Forecasting the production of agricultural machinery in the Russian Federation

V V Nosov¹, M G Tindova², K A Zhichkin³, D A Vorob’eva⁴, T V Pakhomova⁴, N P Ayugin⁵ and M N Kalimullin⁶

¹ Academy of the Investigative Committee of the Russian Federation, 12, Vrubel str., Moscow, 125080, Russia
² Yuri Gagarin Saratov State Technical University, 77, Polytechnicheskaya str., Saratov, 410054, Russia
³ Samara State Agrarian University, 2, Uchebnaya str., Kinel, 446442, Russia
⁴ Saratov State Vavilov Agrarian University, 1, Teatralnaya square, Saratov, 410012, Russia
⁵ Ulyanovsk State Agrarian University named after P.A. Stolypin, 1, Boulevard Novy Venets, Ulyanovsk, 432017, Russia
⁶ Kazan State Agrarian University, 65, K. Marks str., Kazan, 420015, Russia
⁷ Kutafin Moscow State Law University, 9, Sadovaya-Kudrinskaya street, Moscow, 125993, Russia

E-mail: novla@list.ru

Abstract. The article examines the production of agricultural machinery in the Russian Federation for the period from 2000 to 2020. The aim of the work is to develop a forecast for the production of the main types of agricultural machinery in the Russian Federation in modern conditions. Within the framework of this, the following tasks are supposed to be solved: - study of the availability of agricultural machinery for domestic agricultural producers; - identification of trends in the development of agricultural machinery production; - construction of econometric models that describe the volume of agricultural machinery produced. The information base of the study was the data of the Federal State Statistics Service. The study used statistical methods, in particular Student's t-test. The null hypothesis about the presence of a systemic shift in the time series was tested using a dummy variable. The index of production potential was also used in the work. Calculations showed the presence of a systemic shift in the series of the studied indicators. Econometric models were built for each series. For the production of tractors and loaders for agricultural purposes, the model will have a mixed look. Combine production is characterized by quadratic functions. Based on the models obtained, the production of the main types of agricultural machinery in the Russian Federation for the period 2021–2023 was predicted.

1. Introduction
Modern agricultural production, in economically developed countries, is a highly mechanized industry [1-5]. Despite the fact that in recent years the Russian Federation has made significant progress in ensuring its food security through an increase in agricultural production, nevertheless, agriculture faces a number of problems caused by the sanctions imposed against the Russian Federation by the
United States, the EU and other economically developed countries and a response from the Russian Federation with counter-sanctions [6-11]. Therefore, the task of agricultural engineering is not only to equip agriculture with modern agricultural machinery, ensuring its import substitution, but also to achieve an increase in exports, which together will allow this sector of the economy to make a significant contribution to the country's GDP [12-16].

The aim of the work is to develop a forecast for the production of the main types of agricultural machinery in the Russian Federation in modern conditions. Within the framework of this, the following tasks are supposed to be solved: - study of the availability of agricultural machinery for domestic agricultural producers; - identification of trends in the development of agricultural machinery production; - construction of econometric models that describe the volume of agricultural machinery produced.

2. Materials and methods
The information base of the study was data on the production of tractors and other agricultural equipment in the Russian Federation, presented by the Federal State Statistics Service for 2000–2020. Since we are dealing with time series of the studied indicators, to determine the presence of a trend in them, we will apply the method of comparing average levels, dividing the time series into two parts and test the main hypothesis about their equality by applying the Student's t-test [17-26]. We will test the null hypothesis $H_0$ about a systemic shift in the time series using the Heaviside function and construct a regression equation [27-46]. The significance of the parameter with a dummy variable will mean that the hypothesis of the presence of a systemic shift is accepted. Comparison of the actual and calculated levels of indicators of the obtained models, we can use the index of efficiency in the use of production potential:

$$\alpha = \frac{y}{\hat{y}}$$ (1)

The results of the research are presented in tabular and graphical forms [34-37].

3. Results
Dynamics of the main indicators of the production of agricultural machinery in the Russian Federation for 2000–2020 shown in figure 1.

Figure 1. Manufacture of tractors and agricultural machinery in the Russian Federation.
The analysis of group means showed that, according to the Student's t-test, the discrepancies between the means for the selected groups of the analyzed indicators are significant (table 1).

**Table 1. Results of comparison of two means by Student's t-test.**

| Production       | Average 1 group | Average 2 group | t-test | p-level |
|------------------|-----------------|-----------------|--------|---------|
| Tractor          | 12              | 8.1             | 2.448  | 0.0243  |
| Harvesters       | 7.8             | 5.8             | 4.545  | 0.0002  |
| Agricultural loaders | 2.5          | 7.1             | -7.552 | 0.00000 |

In addition, the analysis of figure 1 makes it possible to assume the presence of a systemic shift in the regression equations that form the levels of the time series that occurred in 2013. To test the hypothesis H0 about the systemic shift, we introduce a dummy variable and construct a regression equation:

\[
z_{13} = \begin{cases} 
0, & t < 13 \\
1, & t \geq 13 
\end{cases}
\]  

As a result, the null hypothesis H0 was accepted for production time series:

- Tractors (table 2).
- Harvesters (table 3).
- Loaders for agricultural purposes (table 4).

**Table 2. Parameters of the regression equation, the impact of a structural shift in tractor production.**

| Indicators | Regression equation coefficient | Standard error of the regression coefficient | Student's t-test | p-significance level |
|------------|---------------------------------|---------------------------------------------|------------------|---------------------|
| The intercept | 11.5                           | 0.884                                       | 13.066           | 0.00000             |
| z          | -4.5                            | 1.432                                       | -3.145           | 0.00533             |

Calculated by authors based on the author database using the STATISTICA package. 
\(F(0.05;1;19)=9.89; p=0.00533.\)

The calculation results show that the parameter z is significant according to Student's criterion.

**Table 3. Parameters of the regression equation, impact of structural shift in combine production**

| Indicators | Regression equation coefficient | Standard error of the regression coefficient | Student's t-test | p-significance level |
|------------|---------------------------------|---------------------------------------------|------------------|---------------------|
| The intercept | 7.4                            | 0.337                                       | 22.071           | 0.00000             |
| z          | -1.7                            | 0.546                                       | -3.180           | 0.00494             |

Calculated by authors based on the author database using the STATISTICA package. 
\(F(0.05;1;19)=10.1; p=0.00494.\)

The calculation results show that the parameter z is significant according to Student's criterion.
Table 4. Parameters of the regression equation, the effect of a structural shift in the production of agricultural loaders.

| Indicators | Regression equation coefficient | Standard error of the regression coefficient | Student's t-test | p-significance level |
|------------|---------------------------------|---------------------------------------------|-----------------|----------------------|
| The intercept | 3.5 | 0.571 | 6.202 | 0.00001 |
| z | 3.6 | 0.924 | 3.941 | 0.00088 |

Calculated by authors based on the author data base using the STATISTICA package. F(0.05;1;19)=19.83; p=0.00088.

The calculation results show that the parameter z is significant according to Student's criterion.

Based on the foregoing, it can be stated that for the production of tractors, the model will have a mixed form:

\[ y = \begin{cases} 
13.8 \cdot e^{-0.04t}, & t < 13 \\
41.1 - 4.2 \cdot t + 0.12 \cdot t^2, & t \geq 13 
\end{cases} \tag{3} \]

Where the coefficient of determination \( R^2 = 0.44 \) and all parameters are significant, the modulo average relative error is 12.8.

Combine harvester production is characterized by quadratic functions:

\[ y = \begin{cases} 
7.4 + 0.3 \cdot t - 0.02 \cdot t^2, & t < 13 \\
24.4 - 2.2 \cdot t + 0.1 \cdot t^2, & t \geq 13 
\end{cases} \tag{4} \]

Where the coefficient of determination \( R^2 = 0.48 \) and all parameters are significant, the modulo average relative error is 16.7.

For loaders, we got a mixed type model:

\[ y = \begin{cases} 
1.1 \cdot e^{0.04t}, & t < 13 \\
45.7 - 4.8 \cdot t + 0.14 \cdot t^2, & t \geq 13 
\end{cases} \tag{5} \]

Where the coefficient of determination \( R^2 = 0.74 \) and all parameters are significant, the modulo average relative error is 13.7.

4. Discussion

Average for 2000–2020 9.8 thousand tractors and 6.8 thousand combines were produced. In the total volume of agricultural machinery produced for this period, the share of tractors amounted to 21.2%. In 2000, their production accounted for 65.4% of the total number of agricultural machinery, in 2020 it is already 10.6%.

Currently, in the conditions of the Russian Federation, the provision of agricultural production with machinery (in quantitative terms) is declining (table 5).

So, compared to 2019, the number of tractors per 1000 hectares of arable land decreased by 1.1%, grain harvesters - by 3.2%. The number of agricultural machines is also decreasing: cultivators (by 0.2%), machines for sowing (by 2.2%). At the same time, one can see a trend in the use of more powerful, energy-saturated equipment. Energy supply increased by 0.8%. Compared to the Soviet period, this figure has grown even more significantly. The load standard for one combine harvester at that time was 196 hectares, at present, 451 hectares of harvested area fall on 1 combine harvester. That is, the increase in the productivity of one combine (due to an increase in power, the use of new technical solutions) amounted to 56.5%.
Table 5. Provision of agricultural production equipment.

|                                | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2020 in % to 2019 |
|--------------------------------|------|------|------|------|------|------|-------------------|
| There are tractors per 1000    |      |      |      |      |      |      |                   |
| hectares of arable land, pcs   | 3    | 3    | 3    | 3    | 3    | 3    | 98.9              |
| Arable land per 1 tractor, ha  | 308  | 320  | 328  | 337  | 345  | 349  | 101.1             |
| Accounts for 100 tractors, pcs |      |      |      |      |      |      |                   |
| plows                         | 27   | 28   | 28   | 28   | 28   | 28   | 101.2             |
| cultivators                   | 40   | 40   | 40   | 40   | 40   | 40   | 99.8              |
| sowing machines               | 45   | 45   | 44   | 43   | 42   | 41   | 97.8              |
| Harvesters account per 1000   |      |      |      |      |      |      |                   |
| ha of crops (planting) of the  |      |      |      |      |      |      |                   |
| corresponding crops, pcs       |      |      |      |      |      |      |                   |
| grain harvesters               | 2    | 2    | 2    | 2    | 2    | 2    | 96.8              |
| Crops (planting) of the        |      |      |      |      |      |      |                   |
| corresponding crops account    |      |      |      |      |      |      |                   |
| per 1 combine, ha              |      |      |      |      |      |      |                   |
| grain harvesters               | 422  | 425  | 427  | 424  | 437  | 451  | 103.3             |
| Energy supply (account for     |      |      |      |      |      |      |                   |
| energy capacity per 100        |      |      |      |      |      |      |                   |
| hectares of sown area), hp     | 197  | 200  | 198  | 200  | 199  | 201  | 100.8             |

It should be noted that at present in the Russian Federation the production of agricultural machinery is carried out by a fairly significant number of organizations, the distribution of which in the context of the Federal Districts is presented in the following table (table 6).

A significant part of agricultural machinery manufacturers is engaged in the production of small agricultural machinery, spare parts, batteries, motors, repairs and maintenance. Among the major manufacturers stand out Agrotechmash, the Tractor Company Volgograd Tractor Plant, Rostselmash, and others, which account for about 87% of all agricultural machinery produced in the Russian Federation.

Table 6. Distribution of manufacturers of agricultural machinery by federal districts of the Russian Federation.

| Federal District (FD)                | Number of organizations | Total | including producing tractors | including producing harvesters |
|--------------------------------------|-------------------------|-------|-------------------------------|-------------------------------|
| Far Eastern Federal District          | 1                       | -     | -                             | 1                             |
| Privolzhsky Federal District          | 34                      | 4     | 2                             |                               |
| Northwestern Federal District         | 8                       | 3     | 1                             |                               |
| Siberian Federal District             | 19                      | 3     | 1                             |                               |
| Ural Federal District                 | 10                      | 2     |                               |                               |
| Central Federal District              | 57                      | 2     | 2                             |                               |
| Southern Federal District             | 29                      | 2     | 1                             |                               |
| North Caucasian Federal District      | 5                       | 1     |                               |                               |

If you use the calculated models for the types of agricultural machinery, you can get the following predictive values (table 7).

Table 7. Forecast of production of the main types of agricultural machinery in the Russian Federation.

| Production       | 2021 | 2022 | 2023 |
|------------------|------|------|------|
| Tractor          | 10.0 | 11.5 | 13.2 |
| Harvesters       | 6.8  | 7.5  | 8.2  |
| Agricultural loaders | 10.5 | 12.2 | 14.2 |
A comparison of the actual and calculated levels of the studied indicators of the production of agricultural machinery showed that for the production of tractors the production potential index was 1.23, for combines - 1.05; for loaders - 1.93., which indicates a sufficient use of the existing production potential of manufacturers, which allows increasing the production of agricultural machinery without increasing it.

5. Conclusion
The use of the t-criterion made it possible to assert the presence of a trend in the series of the studied indicators. At the same time, there is a systemic shift in 2013. A mixed model was obtained for the production of tractors and loaders for agricultural purposes. Combine production is characterized by quadratic functions. Average for 2000–2020 9.8 thousand tractors and 6.8 thousand combines were produced. Compared to 2019, the number of tractors per 1,000 hectares of arable land decreased by 1.1%, grain harvesters - by 3.2%. Energy supply increased by 0.8%. Based on the models obtained, the production of the main types of agricultural machinery in the Russian Federation for the period 2021–2023 was predicted. The use of the production potential index made it possible to assert that in modern conditions the existing production capacities will allow increasing the production of agricultural machinery.

References
[1] Honglei J, Chenglin M, Guangyu L, Dongyan H and Zhaochen L 2007 Combined rototilling-stubble-breaking-planting machine. *Soil and Tillage Research* 96(1-2) 73-82
[2] Mattetti M, Molari G and Sereni E 2017 Damage evaluation of driving events for agricultural tractors. *Computers and Electronics in Agriculture* 135 328-337
[3] Khayrzoda S, Morkovkin D, Gibadullin A, Elina O and Kolchina E 2020 Assessment of the innovative development of agriculture in Russia. *E3S Web of Conferences* 176 05007
[4] Han J W, Kim E K, Jung H H and Park Y J 2018 Study on working load analysis of composite working implements for agricultural machines. *Transactions of the Korean Society of Mechanical Engineers A* 42(4) 371-378
[5] Kim W-S, Kim Y-J, Park S-U and Kim Y-S 2021 Influence of soil moisture content on the traction performance of a 78-kW agricultural tractor during plow tillage. *Soil and Tillage Research* 207 104851
[6] Chernyavskaya S A, Leoshko V P, Ovcharenko A V, Berлина S K and Aksenova Z A 2022 Advanced Innovations in the Accounting and Analytical Support of Agricultural Production as the Basis for Sustainable Development of the Region’s Food Subsystem. *Lecture Notes in Networks and Systems* 245 1531–1540
[7] Shchitov S, Tikhonchuk P, Kuzin V, Krivutsa Z, Panova E, Kuznetsov E, Dvoirina N, (...) and Kucher A 2018. Improvement of efficiency of use of wheeled transport vehicles in the agro-industrial complex. *Journal of Advanced Research in Dynamical and Control Systems* 10(13) 707-714
[8] Slepennkov A E, Polikutina E S, Slepennov S V, Kuznetsova E E and Krivutsa Z F 2021 Increasing the efficiency of use of wheeled harrow units in regions of risk farming. *E3S Web of Conferences* 262 01003
[9] Li H, He J, Gao H, Chen Y and Zhang Z 2015 The effect of conservation tillage on crop yield in China. *Frontiers of Agricultural Science and Engineering* 2(2) 179-185
[10] Shonhe T 2022 The politics of mechanisation in Zimbabwe: tractors, accumulation and agrarian change. *Journal of Peasant Studies* 49(1) 179–199
[11] Binswanger H 1986 Agricultural mechanization: A comparative historical perspective. *World Bank Research Observer* 1(1) 27-56
[12] Provodina E V, Krasovskaya O Yu, Gerasimova T A, Predeus Yu V and Tserpento D P 2020 Features of the formation of environmental protection mechanisms during the operation of objects of the electric power complex. *IOP Conference Series: Materials Science and
[13] Binswanger H and Pingali P 1988 Technological priorities for farming in sub-saharan Africa. *World Bank Research Observer* **3**(1) 81-98

[14] Ermakova A M 2021 Sustainable development of rural areas of the Yamalo-Nenets Autonomous Okrug. *IOP Conference Series: Earth and Environmental Science* **723** 042026

[15] Daum T and Bimer R 2017 The neglected governance challenges of agricultural mechanisation in Africa – insights from Ghana. *Food Security* **9**(5) 959-979

[16] Diao X, Cossar F, Houssou N and Kolavalli S 2014 Mechanisation in Ghana: Emerging demand, and the search for alternative supply models. *Food Policy* **48** 168-181

[17] Okunev G, Shepelev S, Kuznetsov N and Lukovtsev A 2021 Aspects of the formation of a tractor fleet of agricultural enterprises. *IOP Conference Series: Earth and Environmental Science* **937** 032050

[18] Morkovkin D, Hutarava I, Ogloblina E, Gibadullin A and Kharchenko S 2020 Assessment of the innovative potential of agriculture of the member states of the Eurasian Economic Union. *E3S Web of Conferences* **176** 05002

[19] Mashkov S, Ishkin P, Zhiltsov S and Mastepanenko M 2019 Methods of determining the need for agricultural machinery. *IOP Conference Series: Earth and Environmental Science* **403** 012079

[20] Dokin B D, Elkin O V and Aletdinova A A 2019 Prediction method of the variants of annual field work complexes and its implementation. *IOP Conference Series: Earth and Environmental Science* **341** 012111

[21] Drovnikov A N and Kalmykov Yu B 2019 On the development trends of the machine-tractor park of the agro-industrial complex of Russia. *IOP Conference Series: Materials Science and Engineering* **632** 012078

[22] Usmanov A, Golikov V, Astafyev V, Utemuratov J, Ploxotenko M and Bobkov S 2017 Justification of the tractor fleet range for the agricultural complex of Kazakhstan. *Journal of Engineering and Applied Sciences* **12**(13) 3323-3328

[23] Ağizan S, Oğuz C, Ağizan K and Bayramoğlu Z 2020 Evaluation of the utilization of mechanization in the agricultural enterprises in terms of productivity. *Yuzuncu Yil University Journal of Agricultural Sciences* **30** 898-907

[24] Khafizov C, Khafizov R, Nurmiev A and Galiev I 2020 Optimization of main parameters of tractor and unit for plowing soil, taking into account their influence on yield of grain crops. *Engineering for Rural Development* **19** 585-590

[25] Kipriyanov F A, Medvedeva N A and Medvedeva S V 2019 Ensuring the operational reliability of the tractor fleet. *IOP Conference Series: Earth and Environmental Science* **315**(6) 062015

[26] Shepelev S, Shepelev V and Cherkasov Yu 2015 Differentiation of the seasonal loading of combine harvester depending on its technical readiness. *Procedia Engineering* **129** 161-165

[27] Ayugin N P, Khalimov R Sh, Yakovlev S A, Matasov A N and Ulyanov M V 2021 Development of a root crop grinder. *IOP Conference Series: Earth and Environmental Science* **723** 032098

[28] Matasov A N, Ulyanov M V, Tseplyaev V A, Kharlashin A V and Ayugin N P 2021 Development of the design of a rotary tool for combing weeds with loosening the soil. *Conference Series: Earth and Environmental Science* **723** 032052

[29] Antisiferova O Yu, Myagkova E A and Tolstoshein K V 2019 Formation of the development strategy of the agro-industrial complex of the tambov region on the basis of the scenario approach. *IOP Conference Series: Earth and Environmental Science* **274** 012084

[30] Nikitin A V, Antisiferova O Yu and Fedotov A N 2021 Development of dairy cattle breeding in the tambov region. *IOP Conference Series: Earth and Environmental Science* **845** 012044

[31] Zhichkin K, Nosov V and Zhichkina L 2019 Economic mechanism of the machine-tractor park updating in the samara region. *IOP Conference Series: Earth and Environmental Science* **403** 012073
[32] Zhichkin K, Nosov V, Zhichkina L, Grigoryeva O, Kondak V and Lysova T 2020 The impact of variety on the effectiveness of crop insurance with state support. *IOP Conference Series: Earth and Environmental Science* 433 012004

[33] Frolova I I, Nosov V V, Zavyalova N B, Dorofeev A E, Vorozheykina T M and Petrova L I 2020 Labor opportunism as a blocking factor for the innovative development of industrial enterprises. *Entrepreneurship and Sustainability Issues* 7(3) 2228-2242

[34] Chistik O F, Nosov V V, Tsypin A P, Ivanov O B and Permjakova T V 2016 Research indicators of railway transport activity in time series. *International Journal of Economic Perspectives* 10(3) 57-65

[35] Chow G C 1960 Test of equality between sets of coefficients in two linear regressions. *Econometrica* 28(3) 591-605

[36] Nosov V V, Suray N M, Mamaev O A, Chemisenko O V, Panov P A and Pokidov M G 2020 Milk production dynamics in the russian federation: Causes and consequences. *IOP Conference Series: Earth and Environmental Science* 548 022091

[37] Provodina E V, Krasovskaya O Yu, Zhelokov N V, Komissarenko E S and Baranova M A 2021 Public danger and mechanisms for preventing damage to land. *IOP Conference Series: Materials Science and Engineering* 723 042058

[38] Smirnova O M 2018 Technology of increase of nanoscale pores volume in protective cement matrix. *International Journal of Civil Engineering and Technology* 9(10) 1991-2000

[39] Mikhaylov A 2015 Russian Oil and Gas Budget Revenues in 2015: Estimation and Risk. *Financial Journal* 2 52-59

[40] Ermakova A M 2021 Digital subsurface - Use as an important factor in the development of the region. *IOP Conference Series: Earth and Environmental Science* 808(1) 012057

[41] Terentyev S E, Gnezdova J V and Semchenkova S V 2020 Features of Machine-Technological Stations Organization in the System of Agro-Industrial Production. *IOP Conference Series: Earth and Environmental Science* 459(6) 062060

[42] Sharipov F F, Krotenko T Y and Dyakonova M A 2021 Talent Management: Needs and Prospects for Business Development in the Digital Economy. *Lecture Notes in Networks and Systems* 161 514–518

[43] Smirnova O M 2018 Development of classification of rheologically active microfillers for disperse systems with portland cement and super plasticizer. *International Journal of Civil Engineering and Technology* 9(10) 1966-1973

[44] Baboshkin P, Mikhaylov A and Shaikh Z A 2022 Sustainable cryptocurrency growth is not possible? Impact of network power demand on bitcoin price. *Financial Journal* 14(2) 49–67

[45] Viyugin S M, Kuchumov A V, Viyugina G V, Terentyev S E and Karamulina I A 2020 Influence of regional technologies of varying intensity on the bioproductivity of sod-podzolic medium loamy soil in the central region of the Russian federation. *Agronomy Research* 18(4) 2653-2664

[46] Ermakova A M 2021 Features of introduction of innovative means in production activity of the agricultural enterprise. *IOP Conference Series: Earth and Environmental Science* 723(3) 032070