TRENDS IN DEVELOPMENT OF GRAIN COMBINE HARVESTER FLEET IN LATVIA

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Abstract. The article presents an analysis of the research results of the development of the cereal harvester fleet in Latvia in 2014-2023. The purpose of the article is to find out changes in the performance of combine harvesters, characterized by total capacity and specific capacity, over a period of ten years, and to compare them with the changes in the area of cereals and rapeseed, and the total harvest. Such a comparison makes it possible to assess compliance of the dynamics of the development of the combine harvester fleet with the possibilities of timely harvesting of the existing volume of cereals. In order to calculate the total capacity of the harvester fleet, several indicators were clarified - the age structure of the harvester fleet, the number of harvesters in technical condition, a methodology was developed for determining the working capacity of harvesters of different brands and age groups. Calculations were made, using data about these harvesters and taking into account that the depreciation period is mostly 15 years. It was assumed that all harvesters of this age are functioning. Data were collected about the combine brand, model, year of first registration and power. Calculations were made, which included the average power of one harvester of the relevant brand and the number of harvesters, resulting in the total capacity of the harvester fleet of the respective year. The results of the calculations have been compared with the area, sown by cereals and rapeseed, and the total harvest by years. An analysis of the changes in the total power and specific power in $kW \cdot ha^{-1}$ during this period has been made, which characterizes the performance of the combine harvester fleet and, in comparison with the area to be harvested, shows the possibilities of timely harvesting of cereals. It has been established that with the increase of the area to be harvested by 1.35 times, the total capacity of the combine harvester fleet has increased by 1.63 times; therefore the increase in the performance exceeds the increase in the area, also considering the increase in the harvest, and allows shortening the duration of harvesting. Since the intensity of growth of the harvested areas will decrease, there is no reason to maintain a high pace of purchase of combines.

Keywords: grain combine harvesters, total engine power, areas under crop.

Introduction

Crop production is the most important agricultural sector; in 2022 it accounted for almost two-thirds (65.5%) of the total value of final production of agricultural goods, produced in the country, while 58.3% were grain, rapeseeds and legumes [1]. In 2022, 18.873 farms grew cereals and rapeseed; since 2014 the number of such farms decreased by 21%. The number of farms with a cereal sowing area decreases in area groups up to 50 ha, the changes are difficult to assess in the area group 50-100 ha, the number of farms with cereal sowing area above 150 ha is increasing. In 2022, in Latvia there were 580 farms with cereal and rapeseed area over 300 ha; since 2014 their number has increased by 25% [2]. The areas of grain to be harvested and the combined harvest are increasing, which also increases the requirements for the harvesting equipment – combine harvesters. A number of authors have focused on the research of the structure, performance, costs, fuel consumption and other characteristics of the combine fleet. The authors of the study [3] state that in the last 25-30 years in the Baltic States, grain growing technologies and harvesting techniques have been completely changed, introducing modern harvesters made in the EU countries. The authors of [4] and [5] conducted research of the fuel consumption, performance and costs of contemporary harvesters, finding that higher capacity harvesters are more economical. The efficiency of the harvester depending on the harvested area over a three-year period is discussed in [6]. The authors of the article [7], collecting data about 90 harvesters in Lithuania and Latvia, find that in 2016-2018 the harvester worked on average only 219.4 ± 13.3 hours per year, using two-thirds of the time for direct work. The authors of [8] compared the work results of five different modern brands of combine harvesters, the harvesting an area of 10-26 ha, according to the three most important indicators – the performance, fuel consumption, grain losses and quality. Increasing the mowing height as an opportunity to reduce the fuel consumption and, therefore, the CO_2 emissions is discussed in the study [9]. On the other hand, the authors of [10] have developed a method for determining the residual value of a used combine harvester. The working possibilities and performance of combine harvesters depending on the type of crop to be harvested and grain moisture in Danish conditions are analysed in [11]. The authors of [10] have developed a method for determination of the

residual value of a used combine harvester. The working possibilities and performance of combine harvesters depending on the type of crop to be harvested and grain moisture in Danish conditions are analysed in [11]. Various data acquisition methods to analyse the need for modernization of the combine harvester fleet are discussed in the article [12]. An extensive study of the performance, fuel consumption and repair costs of the New Holland combines - nine with a tangential threshing machine (CH) and nine with an axial threshing machine (CR) – has been conducted during 63 harvesting seasons by the authors of [13, 14]. It has been established that the CR type combines have higher fuel consumption and also higher performance, and for both types of combine harvesters 10-13% of the price of the combine must be spent for maintenance and repairs. The number of days, suitable for the grain harvesting, the grain moisture changes during the harvesting period and the harvesting costs, depending on these parameters in the Stockholm region over a 30-year period, have been analysed in [15].

All the analysed studies are topical, conducted at a high scientific level. They solve questions about the performance of an individual combine or a group of combine harvesters, the grain losses, fuel consumption, CO_2 emissions, operating parameters etc.. Yet, this review does not cover the performance studies of a larger regional or national combine fleet. The author of the study [11] partially analyzed this issue, finding that the insufficient capacity of the harvester fleet is by 50% more expensive than the excess capacity. In Latvia, the harvested area of cereals and rape has increased by 1.33 times during the last ten years, and the total harvest by approximately 1.20 times [2]. Therefore, it would be expedient to assess whether the development of the combine harvester fleet during this period is appropriate for timely harvesting of the increased harvested area and total yield. Several authors [16, 17] consider that the ratio of the total power of the motors of the combine fleet, or the specific power in $kW \cdot ha^{-1}$, can be a criterion for assessing the adequacy of the performance of the combine fleet. In order to determine this indicator, the age structure of the combine harvester fleet, technical condition, and the most popular combine harvester brands should be determined. The necessary data can be found in the register of the State Technical Supervision Agency (STSA) [18]. The total number of harvesters in the register is 9573, including 2014-2023, on average, 130 new harvesters were purchased annually.

The aim of the study is to find out the dynamics of the total and specific capacity growth of the combine harvester fleet over a ten-year period and to evaluate the sufficiency of the total capacity of the combine harvester fleet for timely harvesting of the areas to be harvested in comparison with the dynamics of the growth of the harvested area of grain and rapeseed. By analysis of the obtained data it is possible to predict the possibility of timely harvesting and the adequacy of the pace of renewal of the combine fleet.

Materials and methods

As mentioned in the previous chapter, the evaluation criterion for the performance of the combine harvesters may the specific power $kW \cdot ha^{-1}$ of the combine engines that are in technical order to the area to be harvested, or the specific power $kW \cdot ha^{-1}$. The harvested area (cereals, rapeseed and legumes) for the harvester fleet in the particular year can be found in the database of the Central Statistics Bureau, Republic of Latvia [2]. To find out the total power, it is possible to calculate the power of the newly purchased combine harvester engines every year by finding the brand, model and engine power of the combine in the register [18] and summing up the power of the respective brand. In a similar way can be calculated the capacity of the used harvesters, purchased in the particular year, by excluding from this list those harvesters that were reregistered several times during the period. It is assumed that all new combines, purchased during the period, are in good working order and are working. Taking into account that in the ten-year period, 88% of the total of 16 brands of combine harvesters belong to four brands - Claas, New Holland, John Deere and Case IH, the data about these combine harvesters were processed to determine the capacity (see Table 1).

In the calculations it is assumed that the power of other brands and models of combines is similar. As the depreciation period of the harvester is usually assumed to be 15 years, a reduction in the capacity should be provided for the replacement (depreciation) of harvesters that have served this period, so the total capacity is reduced by 7.5%. On the other hand, it should be taken into account that in small farms the harvest is also done by combine harvesters in poor technical conditions or unregistered; so the calculated total engine power is increased by 10%, which roughly characterizes the performance of these combine harvesters.

Table 1

Purchase of new harvesters over a period of ten years

Harvester brand	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Claas	71	26	34	46	55	58	29	47	61	64	491
New Holland	33	45	28	41	46	31	25	26	60	41	376
John Deere	10	23	13	26	28	17	9	6	20	22	174
Case IH	8	1	5	6	14	6	8	5	23	10	86
Fendt	-	1	2	5	6	4	1	1	5	4	29
Deutz-Fahr	-	1	2	9	6	3	2	1	2	1	27
Massey Ferguson			1	3	4	5	3	1	-	1	18
The rest	7	8	4	6	7	12	10	13	5	2	84
Total	129	104	89	142	166	136	87	100	176	145	1285

Considering that the publication [17] indicates the total capacity of the harvester fleet in 2014, in the calculations, starting from 2015, the annually calculated capacity should be added to the previous year capacity. The total capacity of the combine harvester fleet should increase every year at least in proportion to the annual growth of the area to be harvested, taking into account the growth of the total harvest. An antecedent increase in total capacity, compared to the harvested area, would mean a possibility of shortening the harvesting period.

Results and discussion

At the end of the year 2023 there were registered 9.573 harvesters, of which 67% were over 30 years old, the majority (64%) in this age group were the harvesters of the SK-5, Yenisei and Don brands,

produced in 1994 [18]. It is clear that the performance of these combines is not essential, some of them are used on small backyard farms. The performance of this group and other harvesters with high wear and tear is evaluated with a 10% increase in the total capacity, based on the methodology. On the whole, 33% or 3.172 harvesters belong to the age groups up to 30 years old, 26% or 2.486 harvesters up to 20 years old (see Figure 1).

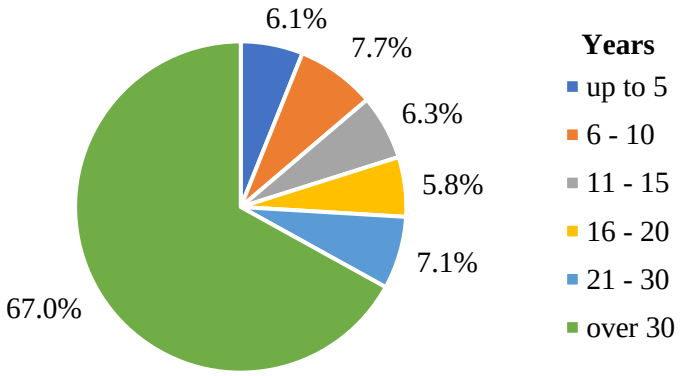

Fig. 1. **Combine harvester distribution by age groups**

The distribution in age groups by five years (Fig. 1) is uniform - 5.9 -7.7% in each; this can be explained by a relatively even purchase of new combines by years with a slight upward trend. On the whole, in the years 2001-2023 there were purchased 2.493 new harvesters or an average of 108 harvesters per year. However, at the beginning of the period, an average of 96 harvesters were purchased per year, at the end of the period – 136, which indicates a slight upward trend. On farms with a harvested area of more than 50 ha, the combine harvesters up to 20 years of age are more often used, the oldest of them being kept in reserve. The average harvested area for one harvester in the age group 1-20 years per season was 410 ha, the harvesters of these age groups harvest most of the area. In technical condition in 2023 there were 36.9% of the registered harvesters, which is a good indicator for the distribution of the age groups, shown in the figure.

In several publications [16; 17] it is recommended to use the specific power in kW·ha^{-1} as a criterion for assessing the adequacy of the performance of the combine fleet, i.e. to relate the total power of the combine harvester fleet engines to the total area to be harvested. The authors of [16] believe that in the developed European countries the sufficient specific power would be 0.32-0.40 kW·ha^{-1}, in the Eastern European countries it is lower. Although the research was conducted more than 20 years ago, considering the development trends of combines, the numerical values could have increased. On the other hand, the study [17] has found that in Latvia in the years 2001-2014 the specific power increased 1.5 times, and in 2014 it was 0.60 kW·ha^{-1}, the increase was roughly proportional to the increase in the average power of one combine harvester.

In order to determine the changes in the total and specific power of the combine harvester fleet in 2015-2023 from the register [18], the brand, model and engine power of the combine harvesters, purchased in the relevant year, were ascertained. By summing up these engine capacities the total power of the combine harvester fleet is obtained for the relevant year. To obtain the specific power, the result is divided by the harvested area.

It has been established that the specific power increased 1.33 times during the period under review and was 0.80 kW·ha^{-1} in 2023. Such an increase can be explained by the aforementioned increase in the purchase of new combines during the period, as well as by the increase in the average power of the purchased new combines from 355 kW·ha^{-1} at the beginning of the period to 410 kW·ha^{-1} at the end. Taking into account the development trends of the combine harvester production [19], it is expected that the increase in power will continue. On the other hand, the total power of the combine harvester fleet in 2014-2023 increased 1.75 times and in 2023 was 825 thousand kW. During this time the harvested area increased 1.35 times, and at the end of the period it was 1022.4 thousand. ha. As it is evident, the increase in the total power of the combine harvester fleet significantly exceeds the increase in the harvested areas. However, the performance of the combine harvesters is also affected by the increase in the harvested total yield, which has increased approximately 1.2 times at the end of the period, compared to the beginning. The influence of the agrobiological properties of the cereals upon the performance results of the combine harvesters is discussed in several works [20, 21]. Using the results of the study [21], it can be estimated that a 20% increase in total yield reduces performance of the combines by 7-8%, i.e. the previously calculated total power as a performance criterion should be reduced by 7.5% at the end of the period. After correction the total power in 2023 was 763 thousand kW, and the increase, compared to 2014, by 1.63 times, which also exceeds the increase in harvested areas, which increased by 1.35 times during this period. Figure 2 shows the total changes in the harvested area, total yield and the power of the harvester fleet in 2014-2023.

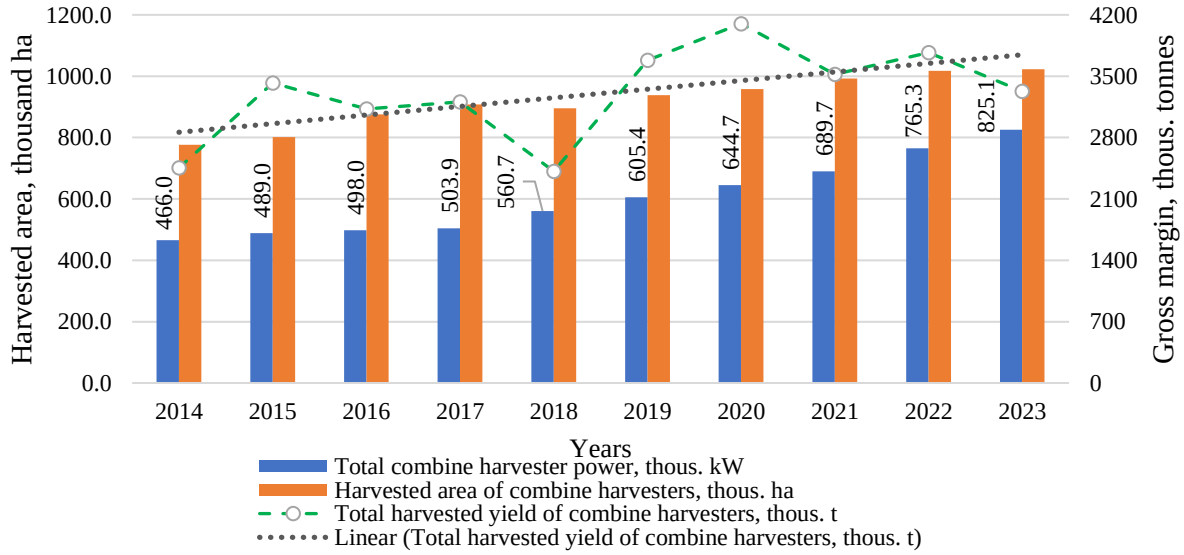

Fig. 2. **Changes in the harvested area, total yield of the harvester fleet 2014-2023**

Evaluating the analyzed factor – the total power, specific power, harvested area and total yield of the engines of the combine fleet, the possible impact upon the performance of the combine fleet, the

harvesting rates and duration of harvesting, it can be found that the increase in the total and specific power is compensated, and it exceeds the increase in the harvested area and total yield, allowing the to increase the harvester fleet performance and shorten the harvesting duration in the period reviewed and from now on. This is important due to extreme climatic conditions several times during the reviewed period.

Viewing these results together with the publication [17], which evaluates the development of the combine harvester fleet in 2001-2014, it can be concluded that the growth rates of the harvested areas are gradually decreasing, whereas the growth rates of the total power of combines are increasing. The rate of growth of the harvested areas will continue to decrease in the future because, in addition to the local conditions, it will be limited by the requirements of several EU directives. Therefore, there is no reason to continue intensively increasing the performance of the harvester fleet. This process can be regulated by the amount of subsidies for the purchase of harvesters.

Conclusions

1. The age group up to 20 years includes 26.0% of harvesters; in a technical condition there are 85.8% of them; the harvesters of this group harvest most of the area; the calculations assume that 66.8% of the harvesters in the age group over 30 years harvest 10% of the area.
2. The total power of the harvester fleet increases during the period under review, as the average power of a new combine engine increases, and the number of the purchased harvesters gradually increases.
3. The pre-emptive increase of the total power of the combine harvester fleet, compared to the area to be harvested, increases its performance, compensating the increase in the area to be harvested and total yield, and allows to reduce the duration of harvesting.
4. As the average capacity of the new harvesters is expected to increase in the future but the rate of growth of the harvested areas will decrease, it is expedient to consider the amount of subsidies for the purchase of new harvesters.

Author contributions

Conceptualization D.V., methodology D.V. and A.R.; investigation A.R. and D.V., writing – review and editing D.V. and A.R. All authors have read and agreed to the published version of the manuscript.

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