ECONOMIC EVALUATION OF COMBINED SOIL PREPERATION, FERTILIZING AND SEEDING MACHINERY USED IN GRAIN PRODUCTION PROCESS

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Abstract. The aim is to compare several soil preparations (that include soil preparation, fertilizing and seeding) technologies: single operation, power-harrow seeder, and direct seeder technologies. This comparison is done including labour costs, machinery depreciation and maintenance costs and fuel costs. The actual fertilizer costs have not been taken into consideration. To proceed successfully with calculations, an economic model of a grain production farm has been created, where it is possible to compare different types of technologies and include any number of agricultural operations in the calculations. The model uses a sophisticated algorithm to determine soil preparation costs at any given land area, calculating the machines' efficiency at any given moment and also giving the possibility to calculate the total number of hours needed to prepare one ha of land for seeding and to seed. The results are compared in the form of a line chart and a data table. Based on these results, each farmer can compare his current technology and machinery to a new different setup of machinery or a completely new technology. It is also possible to see what the land increase limit using the current technology is, because the model also shows how well the current technology complies with the previously set up agro-terms. Therefore, it is possible to plan for the future improvements (new machinery, increase of the land area) and to compare if a technology change is more cost effective.
Key words: combined agricultural machinery, soil preparation efficiency, economic substantiation of the soil preparation technology.
JEL code: Q12

Introduction

As in every business, in agriculture the main goal is to reach the maximum possible profit with the least resources used. There are a few possibilities to increase the profits of a grain farm: you can increase the productivity, therefore increasing the income; you can upgrade machinery efficiency, therefore lowering the running costs of the machinery; and you can choose the most suitable technology for your farm and your needs. The best solution is for each farm owner to decide, however by using the correct agricultural technology, the farm can both increase the income and lower the costs

The main tasks of the soil preparation are to optimize soil physical properties, provide the best conditions for the seed embedding, germination and growing, weed leftovers and fertilizer embedding, weed, and insect combating. The aim of this research is to find the optimal soil preparation method for the given land area and available machinery that is the most cost effective and the least time consuming.

By analyzing the traditional technologies used in grain farms, it has been noted that soil preparation that includes weed control, fertilization, tillage, ploughing, and levelling is done separately with simple agricultural machinery. Due to this fact, the number of passes the tractor has to make on the field is very large, sometimes, if the agricultural conditions are bad, reaching more than five times. That leads to soil compaction, which influences the productivity of the field and can greatly reduce the crop yield (up to 20% yield reduction in places where the soil has been compacted the most).

Using of simple agricultural machinery can also increase tractors' fuel consumption. While using many agricultural machines, it is necessary to switch among them and also to carry each of them to the working field individually, so there is a lot of transport work between the operations which increases the fuel consumption per hectare. Due to many passes that a tractor has made on the field, there will be places with high soil compaction degree. Therefore, this soil will increase much more resistance than a normal soil, which will increase the tractors' fuel consumption when working in these areas.

Every type of agricultural work is limited to several days (agro-terms) when it needs to be done, and with a limited number of tractors available there is a risk that the agro-terms will not be met, which can lead to yield decreases.

The soil preparation is a very important part of the grain production process as it is essential to maximize the possible yields. The mechanical soil preparation aids better water and air circulation and fertilizer dissolving in the ground, which can boost the grain yield. There are several ways to improve agricultural machinery of soil preparation, and the major ones are related to increasing their work efficiency, lowering machineries' resistance and power needed to operate it, thus reducing the fuel consumption of the tractor and increasing and combining several machines into one and reducing the passes needed to prepare the seedbed.

There are several combined machinery variations that can combine the following operations: tillage, ploughing, fertilizing, seeding, and levelling. The simplest combined

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Table 1

The technologies chosen with corresponding machinery used

Operation	Single operation technology	Power-harrow seeder technology	Direct seeder technology
Tractor power, hp	120	135	135
Ploughing	Four-body reversible plough	Four-body reversible plough with packomat (tilling equipment)	Four-body reversible plough – used every fourth year
Tilling	Cultivator, 6.0 meter working width		Direct seeder, 4.0 meter working width
Fertilizer spreading	Fertilizer spreader, 12.0 meter working width	Fertilizer spreader, 12.0 meter working width	
Seeding	Mechanical seeder, 4.0 meter working width	Power-harrow seeder, 4.0 meter working width	

machinery consists of two types of machinery, e.g. ploughing and tilling, tilling and seeding.

Starting from the year 2007, with the help of the European Union funding the number of combined machinery that has been bought in Latvia has increased and has led to more productive farming with increased yields and lower running costs. The need for combined machinery is based on the land area, crop types, technology used, soil, and climate. Often the climate is the principle reason to change agricultural technology and switch to combined machinery, thus lowering the risk of not meeting the agro-terms due to extreme weather conditions.

Research results and discussion

The research regarding soil tillage and direct and combined seeding machinery technologies was performed within the years 1999 to 2001. However, it concentrated on the grain yield and quality parameters, and the main conclusions were that at least the same grain yield can be achieved using combined seeding machinery as with traditional seeding methods and reducing the seeding costs at the same time. Moreover, the field conditions were considered as good, therefore, it did not affect the final grain yield very significantly.[1]

In this research, three different technologies were chosen: single operation, power-harrow seeder and direct seeder technology. The single operation technology is based on the principle that every agricultural operation has to be done with separate agricultural machinery. The power-harrow seeder technology uses a combined seeder with a power-harrow. The direct seeder technology uses an advanced seeder that combines seedbed preparation, seeding fertilizing and levelling operations. These technologies include the following operations and corresponding machinery. To determine the total costs for using each soil preparation technology, the authors used an algorithm, which incorporates the following costs: labour costs, depreciation costs, running and maintenance costs, and fuel costs. To calculate the depreciation costs for a tractor, a yearly workload of 1200 motor-hours has been used (which includes all other operations not connected directly to the soil preparation, fertilizing and seeding, which include, e.g. transport, road maintenance, and forestry works). To calculate the costs for all other agricultural machinery, a yearly workload has been calculated based on the machinery working width, working speed, and land area. All costs are calculated per hectare. This algorithm incorporates all variables present.

$$TC = \sum_{i=1}^{n} TC_i \quad (1)$$

$$TC_i = LC + DC_t + DC_m + MC + FC \quad (2)$$

$$LC = \frac{Hourly\ rate}{WE} \quad (3)$$

$$DC_t = \frac{PC_t * MWL}{YWL * DP * WE} \quad (4)$$

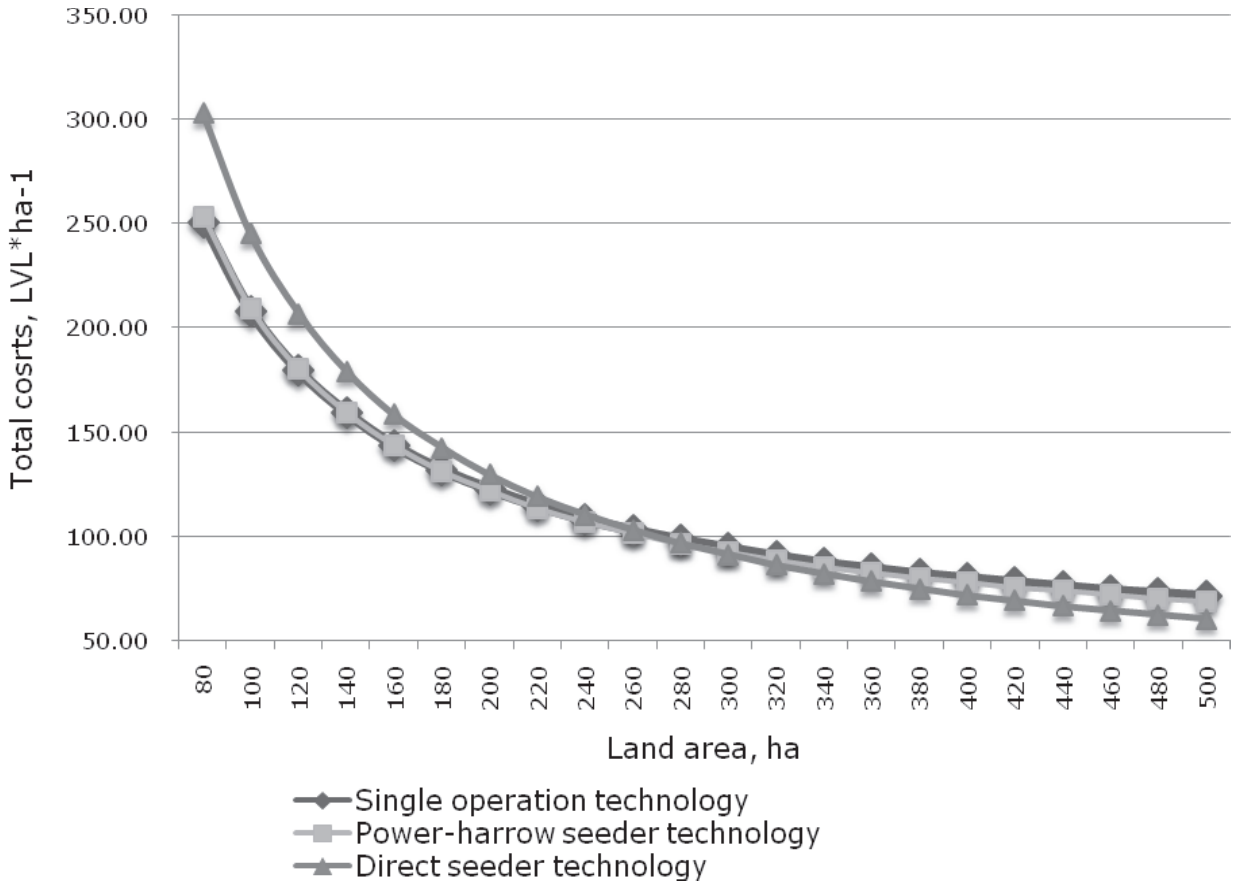
$$DC_m = \frac{PC_m}{DP * MWL * WE} \quad (5)$$

$$MC = \frac{YMC}{WE} \quad (6)$$

$$FC = \frac{C * P_m * FP}{FD * 1000} \quad (7)$$

*TC – total costs of soil preparation, fertilizing and seeding, LVL*ha^{-1}*
*TCi – total costs of one agricultural operation, LVL*ha^{-1}*
i – operation (e.g. tilling, ploughing etc.)
*LC – labour costs, LVL*ha^{-1}*
*DCt – depreciation costs, tractor, LVL*ha^{-1}*
*DCm – depreciation costs, machinery, LVL*ha^{-1}*
*MC – maintenance costs, LVL*ha^{-1}*
*FC – fuel costs, LVL*ha^{-1}*
*Hourly rate – hourly rate for the labour costs, LVL*h^{-1}*
*WE – work efficiency of the machinery for doing the "i" operation, ha*h^{-1}*
PCt – purchase price of the tractor, LVL
PCm – purchase price of the machinery, LVL
MWL – machinery working load, h
YWL – yearly working load of the tractor, h
DP – depreciation period, years

[1] Influence of soil tillage… (2003)



Source: authors' calculations based on the developed economic model of grain production process

Fig. 1. **Total costs of soil preparation, fertilizing and seeding dependent on the land area workable**

C – fuel consumption of the tractor, kg(kW*h)$^{-1}$*
Pm – Required power for the machinery, kW
*FD – density of fuel, kg*m^{3} $^{-1}$*
*FP – fuel price, LVL*l^{-1}*
*YMC – yearly maintenance costs, LVL*h^{-1}.*

After the data input into the model, the results showed that every technology has the lowest costs at a certain land area that has to be worked, Moreover, the land area at which the farm should choose another technology very much depends on machinery cost because a great deal of all the costs are the machinery depreciation costs. This model uses only new machinery (made in the European Union) average prices. The machinery depreciation costs would be lower if already existing machinery is used. It is also possible to buy used machinery and lower the technology switch costs. Consequently, as stated before the prices of new agricultural machinery were used in this calculation to show an adequate comparison of the three technologies.

The figure shows that the lowest total costs can be achieved by working with the single operation technology on the land area up to 145 ha. The power-harrow seeder technology is the most cost effective from 145 ha to 280 ha. Whereas, for land areas starting from 280 ha a farmer should choose the direct seeder technology as it is the most effective technology for large field areas. The costs difference between single operation and power-harrow seeder technologies cannot be considered as significant.

When searching for the best technology to be used, the agro-terms have to be taken into consideration. All the three technologies have one common agricultural operation, and that is seeding, so it is best to use it for comparison of the agro-term abidance. If the optimal agro-term for seeding is eight days, and we propose that there are 10 hours of work each day, then the maximum workable area for each technology (using all the agricultural machinery that was mentioned before) is as follows:

— single operation technology – 198 ha;
— power-harrow seeder technology – 216 ha;
— direct seeder technology – 308 ha.

If this land area is exceeded, there is a risk to loose potential grain yield 0.05 t/ha for every day exceeding the agro-terms.

Therefore, taking into consideration the total costs and agro-terms the optimum usable land area for each technology with its corresponding equipment would be:

— single operation technology: 0 – 145 ha;
— power-harrow seeder technology: 145 – 216 ha;
— direct seeder technology: 280 – 308 ha.

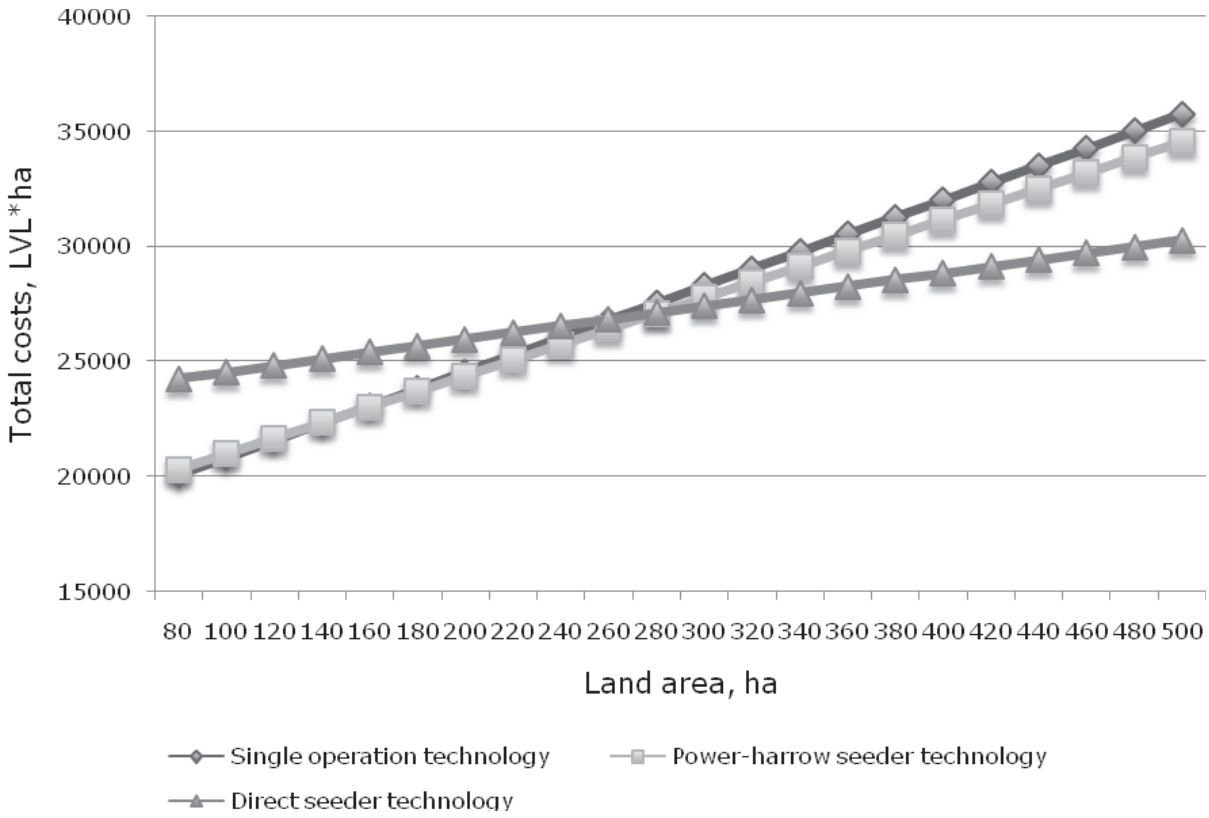
When calculating the total costs for a certain type agricultural operations, the results can be given differently, either per one ha of the land, or per one grain

Table 2

Corresponding grain growing technologies for seedbed preparation, fertilizing and seeding technologies with their average yields

	Single operation technology	Power-harrow seeder technology	Direct seeder technology
Corresponding grain production technology	Traditional technology	Combined technology	Intensive technology
Average grain yield per ha, t*ha^{-1}	3.5	4.5	6

Source: authors' construction based on Optimization of grain...(2012)



Source: authors' calculations based on the developed economic model of grain production process

Fig. 2. **Farms' total costs of soil preparation, fertilizing and seeding based on the land area**

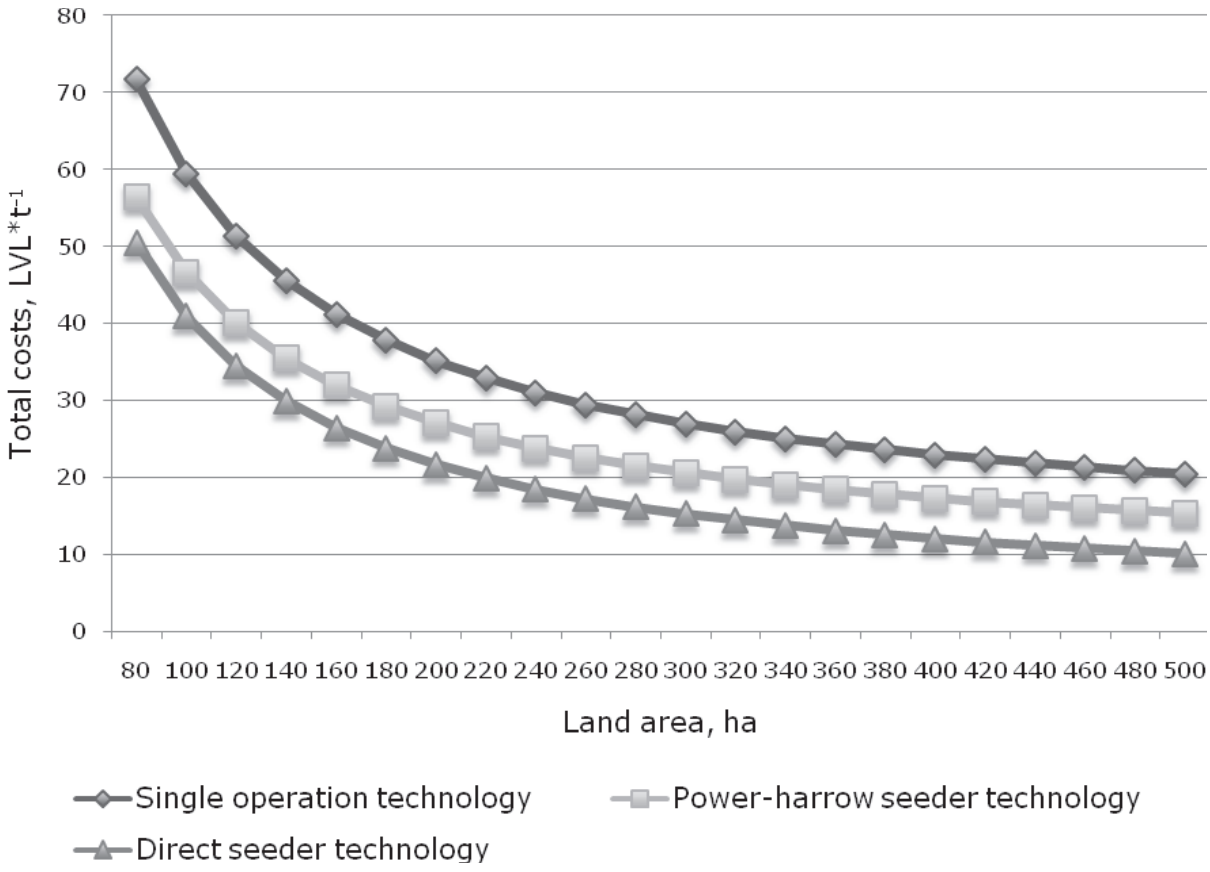
ton produced. The three soil preparation, fertilizing and seeding technologies used in this research correspond to the three technologies of grain production, which use different amounts of fertilizers, herbicides, pesticides, and fungicides. The corresponding technologies and their average grain yield are given in the table.

Based on the farms total grain yield and total costs of seedbed preparation, fertilizing, and seeding; it is possible to calculate each technology's corresponding costs based on one grain ton produced by using particular technology.

The total costs per hectare and total costs of all operations share the same results as the lowest costs for the single operation technology are when the land area does not exceed 45 ha. The power-harrow seeder technology is the most cost effective within 145 to 280 ha, whereas for land areas starting from 280 ha the lowest total costs are reached by working with the direct seeder technology.

Finding the most suitable technology can be aided with knowing which technology would produce the lowest costs per grain ton produced. However, these are only the running and operating costs, not including the seeds, fertilizers, herbicides, fungicides, and pesticides costs, which differ for each technology. The single operation technology would need less fertilizers, herbicides, pesticides and fungicides because of the higher mechanical degree of soil preparation, and the direct seeder technology would need them much more due to the low soil mechanical preparation and the need to combat weeds with the use of chemicals.

If only the operating and running costs are taken into consideration, it is obvious that the most cost effective technology would be the direct seeding technology



Source: authors' calculations based on the developed economic model of grain production process

Fig. 3. **Total costs of soil preparation, fertilizing and seeding for one ton of grain produced based on the land area**

because of the much higher potential grain yields that can be achieved with this technology. In addition, this technology has fewer risks not to meet the agro-terms because it has a lower number of operations that has to be done to reach the optimum grain production conditions of the soil, fertilize it and seed.

No material costs (fertilizers, fungicides, herbicides, and pesticides) have been taken into consideration in this calculation. To reach an average yield of six t/ha^{*-1} using the direct seeder technology, it is necessary to use a lot of chemical substances to enrich the soil and to combat weeds, fungus, bacteria, and insects. With time, this intensive use of chemical substances degrades the soil, and that is why at least once in every four years the soil must be ploughed to restore its natural condition.

Qualified labour has been a problem in Latvia in the past five years starting from 2007 due to workforce migration to the other European Union countries, and many farms are struggling for finding new workers. For this reason, it is also very important how many hours have to be spent to prepare the soil for seeding and seed for each technology. The comparison between the three technologies is made in h*ha^{-1}:

— single operation technology – 1.55 h*ha^{-1};
— power-harrow seeder technology – 1.32 h*ha^{-1};
— direct seeder technology – 0.47 h*ha^{-1};

It is clear that the less labour intensive is the direct seeder technology, followed by the power-harrow seeder and single operation technology, which is the most labour intensive. In fact, the direct seeder technology requires 3.3 times less work than the single operation technology, and due to the great lack of qualified workforce and increasing labour costs it is becoming more efficient to use a technology that requires less work.

Conclusions, proposals, recommendations

1. According to the economic model of farms' grain production, the most cost effective soil preparation, fertilizing and seeding technology is the direct seeding technology for land areas exceeding 280 ha, and the power-harrow seeder technology is the most cost effective for land areas from 145 to 280 ha. Whereas, if the land area is no more than 145 ha, the least expensive way to prepare it and seed would be using the single operation technology.
2. If the agro-terms are taken into consideration, the most effective operation range for each technology is: single operation technology: 0 – 145 ha; power-harrow seeder technology: 145 – 216 ha; direct seeder technology: 280 – 308 ha.

3. Using the direct seeder technology is the a less labour intensive solution for the farm requiring only 0.47 working hours per one hectare of land, which is 3.3 times less than it is required for the single operation technology.

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