

Trends in the Development of the Tractor and Combine Fleet in Latvia

Adolfs Rucins

Latvia University of Life Sciences and Technologies

Jelgava, Latvia

adolfs.rucins@lbtu.lv

Dainis Viesturs

Latvia University of Life Sciences and Technologies

Jelgava, Latvia

dainis.viesturs@lbtu.lv

Abstract— The article contains an analysis of the results of research of the development of the tractor and combine fleet in Latvia in 2014-2023. The age structure and technical condition of the tractor fleet have been determined. More than 100 thousand tractors and 9.5 thousand combines are registered in the country. More than 100 thousand tractors and 9.5 thousand combines are registered in Latvia. 32.2% of tractors are in good technical condition, 71% of tractors are over 30 years old, only 10.8% fall into the age group of up to 15 years, which is usually considered the depreciation period. Combine harvester fleet is in a similar technical condition. The current registration procedure of the tractor equipment - without excluding the obsolete and worn-out equipment from the register - does not provide an impartial impression of the technical condition of the tractor equipment fleet, the performance of the fleet and the energy supply to agriculture. During the period an average of 462 new tractors with a power exceeding 100 HP and 130 new harvesters were purchased annually. Using the available registry data about the capacity and year of registration of tractors and combines, the total capacity of the fleet by year was calculated. To ensure depreciation of the tractor equipment that has been in operation for more than 15 years, the calculated capacity has been reduced by 15%, but increased by 10%, which approximately corresponds to the area, cultivated by the equipment that is more than 15 years old. The calculated total capacity is compared with the cultivated area in the corresponding year. It has been established that during the period the total capacity of the tractor fleet has increased by 35%, and the sown area by 13%, so the increase in capacity significantly outpaces the increase in the sown area, which allows the work to be carried out in shorter agrotechnical terms. The capacity of the combine harvester fleet has also increased similarly. It is expected that the total capacity of the tractor equipment will continue to grow at a similar pace. Since the growth rate of the sown areas will decrease in the future, the issue of the amount of subsidies for the purchase of the new tractor equipment is debatable.

Keywords— engine capacity, fleet of tractors and grain combine harvesters, sown area.

I. INTRODUCTION

The area of the agricultural and arable land in Latvia is increasing annually at the expense of recovery of the overgrown areas, and, consequently, the area sown with agricultural crops. Thus, in the period 2014-2023, the area of land, used for agriculture increased by 5.3%, while the sown area increased by 13.0%, and at the end of the period it was 1303.0 thousand ha. Of the sown areas of agricultural crops, the fastest growth is for cereals, rapeseed and legumes - during the mentioned period their total area increased by 33.3%, and in 2023 it was 1022.4 ha [1]. The production of several other types of crops is also growing. It is important that the crop production accounted for almost two-thirds (65.5%) of the total value of the final agricultural goods, produced in the country in 2022 [2]. Production is gradually concentrating on larger farms; in 2022 there were 580 farms in Latvia with a cereal and rapeseed sown areas of over 300 ha, an increase of 25% since 2014 [1]. Such intensification of production requires also an appropriate increase in the performance of the tractor and combine fleet as an important means of production. Many scientists have focused on research of the structure of the tractor and combine fleets, labour costs, performance, optimal operating modes, fuel consumption, and other characteristics. In a survey of farmers in the EU countries [3] it was found that in the period of time from 2014 to 2020 they would like to invest the largest amount of investments (40.3 %) into machinery, and of the total investment into machines, 39.2% into the purchase of tractors. The age structure of the tractor and combine fleet in Estonia, the operating and repair costs, depending on the age and brand of tractors, are discussed in studies [4] and [5]. The research of the fuel consumption, performance, and costs of the up-to-date combine harvesters has been conducted by the authors of [6] and [7], finding that the combine harvesters with higher capacity are more economically profitable. The authors of publication [8] in their turn, conducted experiments in 13 fields throughout Italy for four years, and then, by collecting and analysing

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol4.8419>

© 2025 The Author(s). Published by RTU PRESS.

This is an open access article under the [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

the extensive material, developed an innovative method for determining the operating costs of the machinery. The characteristics of the Polish farms and tractor fleet are presented in articles [9,10], where it is stated that in 2018 the average farm area was 9.8 ha and the average tractor power was 45.3 kW, and there are also shown changes in these indicators by region and year. The authors of study [11] have identified the most popular brands of tractors and combines in the Czech Republic, the age structure of the machine fleet; and they have also determined the cyclical nature of the number of machines, sold over the years. The efficiency of the combine depending on the harvested area during a three-year period is examined in the work [12]. The authors of [13], compiling data about 90 combines in Lithuania and Latvia, find that in 2016-2018 a combine harvester has worked, on average, only 219.4 ± 13.3 hours per year, using two-thirds of the time for direct work. The age structure of the Latvian tractor fleet, its technical condition, and the energy supply of farms of various sizes are discussed in publication [14].

Methods for determination of the operating and repair costs of tractors are analysed in publication [15]. A methodology for the calculation of the fuel, consumed by tractors in different load modes, is presented in study [16]. The working capabilities and performance of combine harvesters, depending on the type of crop being harvested and grain moisture in Danish conditions, were analysed in [17]. The number of days, suitable for harvesting cereals, changes in the grain moisture during the harvesting period, and harvesting costs depending on these parameters in the Stockholm region over a 30-year period, are analysed in a study [18]. It was found that the average moisture content of the harvested grain in August was 19%. In turn, the authors of [19] have developed a method how to determine the It was found that the average moisture content of grain, harvested in August, was 19%. In turn, the authors of [19] have developed a method how to determine the residual value of a used combine.

The studies reviewed are topical; however, they are addressed to issues, such as the prevalence of a specific type of machines, the performance of the age structures, the losses of grain, the fuel consumption, CO₂ emissions, and other operational parameters. Yet these studies do not consider the issue of the performance and adequacy of the total tractor and combine fleet of a larger region or country for timely completion of the field work in a context with the increase in the sown area and production volume, mentioned at the beginning of the chapter. Therefore, it would be appropriate to assess whether the development of

the tractor and combine fleet is adequate for timely completion of the increased volumes of the field work. This issue has been partly analysed by the author of study [11], finding that insufficient capacity of the combine fleet is by 50% more expensive than excess capacity. Several authors [14, 20] believe that the criterion for the assessment of the adequacy of the performance of a fleet of tractors and combines may be the ratio of the total power of the engines in their fleet to the cultivated area, or specific power kW ha⁻¹, but the increase in the total power of the fleet should outpace the increase in the sown area and harvested area, respectively. To determine these indicators, it is necessary to find out the capacity of each registered tractor and combine harvester, the age structure of their fleet, technical condition, the most common brands, as well as the sown area and the harvested area in each year of the period.

The aim of this study is to determine the dynamics of the growth of the total and specific capacity of the tractor and combine fleet over a ten-year period and, in comparison with the dynamics of the growth of the sown area and the harvested area, to assess the adequacy of the total capacity of the fleet for timely processing of these areas.

By analysis of the obtained data one can predict a possibility of timely completion of work and the need for renewal of the technical fleet.

II. MATERIALS AND METHODS

Intensive modernization of the machine fleet started after Latvia joined the EU in 2004. Due to the availability of structural funds, the purchase of modern tractors and combine harvesters increased essentially. The trade in machines, manufactured in the Commonwealth of Independent States (CIS), had practically ceased at the beginning of the 2000s, with the exception of the Belarus tractors, manufactured in Belarus and certified in accordance with the EU requirements, which were sold in Latvia until 2022. The purchase of new tractors by year is shown in Table 1. As it is evident, 4,617 new tractors have been purchased over the past ten years, or an average of almost 462 new tractors per year. In the table there are compiled data only of tractors with a power of over 100 HP because the tractors with a lower power of the companies, shown in the table, are practically not purchased for agriculture (except for Belarus), and, in addition, on the farms producing goods, tractors with a lower power are used only for auxiliary work.

TABLE 1 PURCHASE OF NEW TRACTORS DURING A TEN-YEAR PERIOD

| Brand of the tractor | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | Total |
|----------------------|------|------|------|------|------|------|------|------|------|------|-------|
| John Deere | 28 | 57 | 105 | 113 | 91 | 70 | 62 | 74 | 110 | 83 | 793 |
| Valtra | 41 | 51 | 62 | 78 | 84 | 83 | 64 | 71 | 112 | 96 | 742 |
| Claas | 14 | 33 | 41 | 61 | 89 | 84 | 86 | 117 | 111 | 102 | 738 |
| Belarus | 91 | 70 | 69 | 78 | 89 | 88 | 19 | 24 | 3 | - | 531 |
| New Holland | 53 | 21 | 20 | 81 | 67 | 48 | 55 | 47 | 64 | 69 | 525 |
| Case IH | 13 | 20 | 31 | 42 | 50 | 39 | 40 | 50 | 49 | 51 | 385 |
| Fendt | 6 | 18 | 23 | 28 | 36 | 18 | 30 | 26 | 51 | 36 | 272 |
| Massey Ferguson | 11 | 28 | 30 | 36 | 29 | 37 | 34 | 16 | 34 | 16 | 271 |
| Deutz-Fahr | 4 | 14 | 16 | 33 | 39 | 27 | 31 | 27 | 22 | 16 | 229 |

| Brand of the tractor | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | Total |
|----------------------|------|------|------|------|------|------|------|------|------|------|-------|
| Others over 100 hp | 5 | 4 | 7 | 11 | 11 | 18 | 17 | 14 | 18 | 25 | 132 |
| Total | 266 | 316 | 404 | 561 | 585 | 512 | 438 | 466 | 574 | 494 | 4617 |

As evident, the most popular tractors, manufactured in the EU countries, are John Deere, Valtra and Claas, which account for approximately half of the total number

purchased. Meanwhile, the purchase of new combines by year is shown in Table 2.

TABLE 2 PURCHASE OF NEW COMBINES DURING A TEN-YEAR PERIOD

| Brand of the combine | 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 |
| Others | 7 | 8 | 4 | 6 | 7 | 12 | 10 | 13 | 5 | 2 | 84 |
| Total | 129 | 104 | 89 | 142 | 166 | 136 | 87 | 100 | 176 | 145 | 1285 |

As it is evident, 1285 new combines would be purchased during ten years, or, an average, 130 per year, of which 88% are from four brands – Claas, New Holland, John Deere, and Case IH. Tractor machinery purchases by year depend mainly on the amount of subsidies granted.

In the register of the State Technical Supervision Agency (STSA) [21], data can be found on the registration of tractors and combines by year, technical condition in the relevant year, number of vehicles purchased each year, make, model and engine power. By processing these data with statistical methods the age structure and technical condition of this fleet of vehicles have been determined. Using the data from the STSA register and Tables 1 and 2, the total capacity of all the new tractors and combine harvesters of the same brand were initially calculated by year, then, by summing the capacity of all the brands, the total capacity of the tractor and combine fleet in the relevant year. Similar calculations were made for the used equipment, purchased in the relevant years. It is assumed in the calculations that the depreciation period of this equipment is 15 years and that all the tractors, purchased since 2014, are in operation. The total capacity of the fleet has been reduced by 7.5% to allow for replacement (depreciation) of worn-out equipment, and increased by 10%, which could roughly characterize the performance of a large number (approximately 77000) of aging equipment manufactured in the CIS countries, which is over 30 years old, in the register. In order to be able to carry out the field work in a timely manner, the increase in the total power of tractors should outpace the increase in sown areas, and the increase in the total power of combine harvesters should outpace the increase in the area to be harvested.

Data about the sown area and the harvested area can be obtained from statistical reports [1]. An anticipated

increase in total capacity, compared to the area to be processed, means the possibility of shortening the work period [22]. In turn, by relating the total capacity of the fleet to the area to be processed, the specific capacity of the machine fleet is obtained. As mentioned, several authors [14, 20] propose using specific capacity as a criterion for the assessment of the sufficiency of a fleet's performance. By analysis of the obtained data one can judge about the sufficiency of the pace of renewal of the machine fleet.

III. RESULTS AND DISCUSSION

The total number of registered tractors and combine harvesters is increasing every year, as an average of 460 new tractors and 128 combines were purchased every year; but the existing registration procedure also allows for a large number of worn-out units of equipment to be in the register; this procedure does not impose any obligations or liabilities on the owner. According to STSA data [21] at the end of 2023 there were registered 103,706 tractors and 9,573 combines.

The distribution of the registered tractors by age group is shown in Figure 1, while that of combines is shown in Figure 2.

As obvious from Figures 1 and 2, 67 - 71% of the equipment is older than 30 years, the majority in this age group are obsolete MTZ, T-40, T-25 and similar low-power brands of tractors and SK-5, Yenisei and Don combine harvesters, manufactured before 1994. The performance of these machines is negligible, some of them are used on small homestead farms or on larger farms for auxiliary work. The performance of this group and other tractors and combines with high wear and tear has been calculated using a methodologically based 10% increase in the total power. The age group up to 15 years, which is most often assumed to be the depreciation period of the

machinery, includes 10.8% or 11,200 tractors and 20.1% or 1,925 combines. Taking into account the sown area [1], the area to be cultivated by one tractor in the age group up to 15 years in 2023 was 116.5 ha, while the area to be harvested by one combine harvester of this group was 530 ha. The equipment of this group in a set of up-to-date inventory, ensures the production of the greatest part of goods. The existing registration procedure – without excluding the obsolete equipment from the register – does not provide an objective picture of agricultural energy supply and makes it difficult to compare the characteristics of the Latvian machinery fleet with the data from Estonia, Poland, the Czech Republic [5], [10], [11], and other countries.

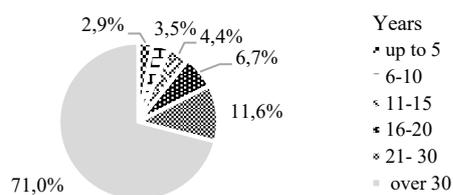


Fig. 1. Distribution of registered tractors by age groups.

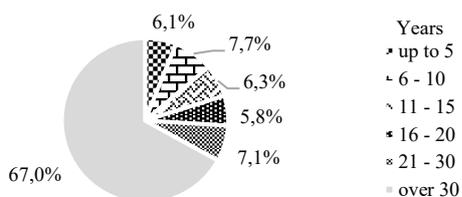


Fig. 2. Distribution of registered combine harvesters by age groups.

As a result of the current registration procedure, the number of tractors has already exceeded 100 thousand. As a result, the average age of the fleet is increasing and the technical condition is deteriorating, creating a false impression about the energy security of agricultural. In 2023 there were 32.2% of registered tractors in technical order, including 90.6% in the age group 1–5 years, and 18.9% in the age group over 30 years. A similar situation is with combines - in 2023, 36.9% were in good technical condition, including 95.3% in the age group 1 - 5 years, but 15.5% - in the age group over 30 years. These indicators have not changed significantly over the past ten years. An average of 32.2 – 36.9% of tractors and combines in good technical condition for the age group distribution, shown in Figures 1 and 2, are considered as a good indicator.

Along with the age structure and technical condition of the fleet, the performance of the fleet is characterized by the total power of its engines. In accordance with the methodology this indicator should be viewed together with the area sown with agricultural crops in the corresponding year. Changes in the total capacity of the tractor fleet, the area sown with agricultural crops, and the specific capacity over a ten-year period are shown in Figure 3.

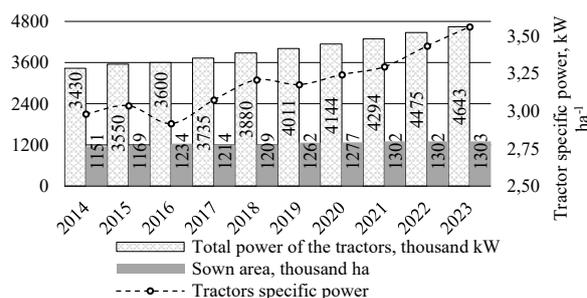


Fig. 3. Changes in the total capacity, specific capacity and sown area of agricultural crops of the tractor fleet in 2014-2023.

The sown area increased by 13% during the period, and at the end of the period it was 1,303 thousand ha, while the total capacity of the tractor fleet increased by 35%. This can be explained by the relatively intensive purchase of new tractors during the period (an average of 462 per year) and the increase in the average power of the purchased tractors. An anticipated increase in the total capacity, compared to the increase in the sown areas, allows the work to be completed in shorter agrotechnical terms, which is important under increasingly extreme climatic conditions. Several authors [14], [20] use specific power as an indicator, characterizing the energy supply of agriculture, which is obtained by dividing the total power of the tractor fleet by the area, sown with agricultural crops in the corresponding year. This indicator has increased from 3.0 to 3.6 kW ha⁻¹ during the period (see Fig. 2). The indicator is relatively high, as a previous study [14] found that in Latvia, depending on the size of the farm, it is 1.3 - 4.1 kW ha⁻¹. It decreases as the farm area increases, as the equipment is used more intensively on larger farms. In turn, the authors of article [20] points out that in the European countries this indicator, depending on the size of the farm, is 1.1 - 8.1 kW ha⁻¹. High energy supply allows for shorter deadlines of work but, at the same time, it increases the cost of the product.

But Figure 4 reflects changes in the total capacity, harvested area and total yield of the combine fleet over a ten-year period. As one can see, the harvested area increased by 35% during the period, and at the end of the period it was 1022 thousand ha, while the total capacity of the fleet of combine harvesters increased by 70%. Such an increase can be explained by increased purchase of new combines during the period, as well as by the increase in the average capacity of a new combine 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 in the combine production [23], it is expected that the increase in capacity will continue. However, the performance of the combine harvesters is also affected by the increase in the total harvest, which increased by approximately 1.2 times at the end of the period, compared to the beginning. The impact of the agrobiological characteristics of cereals upon the performance of the combine harvesters has been discussed in several articles [24], [25]. Using the results of study [25], it can be roughly estimated that a 20% increase in the

total yield reduces the combine performance by 7-8%, i.e., the previously calculated total capacity as a performance criterion at the end of the period should be reduced by 7.5%. After adjustment the total capacity in 2023 was 825.1 thousand kW, an increase of 1.70 times, compared to 2014, which also exceeds the increase in the harvested areas, which increased 1.35 times during this period.

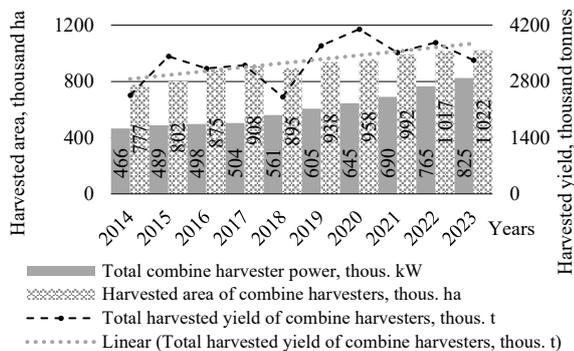


Fig. 4. Changes in the total capacity, harvested area and total yield of the fleet of combines in 2014-2023.

When evaluating these results together with publication [14], which examines the development of the fleet of tractors since 2007, one can conclude that the growth rates of the sown areas are gradually decreasing but the growth rates of the capacity of the total fleet of tractor and combines are increasing. In its turn, the trend, identified in publication [3] – to invest intensively in the purchase of new tractors – indicates that the growth in the total capacity of the tractor fleet will continue. The authors of publication [23] state that the engine power of the new combine harvesters will continue to increase, and thus the total power of the combine harvester fleet will also increase. However, the amount of the land used for agriculture is not increasing, so the intensity of the increase in the arable land will continue to decrease, as its use is limited by the requirements of several EU directives, in addition to the local conditions. Therefore there is no ground for intensive increase in the performance or total capacity of the fleet of tractors and combine harvesters, as it has occurred before; this process can be regulated by the amount of subsidies for the purchase of the aforementioned equipment.

IV. CONCLUSIONS

The age group up to 15 years includes 10.8% of tractors and 20.1% of combines, 78.9 and 83.8% of them are in technical condition, respectively. The equipment of this group, complete with modern inventory, ensures the production of the majority of goods.

The existing procedure of registration of the tractor equipment –without excluding the obsolete and worn-out tractors and combines from the register – does not provide an impartial picture of the technical condition of the fleet, its performance and the energy supply of agriculture.

The anticipated increase in the total capacity of the tractor equipment fleet, compared to the increase in the sown area, increases its performance, compensates for the increase in the sown area and total harvest, and allows work to be completed in shorter agrotechnical terms.

Since the total capacity of the tractor equipment fleet is expected to increase at approximately the same pace as before but the growth rate of the sown areas will decrease, there is debatable the issue of the amount of subsidies for the purchase of new tractors and combines.

REFERENCES

- [1] LR Centrālā statistikas biroja materiāli 2014...2023. g. (Materials of the Central Statistic Bureau of Latvia 2014...2023). (In Latvian). Available at: https://data.stat.gov.lv/pxweb/lv/OSP_PUB/ [Accessed March 19, 2025]
- [2] Latvian agriculture 2022. Annual report of the Ministry of Agriculture, 2023 5-6 pp. (Latvijas lauksaimniecība 2022. Zemkopības ministrijas gada ziņojums). (In Latvian). Available at: <https://www.zm.gov.lv/lv/media/12006/download?attachment> [Accessed March 19, 2025]
- [3] M. Lefebvre, K. De Cuyper et. al. European Farmers Intentions to Invest in 2014-2020: Survey Results. JRC90441, JRC Working Papers, 2014. Joint Research Centre, 100. Available at: <https://publications.jrc.ec.europa.eu/repository/handle/JRC90441> [Accessed March 19, 2025]
- [4] J. Olt, U. Traat. The maintenance costs of Estonian tractor-fleet. Proceedings of 10th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2011, pp. 196-200. Available at: https://www.iitf.lbtu.lv/conference/proceedings2011/Papers/036_Traat.pdf [Accessed March 19, 2025]
- [5] J. Olt, R. Ilves, A. Kuut Overview of developments of cereal harvester fleet in Estonia. Proceedings 18th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2019, pp. 179-184. <https://www.iitf.lbtu.lv/conference/proceedings2019/Papers/N230.pdf> [Accessed March 19, 2025] DOI:10.22616/ERDev2019.18.N230
- [6] J. Masek, P. Novak, T. Pavlicek Evaluation of combine harvester fuel consumption and operation costs. Proceedings of 14th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2015, pp. 78-83. https://www.iitf.lbtu.lv/conference/proceedings2015/Papers/013_Masek.pdf <https://doi.org/10.17221/98/2017-RAE> [Accessed March 19, 2025]
- [7] L. Benes, P. Novak et. al. John Deere combine harvesters fuel consumption and operation costs. Proceedings of 13th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2014, pp. 13-17. https://www.iitf.lbtu.lv/conference/proceedings2014/Papers/02_Benes_L.pdf [Accessed March 19, 2025]
- [8] M. Guerrieri, M. Fedrizzi et.al. An innovative multivariate tool for fuel consumption and costs estimation of agricultural operations. Spanish Journal of Agricultural Research 14(4), e0209, 11 ges (2016) eISSN: 2171-9292. <http://dx.doi.org/10.5424/sjar/2016144-9490> [Accessed March 19, 2025]
- [9] J. Barwicki, S. Gach, S. Ivanovs Proper utilization of soil structure for crops today and conservation for future generations. Proceedings of 11th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2012, pp. 10-15. https://www.iitf.lbtu.lv/conference/proceedings2012/Papers/001_Barwicki_J.pdf [Accessed March 19, 2025]

- [10] E. Lorencowicz, J. Uziak. Regional structure of tractor market in Poland. *Agricultural Engineering* 2020, vol. 24 No. 3 pp. 51-62. ISSN 2 0 8 3 -1 5 8 7; DOI: 10.1515/agriceng-2020-0026
- [11] J. Masek, P. Novak. Overview of combine harvester and tractor structure on farms in the Czech Republic. Proceedings of 17th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2018, pp. 240 - 245. DOI: 10.22616/ERDev2018.17.N282
- [12] M. Pristavka, K. Krištof, P. Findura. Reliability monitoring of grain harvester. *Agronomy Research*, vol. 15 (3), 2017, pp. 817-829. (PDF) [Reliability monitoring of grain harvester](#) [Accessed March 19, 2025]
- [13] D. Savickas, D. Steponavičius et. al. Combine harvester fuel consumption and air pollution reduction. *Water Air Soil Pollution* (2020) 231: 95. <https://doi.org/10.1007/s11270-020-4466-5> [Accessed March 19, 2025]
- [14] N. Kopiks, D. Viesturs, V. Valainis The Fleet of Tractors on the Farms of Latvia, Its Structure and Energy Intensity. Proceedings of 14th International Scientific Conference “Engineering for Rural Development”, Jelgava, 2015, pp.84-87. https://www.iitf.lbtu.lv/conference/proceedings2015/Papers/014_Kopiks.pdf [Accessed March 19, 2025]
- [15] I. Galiev, C. Khafizov et al., Optimization of tractor operation level. Proceedings of 20th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2021, pp. 38-42. [International Scientific Conference Engineering for Rural Development 2021](#) [Accessed March 19, 2025]
- [16] R.D. Grisso, M. Kocher, D. Vaughan. Predicting tractor fuel consumption. *Applied Engineering in Agriculture*. 20(5), 2004, 553-561. (doi: 10.13031/2013.17455) (PDF) [Predicting Tractor Fuel Consumption](#) [Accessed March 19, 2025]
- [17] C. G. Sørensen. Workability and Machinery Sizing for Combine Harvesting. *Agricultural Engineering International: The CIGR e-journal* September 2003, pp. 1-19. <https://www.researchgate.net/publication/280316072> [Accessed March 19, 2025]
- [18] A. de Toro, C. Gunnarsson et.al. Cereal harvesting – strategies and costs under variable weather conditions. *Biosystems Engineering*, Volume 111, Issue 4, April 2012, pp. 429-439. <https://doi.org/10.1016/j.biosystemseng.2012.01.010> [Accessed March 19, 2025]
- [19] I. Herranz-Matey, L. Ruiz-Garcia Agricultural Combine Remaining Value Forecasting Methodology and Model (and Derived Tool). *Agriculture* 2023, 13, 894. <https://doi.org/10.3390/agriculture13040894> [Accessed March 19, 2025]
- [20] J. Pawlak, G. Pelizzi, M. Fiala On the Development of Agricultural Mechanization to Ensure a Long-Term World Food Supply. *Agriculture Engineering International: the CIGR Journal of Scientific Research and Development*. Invited Overview Paper. Vol. IV. June, 2002, pp. 1- 21. (PDF) [On the development of agricultural mechanization to ensure a long-term world food supply](#) [Accessed March 19, 2025]
- [21] Valsts Tehniskās uzraudzības aģentūra (VTUA) State Technical Supervision Agency (STSA) Database: Registration data of agricultural machinery in the Republic of Latvia. (In Latvian). Available at: <https://data.gov.lv/dati/lv/dataset/traktortechnikas-registracijas-dati-latvijas-republika> [Accessed March 19, 2025]
- [22] A. Rucins., D. Viesturs Trends in development of grain combine harvester fleet in Latvia. Proceedings of 23th International Conference “Engineering for Rural Development”, Latvia, Jelgava, University of Agriculture, 2024, pp. 149-154. DOI: 10.22616/ERDev.2024.23.TF033 https://www.iitf.lbtu.lv/conference/proceedings2024/Papers/TF03_3.pdf [Accessed March 19, 2025]
- [23] Trends in threshing crop harvesting process technology: ‘combine harvesters – increased power density and work quality. - October 12, 2023, (DLG). At *Agritechnica* 2023. Available at: <https://www.agritechnika.com> [Accessed March 19, 2025]
- [24] L. Špokas, V. Adamčuk et al. The experimental research of combine harvesters. *Research in Agricultural Engineering*, Vol. 62, 2016 (3): 106–112. doi: 10.17221/16/2015-RAE [The experimental research of combine harvesters](#) [Accessed March 19, 2025]
- [25] I.M. Kuzmich, I.L. Rogovskii et. al. Research of passage capacity of combine harvesters depending on agrobiological state of bread mass. *AGRITECH- IV-20 IOP Conf. Series: Earth and Environmental Science* 677 (2021) 052002. DOI:10.1088/1755-1315/677/5/052002 [Research of passage capacity of combine harvesters depending on agrobiological state of bread mass - IOPscience](#) [Accessed March 19, 2025]