Justification of priority factors affecting the efficiency of the tractor fleet

V. A. Zubina*

Federal Scientific Agroengineering Center VIM, 1-st Institutsky proezd, 5, Moscow, 109428, Russia.

Abstract. Analysis of numerous sources shows that the following group of factors can be distinguished, which can be said to be the main ones: Qualification of machine operator, Annual load of tractors, Number of tractors per 1000 ha of arable land, Age of machinery in the tractor fleet, Agrotechnical terms of harvesting and sowing within the agro-term, General technical level of technology in the tractor fleet, The costs of maintenance and repair of agricultural machinery in the tractor fleet, Tractor technical readiness factor. Based on the methodology for calculating the coefficient of concordance for each group of factors, as a measure of the consistency of a group of experts, priority factors are identified that affect the operation of the tractor fleet. Experts of farms and workers of agricultural departments of Russia took part in the examination, namely: Kaluga region, Kostroma region, Tula region, Yaroslavl region and other organizations. In total, 30 people independently participated in the examination: farm managers, chief engineers, agronomists, etc.

1 Introduction

An objective comprehensive assessment of the performance of the tractor fleet, taking into account specific natural and production conditions, is the main task of analyzing the use of the tractor fleet of agricultural organizations, which directly covers all issues of the production and technical operation of machines. In addition, the yield of agricultural crops, the cost of work and production, as well as other general economic indicators, depend on the degree of use of the tractor park.

Therefore, a comprehensive assessment of the use of the tractor fleet is possible only on the basis of technical, organizational and economic indicators.

2 Materials and methods

For a comprehensive assessment and analysis of the use of equipment in agricultural organizations, it is necessary to take into account the equipment of organizations with equipment, the level of mechanization of crop production, the use of the tractor fleet, the efficiency of servicing the tractor fleet, as well as its technical and economic indicators [1].

* Corresponding author: lera_zubina@mail.ru

Analysis of numerous sources shows that the following group of factors can be distinguished, which can be called the main ones: Number of tractors per 1000 ha of arable land, General technical level of technology in the tractor fleet, Agrotechnical terms of harvesting and sowing within the agro-term, Tractor technical readiness factor, Annual load of tractors, The costs of maintenance and repair of agricultural machinery in the tractor fleet, Qualification of machine operator [2-3].

2.1 Number of tractors per 1000 ha of arable land

One of the main indicators of the technological demand for tractors is the number of tractors per 1000 hectares of arable land. The complex indicator for the tractor fleet and arable land is the tractor equipment, which reflects the energy supply of crop production at a constant average tractor power in the park. In 2019, in the EU countries, there are 85 tractors per 1000 hectares of arable land, in China there are 28 tractors per 1000 hectares of arable land, and in the United States there are 26 tractors per 1000 hectares of arable land, in Russia 3.2 tractors. Number of tractors per 1000 ha of arable land in Russia from 1990 to 2019shown in Figure 1.

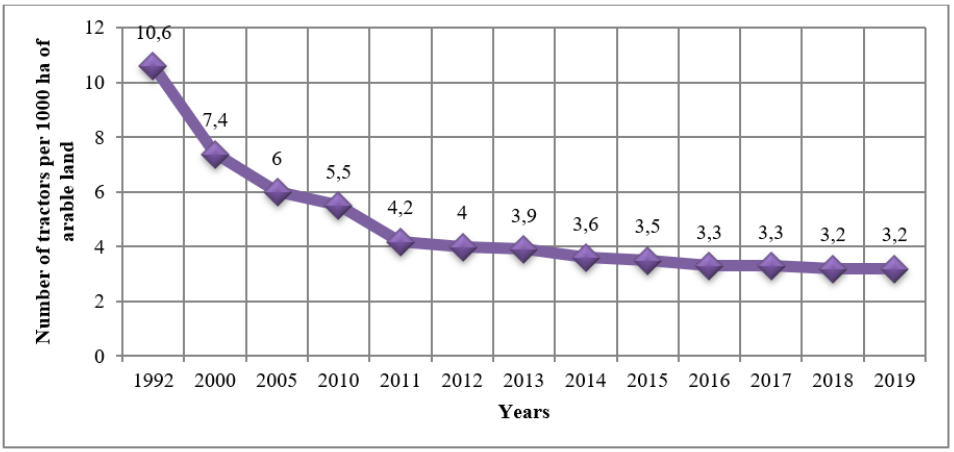

Fig. 1. Number of tractors per 1000 ha of arable land in Russia from 1990 to 2019

2.2 General technical level of technology in the tractor fleet

The general technical level of tractors is one of the most important technical and economic indicators of the use of machine-tractor units, on which the efficiency of all agricultural production largely depends. A distinctive feature of agricultural production is that each operation for the cultivation of a particular crop should be carried out within the optimal calendar terms strictly defined by soil and climatic conditions. Deviation from these dates inevitably leads to both quantitative and qualitative crop losses.

The technical level of the tractor is determined by a complex indicator - the productivity of the plowing unit for 1 hour of shift time under reference conditions. In turn, this complex indicator depends on the unit indicators of the tractor: operating weight; engine operating power; transmission type; type of mover; feature of the kinematics of rotation; location of the control station; the degree of automation of tractor control; the adaptability of the engine to overcome dynamic fluctuations of resistance. Differences in the level of utilization of equipment and the efficiency of using the machine and tractor fleet of agricultural producers are determined by the technical properties of machines (design

parameters and quality of manufacture of the machine, its technical condition, reliability of units and individual units and parts in operation, maintenance of the machine, etc.). The effect of these factors causes the loss of working time for technological and technical reasons. Therefore, an important reserve for increasing the hourly productivity of agricultural machines is to reduce their downtime during working hours, as well as reduce the cost of working time of the unit for idle travels and turns.

2.3 Agrotechnical terms of harvesting and sowing within the agro-term

Providing farms with equipment that performs all agrotechnical operations depends largely on the correct determination of the rational duration of mechanized work. The low level of technological and technical equipment of agricultural production is the main reason for the untimely performance of certain mechanized work, which entails loss of yield, for example, grain (25-30%) and potatoes (40-50%) [4]. In this regard, the determining factor influencing all aspects of the functioning of agriculture is the indicators of the duration of mechanized work on cultivation and harvesting, on which the economic activity of farms of various types largely depends [5-6].

2.4 Tractor technical readiness factor

For the rational organization of the use of technology and management of production processes, it is extremely important to determine the coefficient of technical readiness of machinery and equipment - the degree of readiness of tractors, agricultural machinery and equipment, vehicles - to perform mechanized agricultural and other work. Timeliness of plowing, sowing, care of agricultural crops, harvesting depends on the degree of readiness of machinery and equipment. Where the coefficient of technical readiness of machinery and equipment is higher, the yield is lower, the production efficiency is higher [7-9].

The technical readiness factor (K_{tr}) for certain types of equipment - tractors, cars, combine harvesters, forage harvesters, etc. - is defined as the ratio of serviceable equipment of this type (T_{es}) to all available equipment of this type (T_{ea}):

$$K_{tr} = \frac{T_{es}}{T_{ea}}$$

T_{es} – serviceable equipment of this type
T_{ea} – all equipment in the presence of a tractor fleet

2.5 Annual load of tractors

The level of seasonal utilization of equipment largely determines the amount of operating costs, including labor costs, deductions for renovation and repairs, the cost of fuel and lubricants, and the cost of storing equipment. Depreciation and storage costs are a constant part of the operating cost, independent of the volume of work performed. Therefore, the greater the seasonal or annual load of equipment, the lower the amount of depreciation per load unit, which greatly contributes to the reduction of operating costs and improvement of the efficiency indicators of the use of equipment [10-11].

2.6 The costs of maintenance and repair of agricultural machinery in the tractor fleet

With an increase in the level of utilization of equipment, the amount of deductions for repair and maintenance increases, and the more, the more intensively the equipment is used.

The prevailing market price level for agricultural machinery has a decisive influence on the amount of deductions for depreciation and repair. In this regard, the large price difference between domestic and foreign machines often does not compensate for their best technical and operational indicators and leads to an increase in unit costs for performing mechanized work [12-13]. The value of operating costs is also significantly influenced by the prices of fuel and fuels and lubricants, as well as the level of remuneration of machine operators. The high cost of living labor is one of the motivating factors when making a decision to equip its own machine and tractor fleet with more highly productive, energy-rich equipment. The low cost of labor makes it profitable to use less productive machinery that requires more machine operators. Of great importance in improving the indicators of the use of technology is a rational choice of the organizational and economic form of using or acquiring new technical means.

2.7 Qualification of machine operator

Of particular importance in increasing labor productivity, which has a direct impact on the efficiency of the use of equipment, is also the skill level of machine operators, work experience, education and other factors. The provision of agricultural organizations with highly qualified machine operators is one of the most important conditions for increasing labor productivity, and, as a consequence, the level of efficiency in the use of all equipment. For an agricultural organization, the optimal level of provision with machine operators, the degree of their professional training, the rational organization of their labor contribute to the fullest use of technology, the performance of agricultural work within agro-technical terms [14]. The lack of machine operators leads to incomplete employment of machines during the year or season, while the excess of these personnel is the reason for the unproductive use of labor and a decrease in wages.

2.8 Age of machinery in the tractor fleet

The qualitative characteristic of the tractor fleet is the age of the equipment. In modern conditions, the efficiency of agricultural production is influenced by such characteristics of the tractor fleet as the degree of recovery (quantitative reduction), the number and age of tractors used for the depreciation period [12]. Many authors cite various figures for the age limit of tractors working in agricultural organizations, and the proportion of tractors operating over the depreciation period. This is due to the fact that they consider the data for a specific brand and for a specific region, take individual isolated cases of the age limit of tractors. To reveal the regularities of this phenomenon, it is necessary to averagely consider changes in the age limit of average tractors working in agricultural organizations, together with data on changes in arable land area and the number of employees, taking into account changes in the average tractor power in the fleet and purchase.

The methodology of the expert analysis consisted in the fact that with the help of a group of experts from these eight groups of factors from the standpoint of mechanization of production, select the main ones that determine the final efficiency of the tractor fleet. Of course, all of these eight factors play an important role in the production activities of any agricultural organization [13]. Tractor equipment determines the number of tractors per 1000 hectares of arable land and reflects the energy supply of the entire fleet. An important technical and economic indicator is productivity per shift hour, which shows the state of the technical level of the entire agricultural organization. Without the coefficient of technical readiness, it is impossible to assess the technical and technological levels of the tractor fleet, and without the annual load of tractors it is impossible to determine the amount of

operating costs. The guarantee of harvesting without losses is ensured by the optimal agrotechnical timing of operations for the cultivation and harvesting of agricultural crops, and such an indicator as the qualification of machine operators is responsible for increasing labor productivity [14-16].

3 Results and discussions

The expert analysis is based on the methodology for calculating the concordance coefficient for each group of factors, as a measure of the consistency of a group of experts. Experts of farms and employees of agricultural departments of the Kaluga region, Kostroma region, Tula region, Yaroslavl region and other organizations took part in the examination. In total, 30 people independently participated in the examination: farm managers, chief engineers, agronomists.

Kendall's concordance coefficient determines the degree of agreement of the opinions of the group of experts on the importance of factors in accordance with the task. It is determined by the formula:

$$W = \frac{12S}{m^2 \cdot (n^2 - n)}$$

S – sum of squares of the difference between the sum of the ranks assigned by all experts to each factor and the average value of the sums of the ranks of all factors

n – number of expertise object

m – number of experts

$$S = \sum_{i=1}^{n} \left(\sum_{j=1}^{m} R_{ij}\right)^2 - \frac{(\sum_{i=1}^{n} \sum_{j=1}^{m} R_{ij})2}{n}$$

R_{ij} – *row in group after ranking by importance*

If W = 1, then the consistency of opinions is complete, and if W = 0, then there is no consistency of opinions. The smallest number of ratings indicates a high consensus of expert opinions. The survey is considered positive if W≥0.75. In this case, on the basis of the expertise carried out, you can make positive decisions. The full text of the matrix of experts' opinions on the importance of various factors affecting the efficiency of the tractor fleet is presented in Figure 2.

Expertise object	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Sum of ranks	Deviation from the mean	Standard deviation	Average by ranks
Qualification of machine operators	7	8	7	7	8	7	7	8	8	6	8	7	7	8	7	5	8	6	7	8	7	7	8	8	6	7	7	6	6	6	212	78,5	6162,3	7,18
Annual load of tractors	6	5	5	6	7	6	5	7	5	7	5	6	5	5	6	7	5	7	6	7	8	6	5	5	7	5	6	7	7	8	182	-48,5	2352,3	6,00
Number of tractors per 1000 ha of arable land	3	4	4	4	4	3	4	3	4	3	4	3	3	4	3	3	3	4	4	4	3	4	3	4	3	4	3	4	3	3	105	-28,5	812,3	3,36
Age of machinery in the tractor fleet	4	3	2	3	3	4	3	4	2	4	3	4	4	3	4	4	4	3	3	3	4	3	4	3	4	3	4	3	4	4	103	-30,5	930,3	3,55
Agrotechnical terms of harvesting and sowing within the agro-term	2	1	3	1	1	2	1	2	3	2	1	2	2	1	1	2	2	1	1	2	2	1	2	1	2	2	1	2	2	1	49	-84,5	7140,3	1,64
General technical level of technology in the tractor fleet	1	2	1	2	2	1	2	1	1	1	2	1	1	2	2	1	1	2	2	1	1	2	1	2	1	1	2	1	1	2	43	-90,5	8190,3	1,45
The costs of maintenance and repair of agricultural machinery in the tractor fleet	5	6	6	5	6	5	6	5	6	5	6	5	6	6	5	8	6	5	5	5	5	5	6	6	5	6	5	5	5	5	165	31,5	992,3	5,55
Tractor technical readiness factor	8	7	8	8	5	8	8	6	7	8	7	8	8	7	8	6	7	8	8	6	6	8	7	7	6	8	8	6	6	1	209	75,5	5700,3	7,27
∑ sum of ranks																															1068	S (Sum of average by ranks)	32280,0	
Average of the sum of ranks																															133,5			
n (number of expertise object)	8																															Kendall's concordance coefficient, W	0,85	
m (number of experts)	30																															Pearson's chi-squared test, X2	198,12	
																																Number of degrees of freedom, k	7	
																																Pearson's chi-squared test, X2 (table value)	2,17	

Fig. 2. The matrix of experts' opinions on the importance of various factors affecting the efficiency of the tractor fleet

Three factors received the smallest number of ranks: the general technical level of technology in the tractor fleet, agrotechnical terms of harvesting and sowing within the

agro-term, and age of machinery in the tractor fleet. After processing the results of the questionnaire, the overall coefficient of concordance for these factors was, which proves a high degree of agreement of experts' opinions. Number of tractors per 1000 ha of arable land, the costs of maintenance and repair of agricultural machinery in the tractor fleet to be very close to this group of factors. For the minimum of the average sum of ranks, we take for the subsequent analysis the factors with the smallest sum of ranks, that is, the coefficient of technical readiness and the qualifications of machine operators [17]. In addition, the Kendall coefficient of concordance, or in another way, the Multiple rank correlation coefficient is needed in order to reveal the consistency of expert opinions on several factors. In order to determine the significance of Kendall's concordance coefficient, let us find the Pearson's chi-squared test:

$$X^2 = \frac{12S}{m \cdot n\,(n+1)} = n \cdot (m-1)$$

4 Conclusions

As a result of assessing the indicators affecting the efficiency of the tractor fleet, the following factors were selected: number of tractors per 1000 ha of arable land, the general technical level of technology in the tractor fleet, agrotechnical terms of harvesting and sowing within the agro-term, the age of machinery in the tractor fleet, qualification of machine operator, the costs of maintenance and repair of agricultural machinery in the tractor fleet, annual load of tractors, tractor technical readiness factor.

The expert analysis made it possible to reveal that in order to ensure highly efficient mechanization of agricultural production, the main factors are those that can be directly influenced by the farms themselves. Namely: the general technical level of technology in the tractor fleet, agrotechnical terms of harvesting and sowing within the agro-term, as well as the age of machinery in the tractor fleet. After processing the results of the questionnaire, the the significance of Kendall's concordance coefficient for these factors was $W = 0{,}855$, which proves a high degree of agreement of experts' opinions.

References

1 Shevtsov V G, Lavrov A V, Izmailov A Yu, Lobachevskii Y P. 2015. Formation of quantitative and age structure of tractor park in the conditions of limitation of resources of agricultural production. SAE Technical Papers doi: 10.4271/2015-26-0147.

2 Redreev G V, Myalo O V, Prokopov S P, Solomkin A P, Okunev G A. Machine-Tractor Aggregates Operation Assurance by Mobile Maintenance Teams. 2017. IOP Conf. Series: Materials Science and Engineering 221 012016 **vol 146** pp 31–35.

3 Fedorenko V F, Ezhevsky A A, Soloviev S A, Chernoivanov V I Increasing the efficiency of using the machine-tractor park monograph. 2015. Russian Scientific Research Institute of Information and Technical and Economic Research on Engineering and Technical Support of the Agro-Industrial Complex 336 **p**.

4 Zubina V A Analysis of the impact of the duration of agricultural operations on the loss of agricultural crops Collection of scientific papers. 2017. Materials of the VII International Distance Scientific and Practical Conference of Young Scientists. FGBNU SKZNIISiV Krasnodar **pp 125-129**.

5 Zubina V A Analysis of software and the choice of methods for forming the composition of the machine-tractor fleet. 2017. *Collection of scientific papers*.

Materials of the 5th jubilee international scientific-practical conference "Innovative technologies in science and education" ITNO-2017 " Divnomorskoe **pp 398-402.**

6 Zubina V A Analysis of the state of resource provision of agricultural production. 2018. *Materials of the XII International Scientific and Practical Conference of Young Researchers Volgograd* **pp 320-322**.

7 Pyanov V S. *Large-scale grain production: monograph* Stavropol. 2014 AGRUS of the Stavropol state. Agrarian University **244 p.**

8 Zubina V A Dependence of crop losses on the duration of agricultural operations *Fruit and berry growing in Russi*a. 2017 **vol 50 pp 137-141.**

9 Zubina V A Optimization methods and computer programs for increasing the efficiency of machine-tractor fleet. 2017. *Proceedings of GOSNITI* **vol 129 pp** 213-218.

10 Zubina V A Basic agrotechnical requirements for optimizing the harvesting of agricultural crops Collection of materials of the VIII-th International remote scientific-practical conference of young scientists. Krasnodar. **2018 pp 69-76.**

11 Lavrov A V, Zubina V A, Shevtsov V G. Criteria for optimizing the composition of the tractor fleet depending on the type of reproduction process. 2018. Innovations in agriculture **vol 4 (29). pp 255-261.**

12 Shevtsov V G. Lavrov A V. Zubina V A, Gurylyov G S. Determination of the efficiency of agricultural production with narrowed reproduction. 2017. *Materials of the international scientific and technical conference of the SFNCA RAS "Scientific and technical support of the agro-industrial complex of Siberia"* **vol 1**. **pp** 241-247.

13 Shevtsov V G. Lavrov A V. Zubina V A, Gurylyov G S. Fundamental signs of a narrowed type of reproduction in agriculture. 2017. *Materials of the international scientific and technical conference of the SFNCA RAS "Scientific and technical support of the agro-industrial complex of Siberia*" **vol.1. pp** 235-241.

14 Lavrov A V, Zubina V A, Shevtsov V G, Godzhaev Z A. *Certificate of state registration of the computer program No. 2017614953*. Russian Federation. Program for minimization of unit aggregate costs with a negative development process of mechanized agricultural production 2017.

15 Zubina V A, Lavrov AV, Shevtsov V G, Godzhaev Z A. *Certificate of state registration of the computer* program No 2018664682. Russian Federation. A program for assessing the hourly and shift performance of MTA, taking into account the influence of indicators of the technical level of the tractor. 2018.

16 Zubina V A. Substantiation of the formation of a harmonious tractor fleet of agricultural organizations while minimizing losses of agricultural products: *Diss. Cand. tech. sciences*. - M .: VIM. 2020. **172 p.**

17 Zubina V A, Lavrov A V, Shevtsov V G. *Certificate of state registration of the computer program* No *2019660991 Russian Federation*. The program for calculating the shortage and loss of yield from violation of agricultural terms of cultivation and harvesting of agricultural crops (on the example of the Central Non-Chernozem Zone) 2019.