

Specific Features of Establishment and Maintenance of Tractor Fleet in a Typical Estonian Agricultural Holding

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Abstract. In spite of the high reliability of modern tractors, they are no perpetuum mobiles and need at times designated by the manufacturer's technical condition regular diagnostics, the diagnostic results being determined on the basis of work and the amount of content, technical maintenance and repair, if necessary. This study examines the design and maintenance problems of an Estonian representative farm tractor compared to similar indicators in the Republic of Latvia. The outlines of a typical company are based on expert opinions. These indicators have been analyzed and compared to those of the whole Estonia at the level of one particular farm in real terms. The machine/tractor maintenance-related economic and technical indicators have been set to ensure the reliability of machine/tractor use in competitive agricultural production. The investigation examines the company's actual use of machine/tractor, tractor upkeep and methods for determining the composition of the qualitative and quantitative indicators.

Key words: Tractor, tractor maintenance procedures, maintenance costs, machine-tractor park, repair, diagnostics

INTRODUCTION

Today the number of tractors working in the fields of the Republic of Estonia reaches ca 32 thousand tractors (Statistics Estonia, 2008). Despite the high reliability indicators of a modern tractor, it still needs regular diagnostics of its technical condition at intervals specified by the manufacturer, diagnostics-based technical maintenance and repairs, if necessary. All this accounts for a high volume of repair work that has to be arranged and performed by our farmers or relevant service-providers. The republic still lacks an overview of the problems and indicators of reliability and maintenance of machinery. Due to the application of a highly regulated and mandatory system of tractor maintenance during Soviet times, our system was significantly different from the systems ensuring tractor reliability applied elsewhere in the world. We should also consider the fact that in Soviet times tractor manufacturers were actually not interested in servicing tractors during their useful life. Because of national planned economy, collective holdings were constantly short of new tractors and manufacturers realized their entire production already at the gates of the factory without any problems.

As a result of advancement in technology, extended range of applications, enhancement of automatic processes, increase in loads and speed, reliability has

become more and more important. Solutions to the aforesaid issues represent one of the main sources for costs saving by increased efficiency, material, labour and energy. More complex technology means more expensive failure management. In order to keep a tractor in good working order, the amount of money spent on its repair and technical maintenance during its lifetime is twice as high as the amount spent on purchasing a new tractor (Olt & Traat, 2009).

The present study views the problems regarding the establishment and maintenance of tractor fleet in a typical Estonian agricultural holding, and compares it with similar indicators applicable in the Republic of Latvia (based on limited source data). The outline of a typical holding is based on expert assessments. These indicators have been analyzed at national level and compared to the actual indicators of one particular agricultural holding. For the purposes of the study the latter is referred to as Agro2. According to our knowledge, a similar study has not been carried out in Estonia before.

Objective of the study: To determine economic and technical indicators related to the maintenance of machinery/tractor fleet in order to ensure reliability of machinery/tractor fleet required for their competitive exploitation in production of agricultural products.

Pursuant to the objective, the **purpose of the study** was to determine the actual expenditure on utilization and maintenance of machinery/tractor fleet of the holding, provide a systemic approach and assess the status of resources.

MATERIAL AND METHODS

The present study is based on a qualitative approach to the reviewed problem. A qualitative approach allows the parallel usage of various evidences – documentation, interviews, etc. In several stages of the study, quantitative methods of research and analysis were also used, but a qualitative approach is still dominant, which means that numerical indicators are not used as major arguments when drawing conclusions from empirical evidence. Instead, the study is more similar to the description of factors affecting the development of machinery maintenance and the potential direction of such development.

The present paper uses materials from two previous studies: firstly, a survey carried out in 2009, in which participated expert technical managers of the holdings. In the course of the survey a questionnaire of 68 questions with more than 200 markers was prepared. All the experts had higher education and long-term employment (10-25 years) in the field of exploitation and maintenance of tractors. The opinions of all the experts carried a lot of weight. The majority of respondents had worked as chief engineers and mechanical engineers in collective and state farms during Soviet times. Thus they were capable of assessing the changes and rearrangements made in the course of time.

Most of the experimental material was collected from accounting databases, made available by the technical manager of the holding. The majority of data was retrieved from first-hand communication with the accounting department of the holding, which grants the accuracy and reliability of these data. The survey was carried out in spring 2009, by performing interviews with technical managers of 20

major agricultural holdings, and, in addition to that, information was collected about the expenditure on tractor maintenance.

As of 1 March 2009, the composition of the tractor fleet in the Republic of Estonia comprised of 82% technically old and 18% modern tractors. The proportion of new tractors in total number of tractors is extremely small. During the past 5 years, new tractors constituted only up to 3.8% of the annual number of tractors in active use, according to ARK (ARK, 2009). In Latvia this number is much higher, 6.3%, i.e. the relevant figure in Estonia differs by 1.6 times. From 2000 to 2007 there have been no significant quantitative changes in the composition of tractors in Latvia and in 2000 it reached 54,820 tractors, which was increased by 8.6% by 2007, i.e. within 6 years. The majority of these tractors consist of purchased new tractors. (Kopiks & Viesturs, 2009) The proportion of tractors that allow adequate operation does not exceed 50% and only 38% of them pass technical inspection. Tractor fleet in agricultural holdings shows signs of aging. In 2007 the number of tractors in agricultural holdings with over 50ha of area under cultivation increased by 3.3 times in comparison with the relevant figure in 2000. Average annual growth rate of tractor fleet in terms of tractors manufactured within the past 6 years during the period 2000-2007 was 6.3%. Absolute increase in tractor fleet in terms of tractors produced within the past 6 years was by 1,678 tractors, compared to 2,000 (Kopiks & Viesturs, 2009).

Holding **Agro2** provides work for 23 employees and utilizes 1506 ha of arable land (as of 2008), which is partially rented and partially owned by the holding. The holding makes regular use of 20 tractors, half of which are technically old and another half are more recent and more powerful modern tractors. The composition of tractor fleet during three years is provided in Fig. 1.

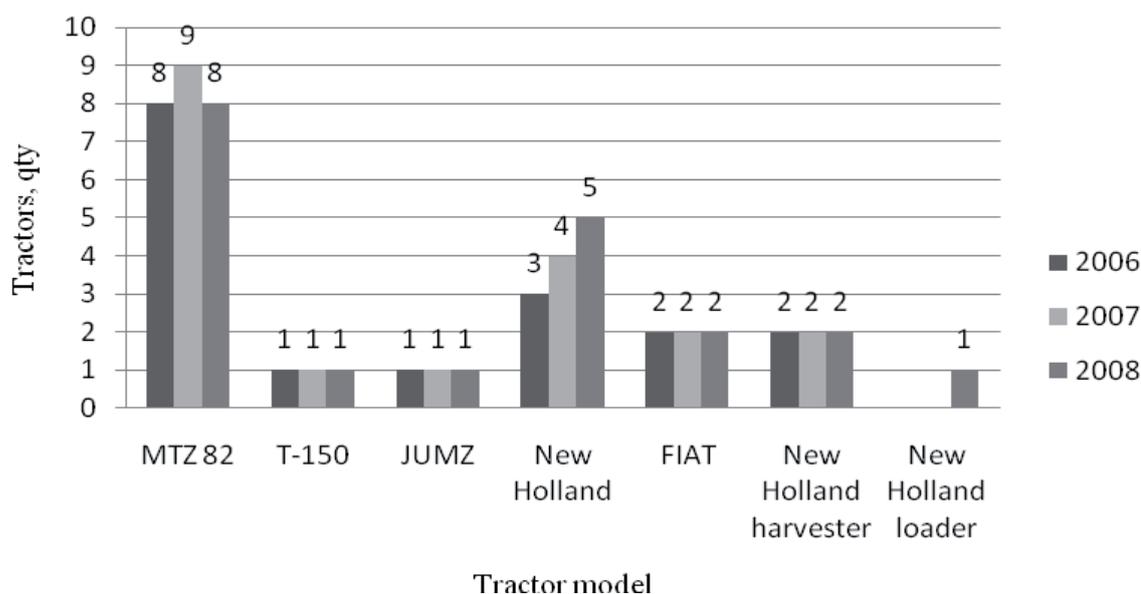


Fig. 1. The composition of tractor fleet of Agro 2 during three years.

The study observed 20 agricultural holdings with high turnover all over Estonia. Primary fields of activity of these companies were animal husbandry and plant production. The total area of land cultivated by these agricultural holdings

ranged from 1,000 to 10,000 hectares. The holdings to be studied were divided into four groups according to the area of arable land (Table 1).

The experts divided the holdings according to the area of land under cultivation and based on their sustainability. In 2007 the average area of arable land under cultivation in hectares was 315 ha for legal persons and 21 ha for private persons (Table 2). In our opinion the experts were correct and the agricultural production is kept alive only by medium-sized and large agricultural holdings that represent the main actors with sustainable area of arable land under cultivation starting from 1,000 ha. These assessments are based on actual profit-earning activities; they are not derived or calculated by unreasonable formulas.

Table 1. Distribution of holdings by the area of cultivated land, expert opinion

No.	Designation of agricultural holding	Area of cultivated land, ha
1.	Small agricultural holding	up to 1,000
2.	Medium-sized agricultural holding	1,001...2,000
3.	Large agricultural holding	2,001...4,000
4.	Very large agricultural holding	over 4,000

Table 2. Average area of arable land under cultivation in ha and change in comparison with 2001 in %. (Source: *Statistics Estonia*)

Year	Total number of households by qty and change in comparison with 2001 in %		Average area of arable land under cultivation in ha and change in comparison with 2001 in %		Average area of arable land under cultivation in ha and change in comparison with 2001 in %						
					Total average ha change %	Private person, ha change%	Legal person, ha change %				
2001	55,702	0%	871,213	0%	16	0%	10	0%	400	0%	
2003	36,792	-33%	795,640	-8.7%	22	+37.5%	13	+30%	450	+12.5%	
2005	27,688	-51%	828,926	-4.9%	30	+87.5%	17	+70%	441	+10.2%	
2007	23,257	-59%	906,833	+4%	40	+125%	21	+110%	315	-21.3%	

The sample was composed of 20 agricultural holdings with the highest turnover. The motivation behind such selection was the fact that the proportion of modern tractors in these holdings was the highest and their exploitation was the most intensive. Another important factor in choosing the sample was the accuracy and reliability of the holdings under examination.

The analysis of expenditure on technical maintenance and fuel is based on data received from Agro2. Source data were collected by going through source and combined records of the holding with regard to the types of expenditure during 2006-2008. The information is truthful, unambiguous, reliable and traceable.

The experimental material was collected by using interviews performed at the site of the holdings under study. Interview comprised questions about the maintenance of the tractor fleet, i.e. diagnostics, technical maintenance and repairs, as well as agricultural questions, a general opinion of the technical manager and

assessment of the current situation. The interview ended by examining the sites for maintenance of the machinery in a given agricultural holding to find out the actual situation and level. The interview was performed in the form of a single prepared questionnaire which was used in all holdings. The experimental material was collected in spring 2009 and most of the agricultural holdings were revisited to specify the information.

RESULTS AND DISCUSSION

A future trend of Estonian agricultural holdings consists in replacement of technically out-of-date equipment with modern machinery. Today we are facing a situation characterized by the shortage of qualified labour – a problem which can actually be solved by help of up-to-date machinery (the work performed by 1 modern tractor equals to the work made by 6 to 8 technically out-of-date machines. Another important reason is that vendors manufacture and distribute agricultural machinery and equipment with increased productivity and in order to use them it is necessary to have modern and powerful tractors. Such a situation is characterized by the fact that the hydraulic system of MTZ type tractor can lift only 800kg, but new agricultural equipment requires much more powerful suspension systems which are available in modern tractors. Another advantage of modern tractors is that the working environment of the operators of these tractors, the driver's compartment in other words, is significantly more work-friendly and has more comfort than the old machinery (Ministry of Agriculture).

According to the Estonian Motor Vehicle Registration Centre (ARK), a total of 607 new modern tractors were registered in 2008. The most popular of them included 143 Valtra, 135 John Deere and 75 New Holland tractors. The tractors of MTZ type are still there, 85 of which were registered in 2008. According to ARK, a total of 22,673 wheel tractors were registered in Estonia as of 31 December 2008. Distribution of these tractors by age is shown in Table 3 (data from *Estonian Road Administration*).

Table 3. Tractors registered in Estonia by age as of 31 December 2008

Age, yrs	Up to 2yrs	3– yrs	6–10yrs	Over 10yrs	Total
Wheel tractors, qty	3,332	2,371	1,627	15,343	22,673
Wheel tractors, %	14.70	10.46	7.18	67.67	100.00

Investments in the renewal of tractor fleet must be based on prior detailed calculations, taking into account the production conditions of a given production unit. The holdings that are more efficient in implementing new machinery show more rapid economic development and greater competitive ability (Möller, 1977). Tractor models preferred by the agricultural holdings participating in the study in comparison with the area of arable land under cultivation are provided in Fig. 2.

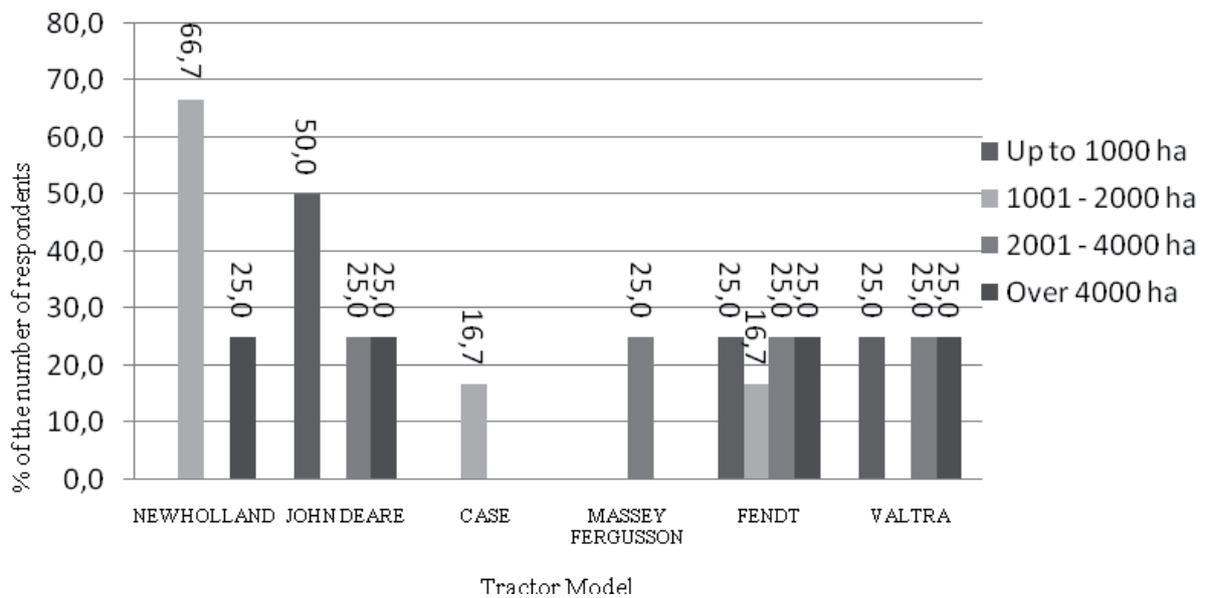


Fig. 2. Preferred tractor models according to experts, based on the area of cultivated land.

According to the results of the study, medium-sized holdings prefer New Holland tractors (66.7%). The most preferred modern tractor for small agricultural holdings is John Deere. Large and very large agricultural holdings have no clear preferences. The analysis of the questionnaires revealed that none of the experts of agricultural holdings preferred tractors of MTZ type, despite the fact that 85 tractors of that type were acquired in 2008. There are several reasons why some agricultural holdings have remained loyal to a certain tractor model, relevant expert opinion is given in Fig. 3.

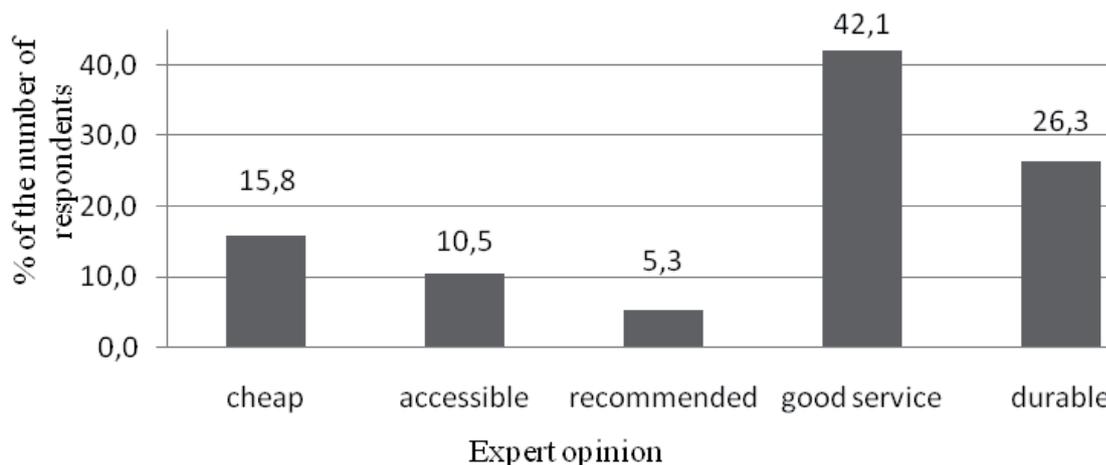


Fig. 3. Expert opinion on motivation of purchasing modern tractors.

According to the study the price is not a decisive factor when purchasing a modern tractor. Only 15.8% of respondents considered the price to be a decisive factor in tractor acquisition. Many experts (68.4%) preferred a tractor with good service and durability. The survey did not support the common understanding that

tractors are purchased based on price. The selection is made on the basis of various technical conditions. There have been significant changes in the qualitative composition of tractors in Latvia, where the power rating of machinery increased by 15% in 2007, in comparison with 2000 (Kopiks & Viesturs, 2009). In Estonia the average age of tractors has decreased from 22.3 to 9.7 years over the past 5 years (renewal rate 43%) and the number of old tractors has been reduced, while engine power has increased from 80 kW to 113 kW in just five years (increase of power 30%).

Within the past 5 years, the average age of tractors has decreased and the power rating has increased (Fig. 4).

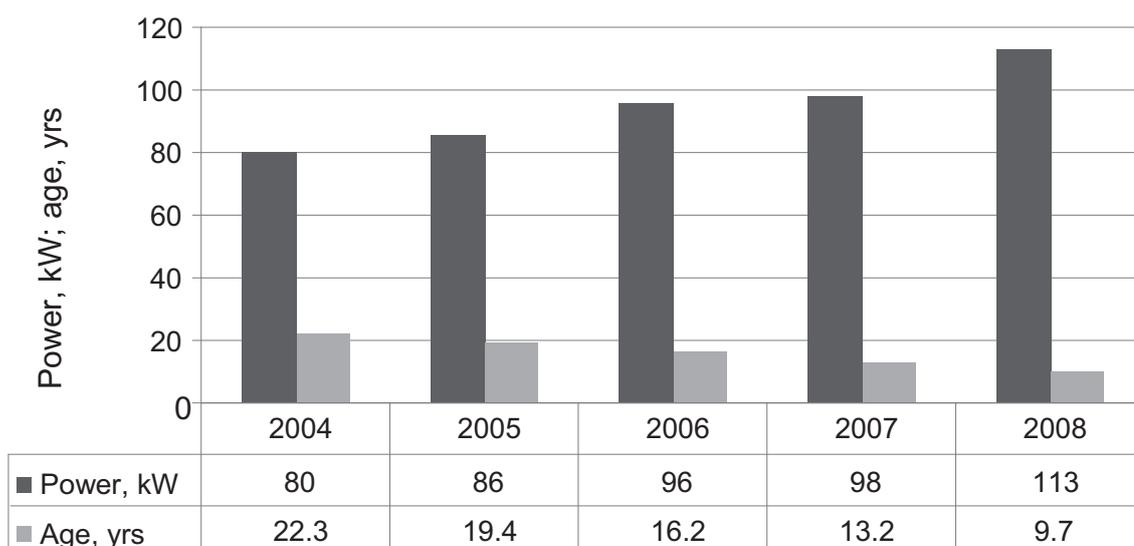


Fig. 4. The average age and power of tractors over 5 years.

One criterion considered today by the heads of agricultural holdings before acquisition of a new tractor is its engine power. As the power of modern tractors yields up to 600 hp, the purchase must be preceded by a careful consideration of particular aggregates or jobs the tractor is expected to perform. This process involves calculations comprising the average area and shape of the field of the holding as well as its soil structure, when considering soil cultivation equipment, etc. Pursuant to the power supply of the agricultural equipment, a tractor with suitable power rating is selected. The second aspect considered in choosing a new tractor is the amount and nature of work performed by the tractor, i.e. acquisition of a tractor with certain power rating, which is later on supplemented by suitable accessories (Möller, 1977). The most suitable power rating in Estonia according to expert opinion, depending on the area of cultivated land, is shown in Fig. 5.

Estonia is currently in the situation where tractors with power rating of 81–160 hp are mostly preferred by small agricultural holdings. Medium-sized and very large agricultural holdings prefer power rating of 191–240 hp. According to the managers of large agricultural holdings they do not prefer one power rating to another and their holding exploits special tractors with different power rating.

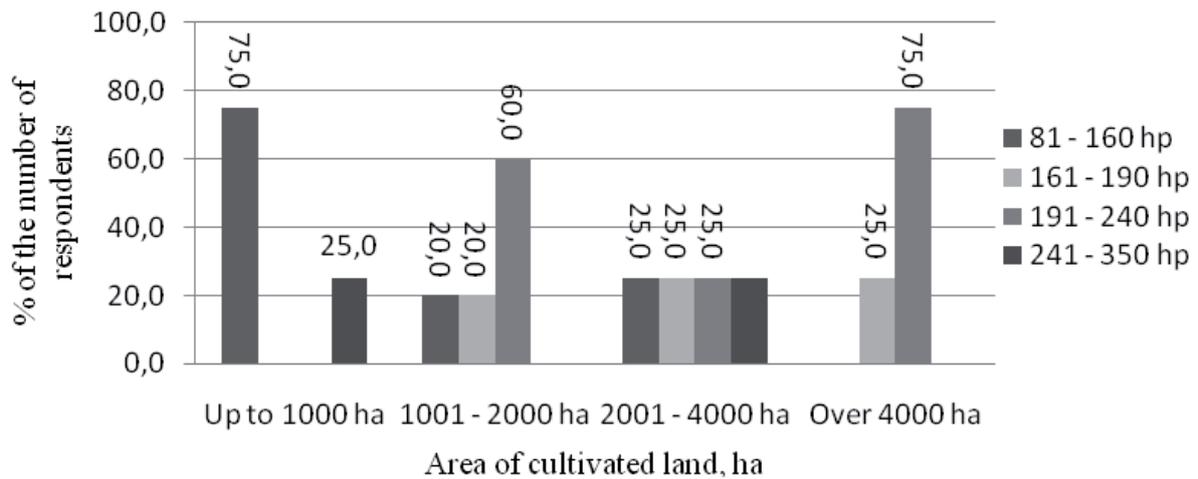


Fig. 5. The preferred power rating depending on cultivated land area.

Just as all other means of production, a tractor requires intensive use, otherwise the work-hours, hectares, tons or other measuring units will be too expensive and operation and production becomes futile. Acquisition of expensive machinery is only reasonable when a tractor is used to the maximum extent all year round and the pay-back period is as short as possible. The cost-effectiveness of modern tractor equals the amount of work it does. The optimum number of work-hours in a year shows the extent of work the tractor should perform in a year to ensure economical profitability. Expert opinion on the optimum annual work-hours per tractor depending on the area of cultivated land is shown in Fig. 6.

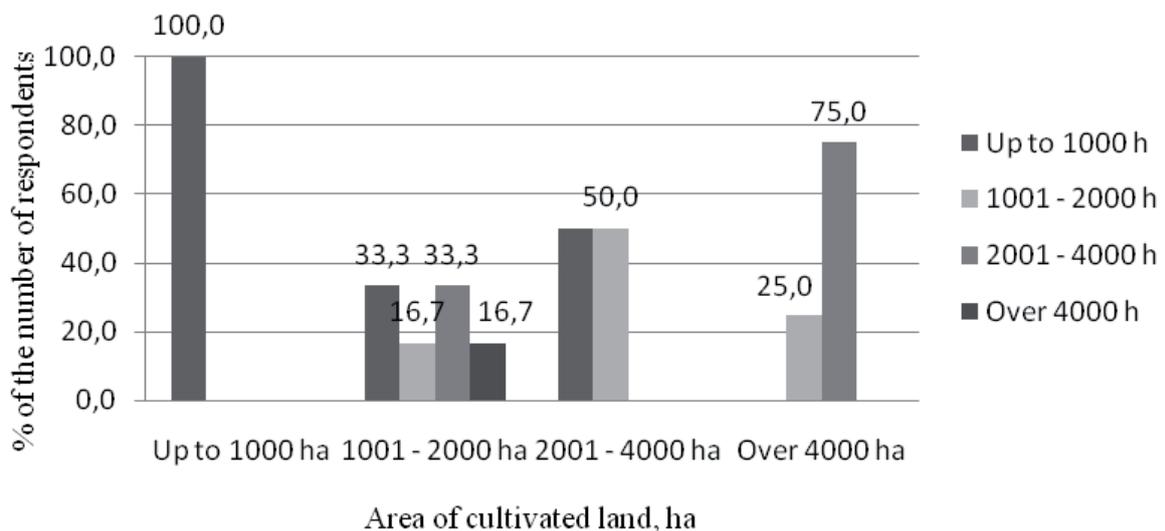


Fig. 6. Expert opinion on tractor's optimal annual number of work hours, depending on cultivated land area.

Pursuant to the expert opinion the optimal annual number of work hours of a tractor is 1,000 h in case of small agricultural holdings (up to 1,000 ha). Considering that our survey scale started from 1,000 work hours, the number of

work hours would probably be even lower in case of small agricultural holdings. The managers of large agricultural holdings (over 1,000 ha) have different opinions – half of them believe 100–1,500 work-hours to be optimal and half of them think that the optimum number of annual work hours is 1,501-2,000. Three quarters of the managers of very large agricultural holdings consider 2,001-2,500 to be the optimal number of annual work-hours. The study proves that large and very large agricultural holdings are able to exploit tractors at full load and more evenly.

Diagnostics-based repairs of tractors

The diagnostics of tractors has shifted to the front. Technical maintenance and repairs are only performed after receiving instructions based on the results of diagnostics, i.e. diagnostics determines the technical condition of the machine and the extent of technical maintenance and (where necessary) repair works to be done and registers it in the main computer (Tšernoivanov, 2003; Mihlin, 1976).

In this case one advantage of communication is that the tractor does not need to be disassembled in order to find out the cause of the failure. All devices of the tractor are connected to common data bus and by connecting this bus to special control panel, it is possible to view from the screen, which device needs to be repaired or replaced. The same bus can be used for fixing a certain failure, for example it allows setting correct injection time.

Navigation system is developed in view of finding those failures that may disappear by the time the tractor is brought to the service station. All kinds of failures can be saved in the memory by a certain code, so that they can be demonstrated in the service station. Upkeep of machinery becomes more and more complicated and requires new skills. Despite the seemingly simplified control over the machine (lots of navigation and control tasks are performed by electronic units), modern machines are actually much more complicated than before.

Performance and resources of the machine or its components can be restored by current or basic repairs. Current repairs are performed to ensure the performance of the machine during its operation. It consists in replacement, restoration or regulation of separate aggregates and mechanisms with low resource. During current repairs the equipment is subjected to diagnostics to identify assemblies and aggregates that need to be replaced. After the equipment is assembled and adjusted, it is tested. (Nikolaenko, 1984; Mihlin, 1976)

Basic repairs are performed in order to restore the technical resource of the machine. The machine is completely disassembled, all details are cleaned, old parts are replaced by new or restored parts, after which the equipment is assembled and its mechanisms and units are adjusted. Assembly is followed by adjustment and testing of the equipment. Basic repairs are performed for sophisticated machinery and equipment (tractors, harvesters, cars, as well as their components), simpler machines are subjected to technical maintenance and current repairs (Tšernoivanov, 2001 & 2003; Mihlin, 1976).

The majority of agricultural holdings purchase tractor diagnostics service from tractor vendors and technically out-of-date machinery is repaired by the holding itself. Contrary to technically aged technology, many Estonian agricultural holdings have the repair works of modern machinery done by the specialists of tractor vendor. Significant changes have been made in the qualitative composition of

tractors in Latvia, as their power rating is increasing. In 2007 the total tractor power increased by 15% in comparison with the year 2000 (Kopiks & Viesturs, 2008).

Fuel consumption

Increasing fuel prices force us more often to think about savings. Savings can be induced by two ways. The first one is the regular technical maintenance of the tractor. If a tractor is in good technical condition, it ensures optimum fuel consumption. Another method to save the fuel is to use proper techniques for operation and selection of cultivation tools. This means finding suitable tool for each job and for each tractor and making relevant adjustments.

A tractor's diesel fuel consumption can be calculated by the following formula:

$$L = \frac{k_l \cdot q \cdot P_m}{\rho}$$

where L is fuel consumption, $l\ h^{-1}$;

k_l – engine power efficiency or level of effort: hard work 0.6–0.7, average work 0.4–0.5, light work 0.3;

q – specific fuel consumption for diesel, $kg\ (kWh)^{-1}$;

P_m – rated engine power of tractor or non-road vehicle, kW;

ρ – fuel density for diesel, $kg\ l^{-1}$, $\rho = 0.86\ kg\ l^{-1}$.

The expenditure on fuel per hour u_k can be calculated by formula

$$u_k = r_k \cdot L$$

where r_k – fuel price, $EUR\ l^{-1}$.

Due to the high consumption and high price of diesel fuel, many agricultural holdings keep records of the amount of money spent on fuel in a year. The assessment of keeping such records (in comparison with cultivated land area) provided by agricultural holdings participating in the study is provided in Fig. 7. This kind of problem is beyond comprehension for several specialists from abroad, as they cannot understand how it is possible to organize business operations without keeping records of fuel consumption. Considering that Estonian agricultural holdings are allowed to use cheaper marked (blue) diesel fuel, which is not subject to excise tax (it is prohibited to use blue fuel in non-agricultural diesel fuels and police performs relevant checks on the road), it is common to store it in separate filling stations of former collective farms dating back to Soviet times, in metal containers ($3\text{--}50\ m^3$). It should be noted that the quality properties of blue fuel are identical to those of the unmarked fuel and it is suitable for use in passenger cars and trucks with diesel engine. A typical refuelling scheme has been described below.

A tractor operator drives to the filling station of an agricultural holding, fills the tank and fixes the amount received by signing the fuel storage documents, based

on the pump reading. At the end of the month all fuel amounts received from the tractor operators are added together without identifying the drivers, and registered as production costs under the entry 'total expenditure on tractors'. This is as far as it goes. According to the methods used by us this scheme does not comply with the purpose of the study and relevant note 'no records kept on fuel consumption' is made in the company database. Such problems are characteristic only in our region and they provide a good example of the goals and purpose of the regional generation.

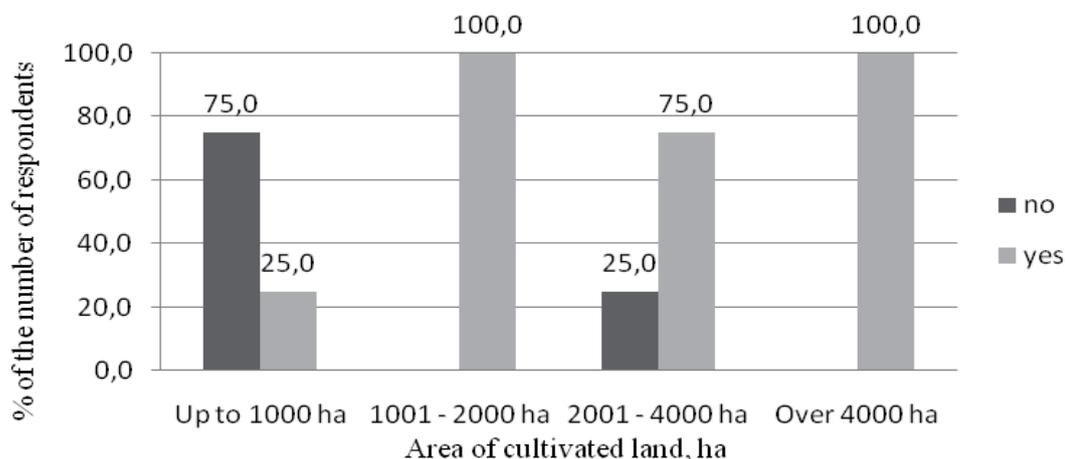


Fig. 7. Proportion of agricultural holdings keeping records of fuel consumption compared to cultivated land area.

The study revealed that medium-sized and very large agricultural holdings keep such records 100%. Three quarters of experts from small agricultural holdings believe that keeping such records gives them no benefits.

The private limited company Agro2 has kept such records for approximately 10 years, because the expenditure on fuel consumption is twice as high as the expenditure on repair and technical maintenance of tractors. Fig. 8 shows expenditure on fuel and repairs of Agro2 during the previous year.

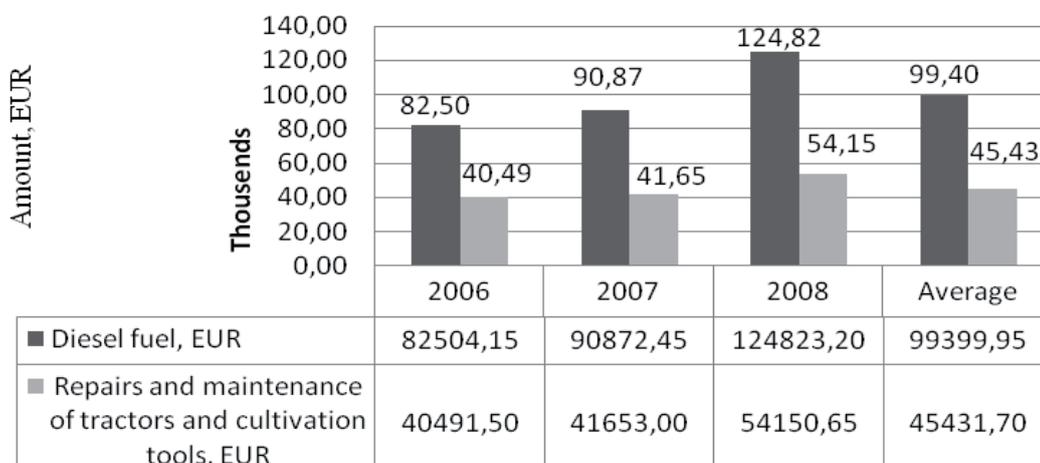


Fig. 8. Agro2 expenditure on diesel fuel in comparison with its expenditure on spare parts for tractors.

The amount spent on diesel fuel needs careful observation. According to the manager of the holding, keeping these records gives an overview of the extent of diesel fuel savings when using modern tractors and agricultural machinery. On the other hand, it provides an opportunity to predict the estimated investment in diesel fuel for seasonal works in spring or autumn.

Organization of repair works

In the private limited company Agro2 repair works are organized as follows – large-scale basic repairs are performed in winter, when tractors are used to a lesser extent. Such organization of work allows better all-year-round staff employment in an undertaking with a seasonal production cycle. In spring, summer and autumn only emergency repairs are performed for tractors and agricultural machinery, as this is the main cultivation time and tractors are working in the field most of the time. Tractors are divided between drivers, so that each driver has his own tractor to take care of. The holding has 7 tractor drivers/mechanics responsible for the machinery, plus three special workers. Each tractor driver has to repair his own tractor, with some assistance if needed, but the tractor driver is held personally responsible for the quality of repairs and good technical condition of the tractor. All major repairs are performed in the service hall which has the necessary equipment and tools.

In terms of purchasing new tractors, Latvian agricultural holdings attributed the highest priority to MTZ tractors in 2000 and 2007. But the number of actual acquisition of MTZ tractors in comparison with all tractors purchased within a year has decreased since 2000. In Latvia these tractors constituted 72% in 2000, but decreased to 26% by 2007. In Estonia the proportion of MTZ was 77.7% in 1998 and dropped to 13.2%. In 2007 the decrease in the proportion of MTZ tractors in comparison with all tractor models was greater in Estonia (13.2%) than in Latvia (26%) (Kopiks & Viesturs, 2009).

Pursuant to collected information, the more preferred trademarks of new tractors in Latvia include Valmet (Valtra), John Deere, Case. In addition to the abovementioned models, Fendt and New Holland are preferred in Estonia. This shows that price is not decisive in the renewal process of tractors, other important factors include reliability, energy intensity, efficient implementation, fuel consumption, comfort and other parameters.

The trends with regard to tractor fleet of the Republic of Latvia:

1. According to data analysis, the structure of tractor fleet in Latvian agricultural holdings is about to change in numbers, increasing the market share of energy-intensive tractors.

2. During the period 2001-2007 the total power rating of tractor fleet has increased by 15% or 390,475 kW.

3. The structure of tractor fleet of agricultural holdings depends on the total area of the farm and plant production volumes.

4. Farms with total area of arable crops 200-300 ha and tractors with power rating 80-100 kW constitute 85%.

5. Agricultural holdings have a tendency to grow, increased numbers of energy-intensive machinery and renewal rates reduce the number of tractors, and

technologically modern tractors enable to predict that in the future the number of tractors in the Republic of Latvia may reach 24-28 thousand.

SUMMARY

The tractor fleet of Estonian agricultural holdings is old. According to ARK the proportion of tractors older than 10 years was 67.8% in 2008, whereas the proportion of tractors not older than 5 years was only 25.1% of all registered tractors. Technically out-of-date tractors are gradually replaced by modern tractors. While only 23 new modern tractors were registered in 1990, the total of 629 tractors was registered in 2008. This process is irrevocable and the pace of modernization of the tractor fleet is determined by the position of tractor in the long and tense list of necessary investments in agriculture.

All in all the following results were achieved:

1. Many experts (68.4%) preferred a durable tractor with good service when planning acquisition of a modern tractor and for them price was not the deciding factor. Price was considered the most decisive factor by only 15.8% of experts.

2. The study proves that large and very large agricultural holdings are able to provide full and even load on tractors. The private limited company Agro2 represents a medium-sized agricultural holding and according to the manager of the holding the optimal annual number of work-hours is 1,500.

3. Own workforce is used for technical maintenance of old tractors 100% both in the private limited company Agro2 and 20 major agricultural holdings in Estonia. Similar to the private limited company Agro2, 47.0% of the agricultural holdings participating in the study perform technical maintenance of modern tractors by using their own workforce. Pursuant to expert opinion this allows to save up to 160 EUR per each technical maintenance session.

4. Medium-sized and very large agricultural holdings keep 100% records on the expenditure on diesel fuel. Three quarters of the experts from small agricultural holdings believe that they gain nothing from keeping such records.

5. During the past three years, the average sum of 100 EUR for fuel consumed by tractors (2006-2008) is supplemented by 46 EUR for repairs and technical maintenance. These expenses should be considered when preparing the cost of tractor works.

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