania ciągników sprzyjały zwiększanie powierzchni gospodarstw, lepsza jakość gleb oraz wyższy poziom intensywności produkcji. Poziom wykorzystania ciągników w gospodarstwach o powierzchni 15 i 35 ha jest zbyt niski, dlatego też powinny one korzystać z maszyn używanych. Przy 130 ha UR rolnych poziom nadal jest dość niski, ale pozwala po 30 latach w pełni wykorzystać ciągnik. Właściwe wykorzystanie daje dopiero areał 600 i 1500 ha UR. Wraz ze zwiększaniem się powierzchni modelowych gospodarstw występowały także coraz większe względne różnice w regionalnym poziomie wykorzystania ciągników.

**Słowa kluczowe:** rośliny energetyczne, modele, regiony, nakłady, ciągniki

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