The Input of Human Labour, Tractive Force and Energy Consumption in Model Technologies of Energy Crop Production

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Abstract

This study was an analysis of the input of human labour, tractive force and energy consumption in the model technologies of production of winter wheat, winter triticale, winter rye and sugar beets grown for bioethanol as well as reed canary grass, Virginia mallow, sorgo and maize grown for biogas in farms of different area, soil quality and intensity levels of production.

Key words: energy crop production, human labour, tractive force, energy consumption, model technologies

Introduction

The continuously growing pressure on the increase in the share of energy from renewable sources causes a growing demand for agricultural raw materials. Typical energy crops, such as energy willow or Virginia mallow, are of primary importance. There is also search for other energy crops, where the cost of establishment and liquidation of a plantation is low (e.g. reed canary grass) or for annual plants (e.g. sorgo). Typical crops, such as maize, cereals, sugar beets and others are also used for energy purposes.

The effectiveness of power generation is a very important aspect of power generation. It is understood as the ratio between the amount of energy acquired from an agricultural product and the amount of energy consumed in the process of energy production. The amount of power generated chiefly depends on the crops and energy content in an agricultural raw material. The amount of energy consumed consists of the energy consumed for the production of fertilizers, crop protection products, seeds, the input of machine tractive force and human labour. The latter two factors are the most important. Therefore, the aim of the study was an analysis of the input of human labour, tractive force and energy consumption in the model technologies of production of winter wheat, winter triticale, winter rye and sugar beets grown for bioethanol as well as reed canary grass, Virginia mallow, sorgo and maize grown for biogas.

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.01.03.01-00-132/08-00, 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:

- 15 ha of farmland,
- 35 ha of farmland,
- 150 ha of farmland,
- 600 ha of farmland
- 1500 ha of farmland.

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 protection:

- 40, 80 and 120 kg N for cereals, sorgo and reed canary grass,
- 80, 120 and 160 kg N for maize and sugar beets.

The assumption was that on a model farm the area under all crops was similar. In order to make sure that the data were fully comparable the process charts included all the scope of works, i.e. the transport of means of production to the farm, field work related with soil cultivation, plant care, protection, harvesting, transport to the economic centre and transport to the distillery (maize for grain, winter wheat, triticale and rye) or biogas plant (sugar beets, maize for silage, sorgo, reed canary grass, Virginia mallow). The assumption was that the processing plants were located at a distance of about 25 km away from the farm.

Results

Input of human labour and tractive force per area unit

The input of human labour and tractive force are strongly dependent upon the degree of mechanisation, the size and efficiency of equipment used on the farm. An increase in the size of a farm favours the purchase of larger and more efficient machinery, which results in reduced workload per head. This process can also be observed on the model farms under study.

As far as the crops for biogas are concerned, the input of human labour per 1 ha ranged from 28.3 h*ha^{-1} to 39.4 h*ha^{-1} on the farms which were not larger than 20 ha, whereas on the largest farms the input of human labour per 1 ha ranged from 12.1 h*ha^{-1} to 16.7 h*ha^{-1} (Fig. 1). There were similar tendencies observed in the tractive force (chiefly tractors), because on the smallest farms the input ranged from 23.1 h*ha^{-1} to 32.0 h*ha^{-1}, whereas on the largest farms the input ranged from 9.4 h*ha^{-1} to 12.5 h*ha^{-1} (Fig. 2).

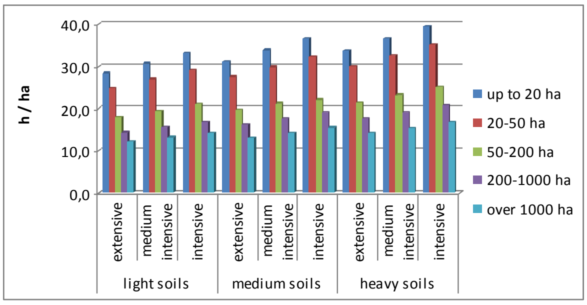

Fig. 1. The input of human labour per 1 ha of silage crops
Source: own calculation

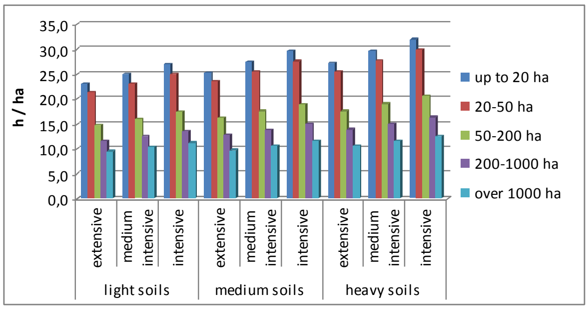

Fig. 2. The input of tractive force per 1 ha of silage crops
Source: own calculation

As far as the cereals are concerned, the input of human and mechanical labour was lower, chiefly because the amount of transported crops was lower. However, the tendencies were similar. The input of human labour per 1 ha ranged from 23.2 h*ha^{-1} to 30.4 h*ha^{-1} on the farms which were not larger than 20 ha, whereas on the largest farms the input of human labour per 1 ha ranged from 4.6 h*ha^{-1} to 5.8 h*ha^{-1} (Fig. 3). As far as the tractive force (chiefly tractors) is concerned, there were similar tendencies, because on the smallest farms the input ranged from 15.8 h*ha^{-1} to 20.7 h*ha^{-1}, whereas on the largest farms the input ranged from 3.3 h*ha^{-1} to 4.2 h*ha^{-1} (Fig. 4).

The intensity of production and quality of soils also have considerable influence on the input level. They contributed to considerable disproportions between the farms of the same size. The intensification of production involves the intensification of plant protection, which requires more treatment and the application of larger amounts of mineral fertilisers. The effect was higher yield. As resulted from the analysis, this led to higher input of logistic works, which were chiefly related with the transport of increased amounts of products. There is about an 8% difference in the input level between the medium-intensive and extensive technologies for the silage crops and cereals. There is a similar decrease in the input between the medium-intensive and intensive farming technologies, i.e. 8% for the silage crops and 5-6% for the cereals. As a result, the input of human and mechanical labour per area unit is lower in intensive production than in extensive production. The difference is about 17% for the silage crops and 15% for the cereals.

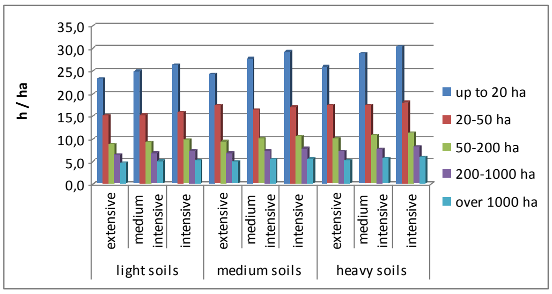

Fig. 3. The input of human labour per 1 ha of cereals
Source: own calculation

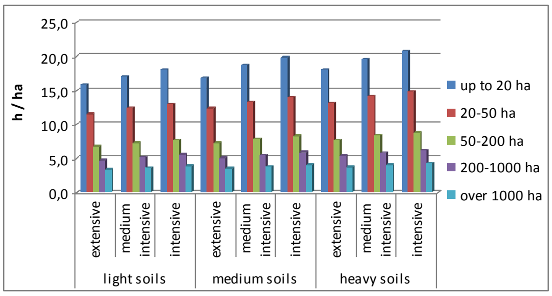

Fig. 4. The input of tractive force per 1 ha of cereals
Source: own calculation

There are even greater input disproportions on soils with different compaction. Soil treatment (post-harvest cultivation, tillage, sowing) can be done much more quickly on poor soils, which have low productive quality because of the high content of sandy particles in them. It is much more time-consuming to carry out soil treatment on heavy soils with high content of clay and loam fractions despite the use of more powerful tractors. It is necessary to carry out more cultivation treatment especially in dry seasons. Apart from that, a higher yield on heavy soils extends the harvest time and causes the need to transport larger masses of farm products. In comparison with light soils the input of human labour on heavy soils was about 20% higher for the silage crops and about 14% higher for the cereals. The input of tractive force was about 18% and 13% higher, respectively.

Human labour and tractive force input per unit of crop harvested

The intensification of production and improvement in soil quality result in higher yield. In consequence, there is a decrease in the input per 1 tonne of crop harvested. In comparison with extensive production the average input of human and mechanical labour in intensive production was about 4% lower for the silage crops and about 8% lower for the cereals (Fig. 5-8).

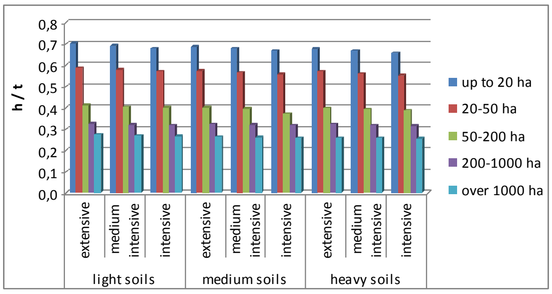

Fig. 5. The input of human labour per 1 tonne of silage crops harvested
Source: own calculation

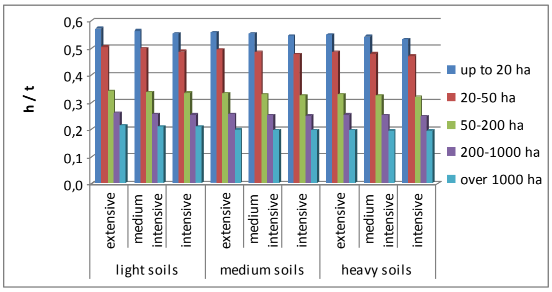

Fig. 6. The input of tractive force per 1 tonne of silage crops harvested
Source: own calculation

There was even greater disproportion in input on farms of different areas. In order to produce 1 tonne of green forage the smallest farms must use from 0.66 to 0.70 $h*t^{-1}$ of human labour, whereas the farms which are larger than 1000 ha must use from 0.25 to 0.27 $h*t^{-1}$ of human labour. As far as tractive force is concerned, the input of the smallest farms ranged from 0.53 to 0.57 $h*t^{-1}$, whereas the input of the largest farms ranged from 0.19 to 0.21 $h*t^{-1}$. The input of the largest farms was as much as about 62-64% lower than the input of the smallest farms. The difference in the input per 1 ha was 58-62%.

As far as the cereals are concerned, in order to produce 1 tonne of grain it is necessary to use 5.7–6.4 h of human labour on the smallest farms and 0.90-1.04 h on the largest farms. It is necessary to consume 3.8–4.3 h and 0.66–0.77 h of tractive force, respectively. The difference in the amount of input reaches about 80% per area unit and about 83% per 1 tonne of crops harvested.

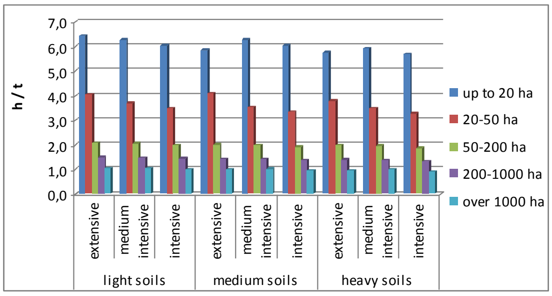

Fig. 7. The input of human labour per 1 tonne of cereals harvested
Source: own calculation

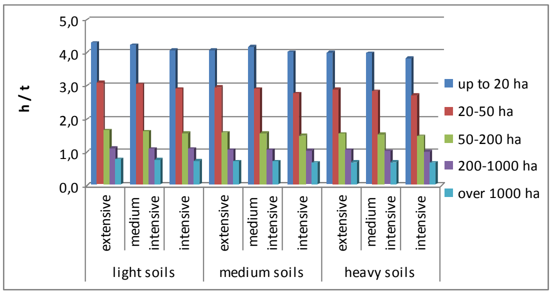

Fig. 8. The input of tractive force per 1 tonne of cereals harvested
Source: own calculation

Energy input

The energy input per 1 ha of the silage crops ranged from 1483 $kWh*ha^{-1}$ to 2386 $kWh*ha^{-1}$ (Fig. 9). The input increased along with an increase in the farm area, intensity level and soil quality. When the energy input was calculated per 1 tonne of green forage produced, it proved to be much less varied – it ranged from 34.6 $kWh*t^{-1}$ to 37.9 $kWh*t^{-1}$ (Fig. 10). On the smallest farms the energy input per 1 ha was about 12% lower than on the largest farms, but this difference decreased to about 2% when the energy input per 1 tonne of harvested crops was calculated. There was similar variability between light and heavy soils and between extensive and intensive production technologies. When the difference was calculated per 1 ha, on average it showed the disadvantage of about 17-20% on heavy soils and in intensive production. However, when the difference was calculated per 1 tonne of crops harvested, there was about 2% disadvantage of light soils and extensive production technology.

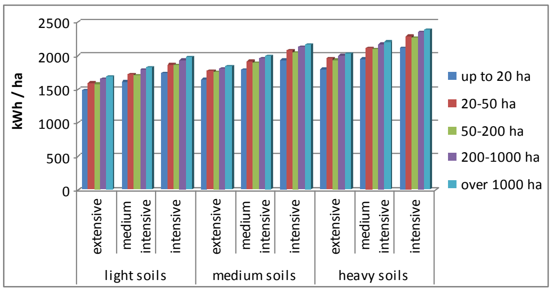

Fig. 9. The energy input per 1 ha of silage crops harvested
Source: own calculation

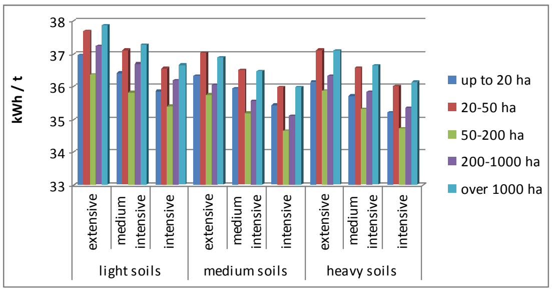

Fig. 10. The energy input per 1 tonne of silage crops harvested
Source: own calculation

As far as the cereals are concerned, the energy input ranged from 666 kWh*ha^{-1} to 1014 kWh*ha^{-1} (Fig. 11) and from 131 kWh*t^{-1} to 208 kWh*t^{-1} (Fig. 12). The input of human and mechanical labour was similar regardless of the farm area (except for the largest farms, where the input was about 10% lower). However, when the input per 1 tonne of harvested crops was calculated, the scale effect was clearly noticeable. An increase in the production intensity and soil quality results in a higher energy input of about 16% and 10%, respectively. However, when the input per 1 tonne of harvested crops was calculated, it proved to be about 4% and 3% lower, respectively.

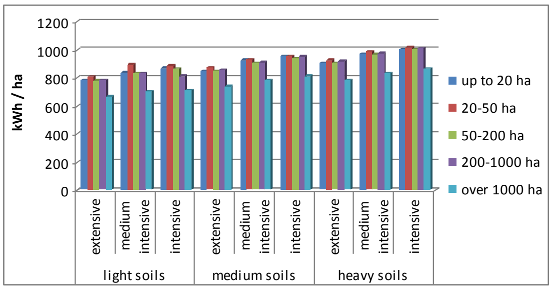

Fig. 11. The energy input per 1 ha of cereals harvested
Source: own calculation

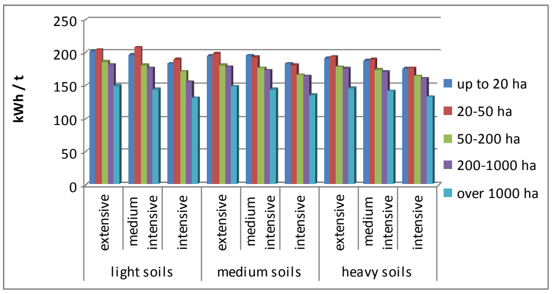

Fig. 12. The energy input per 1 tonne of cereals harvested
Source: own calculation

The level of energy input was similar to the level of input observed in other studies on farms in Greater Poland Voivodeship (see: Pepliński et al., 2012, Baum et al., 2011).

Conclusions

The analysis proved that:
- the increase in the area of the farm results in a decrease in the input of human labour and tractive force, expressed with hours of labour per crop area unit and per tonne of production;
- the energy input expressed with kWh per area unit and per tonne of production are at a similar level regardless of the farm area because more powerful tractors are used;
- the increase in production intensity increased the input of human labour, tractive force and energy per 1 ha, but the input per tonne of agricultural raw material produced was only slightly lower;
- the cultivation of crops on heavier soils increases the input under analysis by a few per cent. However, higher yield generated on heavy soils causes that the input under analysis per yield is 3-5% lower than on light soils.

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