WORKING TIME, FUEL CONSUMPTION AND ECONOMIC ANALYSIS OF DIFFERENT TILLAGE AND SOWING SYSTEMS IN LITHUANIA

Egidijus Sarauskis[1], Sidona Buragiene[1], Kestutis Romaneckas[1], Antanas Sakalauskas[1], Algirdas Jasinskas[1], Edvardas Vaiciukevicius[1], Davut Karayel[2]
[1]Aleksandras Stulginskis University, Lithuania; [2]Akdeniz University, Turkey
egidijus.sarauskis@asu.lt

Abstract. The article presents economic assessment of the working time, fuel consumption, and cost substantiation of conventional, reduced, zero tillage, and crop sowing systems for 2, 10, and 20 ha farms. The economic analysis of the working time, fuel consumption, and costs under Lithuanian conditions was performed for six different tillage and sowing systems. In CT1 system, deep ploughing with a non-reversible plough, disc cultivation, and conventional sowing are performed; in CT2 – deep ploughing with a reversible plough, combined tine cultivation, and conventional sowing; RT1 – deep chiselling, disc cultivation, and mulch sowing; in RT2 – stubble disc cultivation, combined tine cultivation, and mulch sowing; in RT3 – rotary tillage and mulch sowing; NT – zero tillage (direct sowing). On the basis of the analysis of the assessment of different tillage and sowing systems, it was established that the biggest consumption of working time is in the case of application of conventional tillage and sowing systems (CT1 and CT2). In the case of application of reduced tillage systems (RTI, RT2, and RT3), 0.4 to 1.3 $h \cdot ha^{-1}$ of the working time compared to conventional systems can be saved, and application of zero tillage systems allows saving 1.5 to 1.9 $h \cdot ha^{-1}$ of the working time compared to conventional systems. In conventional tillage and sowing systems, the fuel consumption is more than 5 times higher compared to zero tillage systems, and in reduced tillage and sowing systems, the fuel consumption exceeds that in zero tillage systems by 2.5 to 4.8 times. If the farm size is increased to 20 ha, the costs in different tillage and sowing systems decrease by 12 to 27 % per hectare.

Keywords: tillage systems, sowing, working time, fuel consumption, economic analysis.

Introduction

Proper selection of the tillage system is highly dependent on the climatic conditions, properties of soil, available fleet of the tillage machinery, plant species, and other factors. Each tillage system has its own advantages and disadvantages. In the case of application of the conventional tillage system, there is a higher probability of obtaining bigger crop yield and better quality thereof; however, because of low working capacity of the tillage machinery and need for high-capacity tractors, costs of such tillage system will be the highest. In the case of application of reduced, minimum, strip, or zero tillage systems, the crop yield and quality may be expected to be poorer; however, the costs for tillage will be lower and the impact on the environment, soil, and biodiversity will be more positive. Morris et al. [1] presented the relation between the tillage systems and various performance indicators visually (Fig. 1).

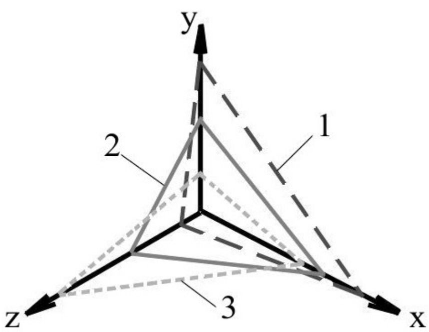

Fig. 1. **Relation between performance indicators (x, y, z) and different tillage systems (1, 2, 3):** x – crop yield and quality; y – tillage systems costs; z – soil, environmental and biodiversity benefits; 1 – conventional tillage; 2 – reduced tillage; 3 – zero tillage (prepared according to [1])

During the course of time, the use of reduced and zero tillage system has been rapidly expanding. Derpsch et al. [2] claim that at present, the no-tillage system (synonymous of zero tillage farming or conservation agriculture) is applied at an area of around 111 million hectares. During the recent ten years, the annual increment in the use of this system amounts to 6 million ha per year. Most broadly, the no-tillage system is applied in the USA (26.5 million ha), Brazil (25.5 million ha), Argentina (19.7 million ha), Canada (13.5 million ha), Australia (12.0 million ha), etc. In Europe, areas of sowing into non-tilled soil have also been growing during the recent years. In the recent years, more than one million hectares are sowed according to these tillage and sowing technologies, mostly in Spain and France [2 and 3].

When selecting a tillage system, it is very important to establish the priorities for the goals to be achieved and the consequences that may occur in case of change in climatic conditions and properties of plant residues and soil. The main purposes of reduced tillage are to conserve environment and soil, to protect soil against wind and water erosion, to reduce levigation of the fertile soil layer, fertilisers, and pesticides into water reservoirs, to increase biodiversity, to reduce fuel consumption, to save working time, to reduce the self-cost of the cultivated agricultural products, etc. [4 – 8]. Another very important factor is that decreasing of tillage intensity can allow reducing the number of tillage technological operations and thus the number of tractor and tillage implement trips over soil. When performing several technological operations, up to 80 % of the whole soil surface is run over, while at the end of a field, at the turning point, one place is crossed several times. This causes densification of deeper-lying soil layers, and it becomes more difficult for moisture to reach the roots of plants. If conventional tillage is abandoned and reduced or zero tillage systems are applied, the tillage conditions change. Lots of non-embedded plant residues of crops remain on the surface of soil, and the upper soil layer can be harder compared to the soil treated using the conventional tillage method. Special tillage machinery, which can embed seeds into harder soils covered with plant residues, is required [9].

Scientists of many countries [4 – 7; 10] conducted various scientific studies of tillage and sowing systems, whereby they studied the impact of different tillage and sowing systems on the properties of soil, environment, consumption of fuel and consumption of working time, and productivity and self-cost of plants. Rusu at al. [10] claim that in the case of application of the reduced tillage system, the amount of water conserved in the layer at a soil depth of 0-50 cm is by 1 to 32 $m^2 \cdot ha^{-1}$ greater than that in the soil treated by the conventional tillage method. This is especially relevant in dry years, when the amount of precipitation is small and lack of moisture occurs.

Hernanz et al. [11] conducted long-term, 10 year long experimental studies with winter wheat, winter barley, and other plants. In terms of energy consumption, three different tillage systems were compared: conventional tillage (ploughing to a depth of up to 30 cm), minimum tillage (cultivation to a depth of 15 cm), and zero tillage. The results of the studies showed that taking into account the costs of machinery, fuel, seeds, fertilisers, and other costs incurred before harvesting, minimum and zero tillage for grain crops allow saving 7 to 11 % of the energy costs compared to conventional tillage.

At Mushaqar Agricultural Experiment Station, experimental studies were conducted in soils with three different levels of moisture content: dry (moisture content of soil 10.71 %), medium moist (19.55 %), and moist (31.47 %) [12]. The studies showed that fuel consumption for tillage is highly dependent on the design of the tillage machinery, depth of tillage, and moisture content of soil. It was established that the lowest fuel consumption was in the case of tilling medium moist (19.55 %) soil. Tilling with a mouldboard tillage implement, irrespective of the depth of tillage and moisture content of soil, was less economically effective than tilling with a disk tillage implement.

Lithourgidis et al. [8] claim that conservation tillage in Greece has many advantages compared to conventional tillage, it allows conserving environment and soil and saving costs for machinery, their repair and maintenance, and fuel. Backer et al. [4] believe that if tillage is fully abandoned, up to 80 % of the costs for fuel and 60 % of the working time spent for machinery repair and maintenance can be saved.

Scientists of the University of Dicle conducted studies of different tillage systems for sunflowers and established that in the case of direct sowing into non-tilled soil, the fuel consumption was 6.6 $l \cdot ha^{-1}$, and in the case of sowing into soil tilled by the conventional method, the fuel consumption was 33.5 $l \cdot ha^{-1}$ [13].

In Croatia, three different tillage and sowing technologies: conventional, reduced, and no-tillage, were analysed in energy aspects [14]. It was established that 48.13 ± 11.49 to 60.99 ± 15.23 $l \cdot ha^{-1}$ of fuel is consumed for tillage and sowing by the conventional method. When tilling soil by the reduced method instead of ploughing, the fuel consumption decreases by 1.5 to 2.0 times compared to the conventional technology. In the case of sowing into non-tilled soil, the fuel consumption is by 5 to 8 times lower than for the conventional technology.

The studies conducted by the Turkish scientists showed that application of the direct sowing method allows reducing the fuel consumption by around 6 times and saving of the working time by around 4 times compared to the conventional tillage and sowing technology. The yield was by approximately 400 $kg \cdot ha^{-1}$ bigger in the case of sowing into soil tilled by the conventional method [15].

In Italy, the energy balance of three technologies with different tillage intensity was studied. It was established that when the deep tillage (35 cm), minimum tillage (15 cm), and no-tillage technologies were compared, the highest positive energy balance was observed in the case of deep tillage [16]. Safa and Tabatabaeefar [17] analysed fuel consumption of operations of agricultural machinery working technologies when cultivating wheat in farms of different sizes. Depending on the farm size, the fuel consumption amounts to 75 to 121 $l \cdot ha^{-1}$ for tillage and 14.2 to 20.7 $l \cdot ha^{-1}$ for sowing.

In Lithuania, the following three tillage systems are used for the cultivation of grain crops most broadly: conventional, reduced, and zero tillage. In the conventional system, soil is ploughed with a reversible or non-reversible plough to a depth of 22 – 24 cm, tilled with a disk implement to a depth of 8 – 12 cm or combined cultivator to a depth of 5 – 8 cm, and sowed by the conventional method. Recently, an increasing number of farmers and agricultural companies apply the reduced tillage system. Such system in Lithuania is understood so that the main tillage with plough is not performed, and soil is tilled only using other tillage implements. In one case, it can be disc harrows; in another – cultivators with passive or rotary working parts; in a third case – deep tillage chisels. Combined tillage and sowing machines, which can both till soil and sow plant seeds in one trip, are used most frequently. Shallow ploughing (up to a depth of 15 cm), which allows reducing consumption of fuel and does not require tractors of such high capacity as in the case of conventional tillage, is also attributed to reduced tillage. In the no-tillage system, no tillage is performed and sowing is made directly into non-tilled soil [18 – 22].

In Lithuania, as well as in other Baltic countries where the climatic and economic conditions are quite similar, assessments of different tillage and sowing systems in energy and economic aspects are lacking. According to the Statistical Book of Lithuania 2011, the country had 199 913 farms, with small-size (up to 10 ha) farms accounting for 78.6 %. Therefore, analysis of tillage and sowing systems is performed for small-size farms with areas of 2, 10, and 20 ha.

The purpose of the study is to perform economic analysis of the working time, fuel consumption, and cost substantiation of conventional, reduced, and zero tillage and sowing systems used for the cultivation of grain crops in Lithuania.

Materials and methods

Economic and energy analysis of tillage and sowing systems was performed with six grain crops tillage and sowing systems used in Lithuania most broadly (Table 1). They include two conventional systems (CT1 and CT2), three reduced ones (RT1, RT2, and RT3), and one zero tillage system (NT). In the conventional tillage systems, ploughing with a non-reversible or reversible plough, pre-sowing tillage, and conventional sowing are performed. In reduced tillage systems, three different options are chosen. In the RT1 system, deep chiselling and pre-sowing hollow disc cultivation are performed; in RT2 – stubble disc cultivation and pre-sowing tine cultivation with a combined cultivator; in RT3 – only hollow tillage with a rotary cultivator is performed. In all the reduced tillage systems, plant residues are not embedded into soil completely, and a part of plant residues remains on the soil surface; this is why the mulch sowing system is used. Sowing into non-tilled soil (NT) is performed by the direct sowing method.

In order to calculate the working time, fuel consumption, and costs in the tillage and sowing systems, the working widths of the tillage and sowing machinery broadly used in Lithuania and power of tractors were chosen first of all. The parameters of the tillage and sowing machinery are determined for operation under normal conditions, i.e., in regular contour, medium hardness, non-stony, even relief areas with different sizes of 2 ha, 10 ha, and 20 ha. The direct and indirect costs were evaluated for the calculation of the costs of technological operations. The direct costs include the costs for upgrading, repair, and technical maintenance of the machinery, fuel and lubricants, and labour compensation.

Table 1

Characteristics of six different tillage and sowing systems

Tillage system	Primary tillage	Pre-sowing tillage	Sowing system
(CT1) Conventional	Deep ploughing with non-reversible plough	Disc cultivation	Conventional sowing
(CT2) Conventional	Deep ploughing with reversible plough	Combined tine cultivation	Conventional sowing
(RT1) Reduced	Deep chiselling	Disc cultivation	Mulch sowing
(RT2) Reduced	Stubble disc cultivation	Combined tine cultivation	Mulch sowing
(RT3) Reduced	–	Rotary tillage	Mulch sowing
(NT) No-tillage	–	–	Direct sowing

The costs for upgrading, repair, and technical maintenance of the machinery are calculated pursuant to the methodology prepared by the Lithuanian Institute of Agrarian Economics, average prices of the machinery market, and average deductions for upgrading, repair, and technical maintenance. The costs of diesel fuel are calculated with application of the complex price of fuel intended for agriculture, i.e., 0.86 EUR·l^{-1}. When calculating the indirect costs, operational costs related to the management of the agricultural service company and maintenance of the premises and equipment are assessed. They amount to 5 – 10 % of the direct costs. The value added tax is not included. The working capacity of the tillage and sowing machinery, fuel consumption, and technological operation costs for farm areas of 2, 10, and 20 ha are presented in Table 2.

Table 2

Technology, energy and economic parameters of different tillage and sowing operations in Lithuania [23]

Tillage/sowing operation	Working width, m	Tractor power, kW	Field capacity, ha·h^{-1}			Fuel consumption, l·ha^{-1}			Operations costs, EUR·ha^{-1}		
			2 ha	10 ha	20 ha	2 ha	10 ha	20 ha	2 ha	10 ha	20 ha
[1]Ploughing 22 – 24 cm	1.75	102	0.80	0.91	0.93	24.1	23.6	23.2	51.6	48.7	46.7
[2]Ploughing 22 – 24 cm	1.75	102	0.83	0.92	0.94	24.1	23.5	23.1	60.9	58.0	55.4
Deep chiselling 24 – 28 cm	3.0	83	1.28	1.38	1.49	15.8	15.3	14.9	35.1	33.0	31.3
Stubble disc cultivation 12 – 15 cm	4.0	120	2.21	2.70	3.13	9.0	8.1	7.2	26.1	22.9	19.4
Disc cultivation 8 – 12 cm	4.0	83	2.01	2.23	2.56	8.4	7.6	7.3	25.5	23.2	20.9
Rotary tillage 5 – 8 cm	4.0	102	1.61	1.76	1.91	11.4	11.0	10.6	33.9	31.9	29.6
Combined tine cultivation 6 – 12 cm	6.0	83	3.96	4.35	4.75	5.9	5.4	4.9	15.1	13.9	12.6
[3]Conventional sowing	3.0	45	1.41	1.59	1.64	4.0	3.7	3.6	14.5	13.0	12.9
[3]Direct/mulch sowing	3.0	67	1.77	2.15	2.26	7.3	6.5	6.3	27.5	23.2	22.0

[1]Non-reversible plough; [2]reversible plough; sowing rate 200 kg·ha^{-1}, sowing depth 3 – 4 cm.

Results and discussion

On the basis of the analysis of the tillage systems, it was established that deep ploughing is the least productive tillage technological operation. A plough with a working width of 1.75 m allows ploughing of land with an area of approximately 0.8 – 0.94 ha within one hour. A tractor with the same or lower power can be used for other tillage operations, i.e., deep chiselling, stubble disc cultivation, or rotary cultivation; however, land areas exceeding those in the case of ploughing 1.5 to 3 times can be tilled within one hour. When tilling bigger land areas, this difference increases further. For reduced tillage operations, machinery with bigger working width can be used because the resistance of soil to traction is considerably lower than that in the case of ploughing. Besides, when applying reduced tillage machinery, work can be performed with a speed 1.5 – 2.5 times greater than that in the case of ploughing [19].

By assessing the consumption of the working time in different tillage and sowing systems, it was established that when sowing grain crops directly into non-tilled soil (NT) with an area of 2 ha, around (from) 0.4 $h \cdot ha^{-1}$ is spent, and when sowing a land area of 20 ha, the time consumption is around 0.6 $h \cdot ha^{-1}$ (Fig. 2). In reduced tillage and sowing systems, the consumption of the working time amounts to 1.0 to 1.8 $h \cdot ha^{-1}$. The biggest consumption of the working time in reduced tillage and sowing systems is in the case of deep chiselling (RT1). By comparison of all tillage and sowing systems, it was established that conventional technologies, irrespective of the size of the farm area, require most working time. In the case of ploughing with reversible ploughs (CT2), the consumption of the working time is by approximately 0.2 – 0.3 $h \cdot ha^{-1}$ lower than in the case of ploughing with non-reversible ploughs (CT1). The data of the working time analysis show that working time can be saved by abandoning conventional tillage and switching to reduced tillage and sowing systems. It is especially important when the working timeframes of separate technological operations in the plant cultivation technological chain are very tight. Abandonment of one or several tillage technological operations or their replacement with a more productive operation gives more space for planning of other agricultural technological operations and use of agricultural machinery. Besides, the saved time of farmers can be used for performing other important agricultural works.

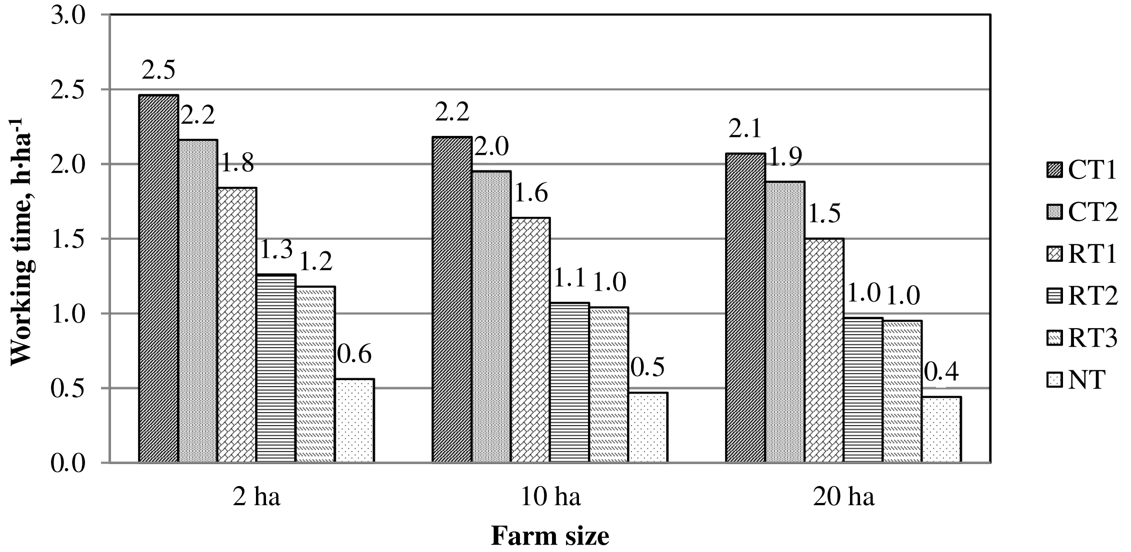

Fig. 2. **Working time by different tillage and sowing systems for different farm size**

By energy assessment calculations, it was established that in the case of sowing grain crops directly into non-tilled soil (NT), the fuel consumption per hectare amounts to 6 – 7 $l \cdot ha^{-1}$ (Fig. 3). The fuel consumption increases rapidly as the intensity of tillage grows and low-capacity tillage machinery is used. In the case of sowing into deep (22 – 24 cm) ploughed and cultivated soil (CT1 and CT2), the fuel consumption is by more than 5 times, and in the case of soil tilled by the reduced method (RT1, RT2, and RT3), it is by around 2.5 – 4.8 times higher than in the case of application of the direct sowing system (NT). In tillage and sowing systems with the application of ploughing, the fuel consumed for ploughing accounts for approximately 70 % of the total fuel consumption. In reduced tillage and sowing systems, when soil is tilled for sowing without using ploughs, only with deep or shallow soil tillage machinery, the fuel consumption is by 10 % to 2 times lower compared to the conventional tillage and sowing system. When the land area is increased from 2 to 20 ha, the fuel consumption in all tillage and sowing systems decreases by approximately 10 – 20 %.

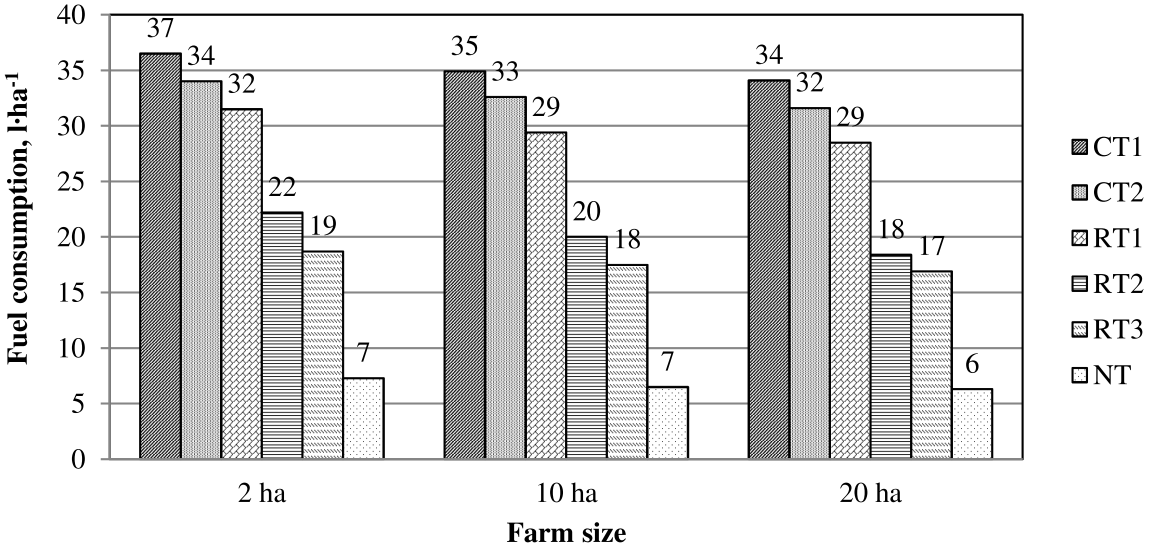

Fig. 3. **Fuel consumption of different tillage and sowing systems for different farm size**

Ploughing, cultivating, and sowing with grain crops of one hectare in the conventional sowing system (CT1 and CT2) costs around EUR 92 (Fig. 4). With the tillage area growing, the costs decrease. When applying the conventional tillage system in an area of 20 ha, the costs for tillage and sowing amount to approximately EUR 81. Application of reduced tillage and sowing systems (RT1, RT2, and RT3) allows cutting the costs by 5 to 50 %, and application of direct sowing provides cost reduction of up to 3.5 times compared to conventional systems. Lower fuel consumption is the biggest contributor to this reduction. If ploughing is abandoned and only reduced tillage is applied, 3.0 to 18.0 $l \cdot ha^{-1}$ of fuel can be saved, and in the case of application of direct sowing, the savings can be 26.0 to 30.0 $l \cdot ha^{-1}$.

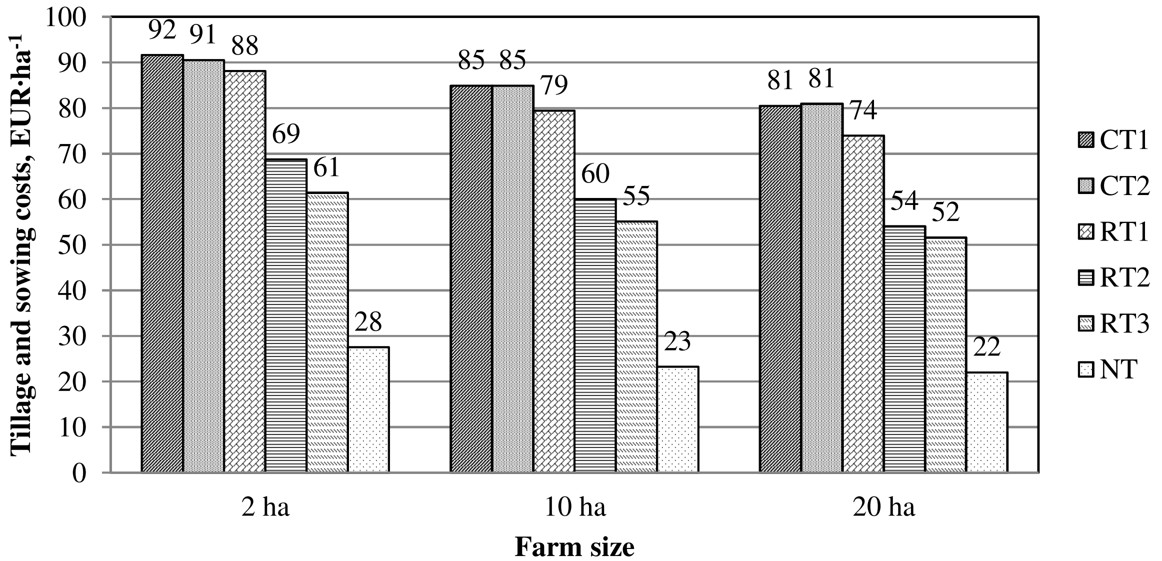

Fig. 4. **Costs of different tillage and sowing systems for different farm sizes in Lithuania**

With areas of non-ploughed lands growing worldwide, the application of reduced tillage and sowing systems in Lithuania will also increase. In Lithuania, land under grain crops occupies around one million hectares. Based on the forecast that reduced tillage and sowing systems could account for 50 %, and the share of direct sowing could be 10 % of all lands under grain crops, the costs of tillage and sowing, depending on the selected system, could be reduced by 9.4 million EUR to 20.4 million

EUR. Besides, in the case of application of reduced or zero tillage systems, the negative impact on soil is lower and environment is conserved. It is difficult to assess this factor in terms of financial indicators, but the economic benefit would be even higher.

Conclusions

1. Decreasing of the intensity of tillage conserves environment and soil, protects plant residues, protects soil against wind and water erosion, reduces levigation of the fertile soil layer, fertilisers, and pesticides into water reservoirs, increases biodiversity, reduces the fuel consumption, saves the working time, reduces the self-cost of cultivated agricultural products, and improves the competitive ability of farmers.
2. The biggest consumption of the working time is in the case of application of conventional tillage and sowing systems (CT1 and CT2). In the case of application of reduced tillage systems (RTI, RT2, and RT3), 0.4 to 1.3 $h \cdot ha^{-1}$ of the working time compared to conventional systems can be saved, and application of zero tillage systems allows saving 1.5 to 1.9 $h \cdot ha^{-1}$ of the working time compared to conventional systems.
3. In the case of application of the zero tillage system (NT), the fuel consumption is more than 2.5-4.8 times lower compared to the application of reduced (RT1, RT2, and RT3), and more than 5 times lower compared to the application of conventional tillage and sowing systems (CT1 and CT2).
4. The costs of the conventional tillage and sowing system are by 5 to 50 % higher than those of various reduced systems and by up to 3.5 times higher than the costs of direct sowing.
5. In very small farms with areas of 2 ha, the costs of tillage and sowing are highest. If the farm size is increased to 20 ha, the costs in different tillage and sowing systems decrease by 12 to 27 % per hectare.

References

1. Morris N.L., Miller P.C.H., Orson J.H., Froud-Williams R.J. The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment – a review. Soil & Tillage Research, vol. 108, 2010, pp. 1 – 15.
2. Derpsch R., Friedrich T., Kassam A., Hongwen L. Current status of adoption of no-till farming in the world and some of its main benefits. International Journal of Agricultural and Biological Engineering, vol. 3(1), 2010, pp. 1 – 25.
3. Linke C. Entwicklung der Direktsaat. Landtechnik, vol. 61, 2006, pp. 312 – 313.
4. Baker, C.J., Saxton, K.E., Ritchie, W.R., Chamen, W.C.T., Reicosky, D.C., Ribeiro, M.F.S., Justice, S.E., Hobbs, P.R. No-Tillage Seeding in Conservation Agriculture. 2nd Edition. CABI and FAO, Rome, 2007. 326 p.
5. Tahir M.A., Sadar M.S., Quddus M.A., Ashfaq M. Economics of zero tillage technology of wheat in rice-wheat cropping system of Punjab-Pakistan. Journal of Animal and Plant Sciences, vol. 18(1), 2008, pp. 42 – 46.
6. Šarauskis E., Romaneckas K., Buragiene S. Impact of conventional and sustainable soil tillage and sowing technologies on physical-mechanical soil properties. Environmental Research, Engineering and Management, vol. 49(3), 2009, pp. 36 – 43.
7. Feiziene D., Feiza V., Vaideliene A., Povilaitis V., Antanaitis Š. Soil surface carbon dioxide Exchange rate as affected by soil texture, different long-term tillage application and weather. Zemdirbyste=Agriculture, vol. 97(3), 2010, pp. 25 – 42.
8. Lithourgidis A.S. Damalas Ch.A., Eleftherohorinos I.G. Conservation tillage: a promising perspective for sustainable agriculture in Greece. Journal of Sustainable Agriculture, vol. 33(1), 2009, pp. 85 – 95.
9. Šarauskis E., Godlinski F., Sakalauskas A., Schlegel M., Kanswohl N., Romaneckas K., Jasinskas A., Pilipavicius V. Effects of soil tillage and sowing systems on sugar beet production under the climatic conditions of Lithuania. Landbauforschung, 2(60), 2010, pp. 101 – 110.
10. Rusu T., Gus P., Bogdan I., Moraru P. I., Pop A. I., Clapa D., Marin D. I., Oroian I., Pop L. I. Implications of minimum tillage systems on sustainability of agricultural production and soil conservation. Journal of Food, Agriculture & Environment, vol. 7(2), 2009, pp. 335 – 338.

11. Hernanz J.L., Giron V.S., Cerisola C. Long-term energy use and economic evaluation of three tillage systems for cereal and legume production in central Spain. Soil & Tillage Research, vol. 35(4), 1995, pp. 183 – 198.
12. Sirhan A., Snobar B., Baltikhi A. Management of primary tillage operation to reduce tractor fuel consumption. Agric Mech Asia Afr Lat Am, vol. 33(4), 2002, pp. 9 – 11.
13. Sessiz A., Sogut T., Alp A., Esgici R. Tillage effects on sunflower (Helianthus Annuus, L.) emergence, yield, quality, and fuel consumption in double cropping system. Journal of Central European Agriculture, vol. 9(40), 2008, pp. 697 – 710.
14. Filipovic D., Kosutic S., Gospodaric Z., Zimmer R., Banaj D. The possibilities of fuel saving and the reduction of CO_2 emissions in the soil tillage in Croatia. Agriculture, Ecosystems and Environment, vol. 115, 2006, pp. 290 – 294.
15. Yalcin H., Cakir E., Aykas E. Tillage parameters and economic analysis of direct seeding, minimum and conventional tillage in wheat. Journal of Agronomy, vol. 4(4), 2005, pp. 329-332.
16. Bertocco M., Basso B., Sartori L., Martin E.C. Evaluating energy efficiency of site-specific tillage in maize in NE Italy. Bioresource Technology vol. 99, 2008, pp. 6957 – 6965
17. Safa M., Tabatabaeefar A. Fuel consumption in wheat production in irrigated and dry land farming. World Aplied Sciences Journal vol. 4(1), (2008, pp. 86 – 90.
18. Adamavičiene A., Romaneckas K., Šarauskis E., Pilipavičius V. Non-chemical weed control in sugar beet crop under an intensive and conservation soil tillage pattern: II Crop productivity. Agronomy Research, vol. 7(Special issue I), 2009, pp. 143 – 148.
19. Šarauskis E., Vaiciukevičius E., Sakalauskas A., Romaneckas K., Jasinskas A., Lillak R. Impact of sowing speed on the introduction of winter wheat seeds in differently-tilled soils. Agronomy Research, vol. 6(Special issue), 2008, pp. 315 – 327.
20. Feiza V., Feiziene D., Auškalnis A., Kadžienė G. Sustainable tillage: results from long-term field experiments on Cambisol. Zemdirbyste=Agriculture, vol. 97(2), 2010, pp. 3 – 14.
21. Šarauskis E., Vaiciukevicius E., Romaneckas K., Sakalauskas A., Baranauskaite R. Economic and energetic evaluation of sustainable tillage and cereal sowing technologies in Lithuania. Proceedings of the fourth international scientific conference „Rural Development 2009“, vol. 4(1), October 15-17, 2009, Akademija, Lithuania, pp. 280 – 285.
22. Šarauskis E., Romaneckas K., Vaiciukevicius E., Jasinskas A., Sakalauskas A., Buragiene S., Katkevicius E., Karayel D. Effect of environmentally friendly tillage machinery on soil properties. Proceedings of 10 th International scientific conference „Engineering for Rural Development“, May 26-27, 2011, Jelgava, Latvia, pp. 70 – 75.
23. Mechanizuotų žemės ūkio paslaugų įkainiai. I dalis. Pagrindinio žemės dirbimo darbai. Vilnius: Lithuanian institute of agrarian economics. 2011. 85 p. (In Lithuanian). [online] [15.02.2012]. Available at: http://www.laei.lt/?mt=leidiniai