Scientific Support for Innovative and Technological Development of Agriculture in the Context of Ensuring Technological Leadership in Food Security in Russia

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Abstract: - This article examines the main areas of scientific support for the innovative and technological development of agriculture in the context of digitalization, automation, and robotization of the agro-industrial complex. It analyses current trends in research and patent activity related to improving agricultural machinery, increasing the operational reliability of machines, developing technical services, and implementing digital and automated solutions in agricultural production. It reveals that the scientific agenda in this area is shifting from a general discussion of digital transformation to the development of specific engineering solutions and their practical implementation. It is shown that the growing number of monographs and books reflects the need to systematize accumulated knowledge and develop a methodological base for further industry development. It is concluded that scientific support for innovative and technological development is key to improving the efficiency, reliability, and sustainability of modern agriculture.

Key-Words: - agriculture, food security, scientific activity, agricultural machinery, agri-food market, technological leadership, institutional change, transformation of scientific research.

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1 Introduction

The current development of Russian agriculture is increasingly determined by the level of scientific and technological support, the industry's ability to quickly adapt to technological changes, and the introduction of digital, automated, and robotic solutions into production processes.

With increasing demands on productivity, resource conservation, environmental sustainability, and technological sovereignty, scientific support for the innovative and technological development of the agro-industrial complex is particularly important. Science is now becoming the foundation for modernizing machine-technological systems, improving engineering infrastructure, increasing the reliability of agricultural machinery, and implementing intelligent production management methods.

The relevance of this research stems from the fact that digitalization, automation, and robotization of the agro-industrial complex have ceased to be isolated areas of technological innovation and have become a systemic factor in enhancing the industry's competitiveness. Under current conditions, agricultural production requires not only new machinery and equipment, but also comprehensive solutions, including digital monitoring, intelligent control systems, precision farming elements, automated production lines, robotic systems, and new methods of technical service. A key objective is to assess how scientific results reflect the actual trends in the technological transformation of agriculture.

The aim of the study is to analyze the scientific support for the innovative and technological development of Russian agriculture in the context of digitalization, automation, and robotics in the agro-industrial complex, as well as to identify the key areas shaping the modern engineering and technological agenda in the agricultural sector.

The study focuses on the dynamics of scientific publications, patent activity, the thematic structure of research, and the shift in emphasis from quantitative research accumulation to qualitative systematization of knowledge and applied technical solutions.

2 Problem Formulation

The study's information base consisted of scientific publications, monographs, patents, and materials reflecting the results of research activities in the fields of engineering and technical support for agriculture, digitalization of agricultural production, automation of technological processes, and robotics in the agro-industrial complex. These materials were collected from the Scientific Electronic Library of Russia, the Unified State Information System for Civil Research, Development, and Technological Work, and the Directory of Open Access Journals.

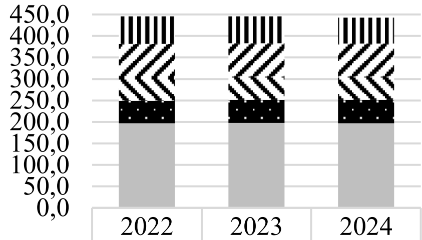
The empirical base included data on the dynamics of publication activity, changes in the structure of scientific results, and the substantive content of developments related to the improvement of agricultural machinery, technical service technologies, fuel systems, methods for refurbishing parts and components, as well as digital and automated solutions for the agricultural sector.

The study utilized analytical review, comparative analysis, and the synthesis and interpretation of scientific and technical information. The comparative approach allowed us to identify changes in the structure of scientific results in specific areas, while the analytical review helped us identify the most significant technological development vectors. To assess the qualitative characteristics of scientific support for innovative and technological development in agriculture, we used a substantive analysis of publications and patent materials. This allowed us to identify which technical and digital solutions are the subject of the most active scientific development.

The research methodology aimed to identify the relationship between the dynamics of scientific activity and the current needs of the agricultural sector. When interpreting the results, we took into account the current conditions of the agro-industrial complex, including the need for import independence, increased equipment reliability, cost reduction, greener production processes, and the implementation of intelligent control systems. This allowed us to consider research not in isolation, but as an important element in building the technological sustainability and innovative potential of agriculture.

3 Problem Solution

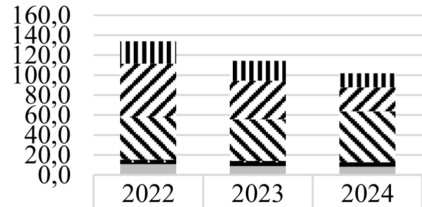
The fleet of primary equipment types in Russian agricultural organizations remains virtually stable, with minor fluctuations, from 2022 to 2024. The key trend is a gradual decline in the number of seeders and cultivators, while the grain harvester segment has shown steady, albeit moderate, growth throughout the period. The number of general-purpose plows remains unchanged, and the agricultural tractor category, which holds the largest share in the structure (approximately 44.5%), has returned to its 2022 baseline after a slight increase in 2023. Overall, equipment; it remains highly stable, with a slight shift in share in favor of harvesting machines. These changes are presented in Figure 1.



	2022	2023	2024
Seed Drills	64,1	62,4	60,7
Cultivators	77,5	77,2	76,7
General Purpose Plows	54,7	54,7	54,7
Grain Harvesters	52,3	53,6	54,2
Agricultural Tractors	196,7	197,6	196,7

Fig. 1: The fleet of the main types of equipment in agricultural organizations in Russia in 2022-2024
Source: Calculations and data based on the statistical yearbook [1].

In the Russian Federation, there is a general downward trend in production volumes for most types of agricultural machinery in 2024 compared to 2022. The most significant decreases were in the number of cultivators (-28.8 thousand units) and seeders (-8.4 thousand units). The number of grain harvesters changed little, while the number of agricultural tractors is gradually declining. These trends are presented in Figure 2.



	2022	2023	2024
Seed Drills	22,4	19,7	14,0
Cultivators	52,9	38,8	24,1
General Purpose Plows	43,5	41,8	50,9
Grain Harvesters	4,5	5,1	4,6
Agricultural Tractors	10,6	8,8	8,1

Fig. 2: Production of the main types of a gricultural machinery in Russia in 2022-2024
Source: Calculations and data based on the statistical yearbook [1].

To assess trends in the volume of domestic equipment, we will compare historical data on changes in the number of agricultural equipment in Russian agricultural organizations (Table 1).

Table 1. Average annual rate of change in the availability of agricultural machinery, averaged over 5 years, %

Type of agricultural machinery	2005-2009	2010-2014	2015-2019	2020-2024
Agricultural Tractors	-7,23%	-4,44%	-2,41%	-0,68%
Grain Harvesters	-5,76%	-5,27%	1,23%	0,13%
General Purpose Plows	-6,50%	-5,94%	0,00%	-0,40%
Cultivators	-5,88%	-4,96%	-0,30%	-1,10%
Seed Drills	-6,84%	-6,63%	-1,82%	-3,06%

Source: Formed on the basis of the [1], [2].

The analysis of the presented data allows us to identify three consecutive historical phases in the availability of equipment in the Russian agricultural sector.

1. The period of intensive degradation of the fleet (2005-2014)

During these two decades, there was a systematic decline in the number of vehicles in all categories, and for most types, this decline accelerated towards the end of the period:

The reasons for this phase include the completion of the depreciation period for Soviet-era equipment without adequate replacement, the disparity in prices between industrial products and agricultural raw materials, and the insufficient scale of government support measures for asset renewal.

2. The turning point and stabilization (2015–2019)

The period became a turning point. The decline in the fleet almost stopped or turned into weak growth:

This shift coincides with the implementation of the import substitution policy after 2014 and the increase in investments in the localization of foreign brands in the Russian Federation.

3. The phase of stagnation and qualitative shift (2020–2024) is characterized by a minimum level of losses, but the net growth has been preserved only in the combine harvester segment:

Based on the presented data, it can be concluded that the era of mass sales and disposal of old Soviet equipment is over. The bottom in terms of the number of physical units has almost been reached.

Negative values no longer solely indicate decline. Many old low-power tractors and simple tools are being replaced with fewer energy-intensive machines.

The focus has shifted to digitalization. The slowdown in the physical growth of the fleet is compensated by the introduction of precision farming, autopilot, and telemetry systems. The efficiency of hectare processing is increasing while the number of basic machines remains the same or decreases slightly.

The average annual rate of change in equipment volumes over the next 5 years will fluctuate around zero (between -1% and +1%).

The main development vector will shift from quantity to quality: the technical readiness ratio, specific capacity per hectare, and automation level will become the main metrics for the state of the domestic agricultural sector.

To address the declining production and range of domestic agricultural machinery in Russia, the federal project "Technological Independence of Agriculture, Food, and Processing Industries" has been launched as part of the national project "Technological Support for Food Security." According to the federal project, which aims to develop domestic equipment, the share of new Russian- and Belarusian-made tractors in the total number of tractors will increase from 10.6% to 20% by 2030. Over the same period, the share of Russian- and Belarusian-made combine harvesters will increase from 10.2% to 20%. The share of domestically produced mounted and trailed equipment will increase from 60% to 80%. Investments in the development and production of equipment will reach 305 million rubles. By 2030, 27 new types of machinery and equipment will be developed in Russia. Production of 60 new types of breeding combine harvesters will also begin in Russia. The share of domestically produced equipment used for packaging, bottling, and filling, as well as for oil and fat production and baking, will increase from 18% to 57%. The same figure for grain storage and processing will increase from 49% to 87%. The key performance indicators for the federal project are presented in Table 2.

However, if we compare the data on the availability of agricultural machinery in the Russian Federation (Figure 1) and its production (Figure 2), adjusted for the value of domestic agricultural producers' purchases of this machinery, and the trends of their changes until 2030 in the current paradigm, the share of domestic machinery by 2030 will be (Table 3).

Table 2. Key indicators of the federal project "Technical and technological independence of agriculture, food and processing industries"

Indicators	**2023**	**2030**
Share of new Russian and Belarusian tractors in the total number of tractors, %	10,6	20,0
Share of new Russian and Belarusian combine harvesters in the total number of combine harvesters, %	10,2	20,0
Share of Russian-made trailed and mounted equipment, %	60,0	80,0
Volume of investment in the development and production of machinery and equipment, million rubles	-	305,0
Number of new types of machinery and equipment developed, units	-	27,0
Number of new types of breeding combine harvesters produced, units	-	60,0
Share of Russian equipment for:		
- meat industry, %	21,0	60,0
- dairy industry, %	41,0	79,0
- grain storage and primary processing, flour and cereal industry, %	49,0	87,0
- sugar industry, %	27,0	65,0
- oil and fat, bakery industry, for packing, packaging and bottling, %	18,0	57,0

Source: Formed on the basis of the [2].

Table 3. Forecast of the share of domestic agricultural machinery in the Russian agricultural sector by 2030, assuming current trends in production, demand, and macroeconomic conditions remain unchanged, %

Type of agricultural machinery	Fraction
Agricultural Tractors	18,8%
Grain Harvesters	23,8%
General Purpose Plows	70,1%
Cultivators	67,2%
Seed Drills	64,3%

Source: created by the authors.

This situation will allow us to achieve our targets only for agricultural tractors. In this context, the Russian government is taking a number of targeted measures to influence the market.

Tools for developing technological support for the technical equipment of the agricultural sector within the framework of the federal project:

Support for scientific research (RF Government Resolution No. 2281).

Support for demand for Russian machinery and equipment: preferential lending, preferential leasing (RF Government Resolutions No. 1135, 811); subsidized discounts (RF Government Resolutions No. 1432, 823).

Support for projects to localize critical equipment and components for machinery through the creation of a specialized center at the Agency for Technological Development.

As part of Russia's scientific and technical policy for 2022-2024 in the field of mechanization, automation, and digitalization of agriculture, this document reflects the industry's structural transformation and changing priorities in the scientific community, as presented in Table 4.

Table 4. Trends in changes in indicators for mechanization, automation, and digitalization of agriculture in Russia for 2022–2024

Indicators	2022	2023	2024
Research reports, units	56	55	13
Dissertations, units	134	80	59
Results of intellectual activity protected by patent law, units	1777	728	734
Books, monographs, units	1411	1454	1508
Articles in peer-reviewed journals, units	5512	5961	5778

Source: created by the authors. Formed on the basis of data from the information resource of the Unified State Information System for Accounting of Scientific Research, Experimental Design and Technological Work for Civil Purposes and the National Electronic Library.

To assess the dynamics of research activity, we apply the $\chi 2$ independence test (the data meet the basic conditions for the applicability of Pearson's $\chi 2$ test). Calculating the statistics without preliminary processing yields the following approximate values:

Total $\chi 2 \approx 12{,}850$.

Degrees of freedom (df) = 8

P-value (significance level) < 0.001

This enormous statistical value is explained by the colossal gap in the "Intellectual Activity Results" category (a drop of almost 2.5 times in 2023). With such a p-value, the null hypothesis is confidently rejected.

However, concluding that there has been a "structural shift in the entire system" is premature. The test only shows that the data sets differ, but it is extremely sensitive to large categories. The results are influenced by thousands of articles and monographs, so the drop in small categories (reports) mathematically becomes insignificant noise compared to them. To understand whether the university's research profile has changed, the table needs to be modified and the smaller categories combined into a single group, "Qualification and Final Theses."

When recalculating the adjusted data, $\chi 2$ will be approximately 1360 at df = 6, and the p-value will remain < 0.001. We can now confirm that the distribution has changed statistically significantly. The calculation confirms that the decline is a statistically significant structural shift, not a random fluctuation ($p < 0.001$). The main driver of this shift is the twofold reduction in intellectual property output and the accompanying decline in qualification theses, against a backdrop of stable indicators for monographs and articles.

The most dramatic decline was observed in the sector of research reports and dissertation defenses. The reduction in the number of reports from 56 to 13 and dissertations from 134 to 59 indicates the completion of major fundamental state programs and a shift to more focused, applied research. The decline in dissertations may also be related to stricter requirements for scientific papers in technical specialties in the agricultural sector.

An analysis of the research topics presented for the period 2022–2024 allows us to identify key vectors for the development of scientific and technical thought in the field of mechanization of the agro-industrial complex. Modern research in agricultural engineering is focused on improving the efficiency and reliability of agricultural machinery. Much attention is paid to new materials, improved machine components, and extended equipment service life, which helps reduce costs and increase productivity. Digitalization has become an important area: precision farming systems, elements of robotics, and "smart" process control are developing in crop production and horticulture. Researchers pay particular attention to the impact of technology on agricultural sustainability, [3]. This enables more accurate decision-making, resource conservation, and improved product quality. There is also a noticeable interest in low-tech farm mechanization, environmentally friendly technologies, and improved machine maintenance. Overall, the research aims to modernize agricultural production, achieve technological independence, and promote sustainable development.

Patenting activity declined sharply during the second stage (from 1,777 to 728), which is typical of the transition from traditional mechanization to complex digital solutions. Modern automation systems and software for agriculture are more difficult to patent than hardware, leading to a temporary decline in performance.

A key area of patent protection in Russia in the field of agricultural mechanization has been improvements to the working parts of tillage and harvesting machines. The development of innovative cabbage harvesters, rotary tools for inter-row cultivation, and specialized tools for no-till plowing aims to reduce crop damage and preserve soil fertility. At the same time, technologies for the precise application of liquid organic fertilizers and the automation of processes in highly specialized industries, such as beekeeping and protected soil, are rapidly advancing.

Particular attention is being paid to digitalization and high-precision resource accounting. Recent research has focused on creating ecosystems for monitoring and diagnosing tractors, enabling early detection of malfunctions. Software solutions and calculators for calculating feed volumetric consumption, fuel consumption in logistics, and forecasting winter crop yields occupy a prominent place. These tools ensure transparency of agricultural processes and significant savings in production costs.

A third significant area is improving the operational reliability and maintainability of equipment. Patents are being filed for new methods for restoring threaded connections, devices for balancing long shafts and straightening disc working tools, as well as methods for evaluating the effectiveness of parts cleaning. Improvements to fuel equipment and soil disinfection systems highlight the researchers' commitment to combining engineering reliability with environmental safety, thereby forming a comprehensive approach to the technical modernization of modern agriculture.

The only indicator of scientific research activity demonstrating continuous growth is books and monographs (from 1411 to 1508). With the digitalization of agriculture, the need for theoretical understanding of new processes and the creation of a training base is growing. Scientists are accumulating their accumulated experience in implementing automation in extensive published works, which serve as a methodological foundation for the industry.

The topic of automation has reached a certain saturation point in periodicals, moving from general concepts to specific technical solutions.

Overall, these indicators indicate a shift from the quantitative accumulation of results to the qualitative systematization of knowledge in the form of monographs and targeted patenting of digital developments.

The obtained results show that scientific support for the innovative and technological development of agriculture is currently characterized not so much by an expansion of the overall number of studies, but by a deepening of their applied focus and strengthening of technological specialization in the context of the current challenges facing the agricultural sector of Russia, [4]. For example, researchers from Jiangsu University (China) concluded that the global transition to sustainable and intelligent agriculture has elevated electrified agricultural machinery to a central position in the development of modern equipment. [5] the digitalization of agriculture is no longer a theoretical concept but the primary driver ensuring the sustainable economic growth of Russia's agrarian sector. This transformative process signifies that agricultural engineering science in Russia has reached a more mature stage of development. The current priority shifts from general research to creating specific, implementable solutions capable of seamless integration into existing production practices. A key vector of this maturation is the comprehensive digitalization of the domestic machine-building industry and the modernization of the tractor fleet within the agricultural sector, [6]. This is particularly noticeable in areas related to equipment operational reliability, improved repair and restoration technologies, digital process control, and automation of individual process operations. The systematic integration of digital tools and platform technologies is transforming traditional approaches to agribusiness. According to several Russian authors, "the automation of agronomic, production, and technological processes in agriculture is a key factor in the intensive development of Russia's agro-industrial complex", [7]. According to Chinese researchers, there is a need to develop and improve all-wheel drive tractors using force sensors on the wheels, [8]. Of particular importance are studies of the impact of strategic methods for increasing the efficiency of specific agricultural techniques using intelligent agriculture, [9].

The growing importance of monographs and books as a form of scientific output deserves special attention. The continuous increase in this indicator can be interpreted as a reflection of the industry's need to systematize accumulated knowledge, methodologically understand ongoing changes, and develop a scientific and educational foundation for training new types of specialists. Similar trends are also reflected in Western European countries, [10]. In the context of the digital transformation of the agro-industrial complex, this is particularly important, as implementing automation and robotics requires not only individual engineering developments but also a holistic conceptual framework that integrates technical, economic, and organizational aspects. In this regard, the role of universities and research institutes is particularly important for Russia, [11].

At the same time, the stabilization of publication activity in a number of areas should not be viewed solely as a negative trend. On the contrary, it may indicate that a number of general theoretical propositions have already been formulated, and further development is proceeding toward practical specification and patenting. This trend indicates a shift in emphasis from declarative discussions of digitalization to the creation of specialized solutions focused on the real needs of the industry: component remanufacturing, increasing the reliability of components, modernizing fuel injection equipment, developing devices for balancing and straightening working parts, and implementing technologies that combine production efficiency and environmental safety. A number of researchers are drawing attention to the role of artificial intelligence in scientific research, including through case studies, [12].

Thus, scientific support for innovative and technological development in agriculture should be viewed as a comprehensive process in which digitalization, automation, and robotics do not exist in isolation but are integrated into the overall logic of technological modernization in the agro-industrial complex. The results discussed confirm that the modern scientific agenda in agriculture is focused on integrating engineering, information technology, and biotechnical approaches. This creates the foundation for the further development of a sustainable technological model for agriculture capable of addressing the challenges of resource constraints, labor shortages, and the need to improve production efficiency.

4 Conclusion

The study revealed that scientific support for innovative and technological development in agriculture in modern conditions is closely linked to digitalization, automation, and robotization in the agro-industrial complex. It was established that the key feature of the current stage is the transition from the quantitative accumulation of scientific results to their qualitative systematization and practical orientation. Scientific activity is increasingly focused on developing specific technological solutions aimed at increasing equipment reliability, improving technical service, implementing digital management tools, and ensuring the environmental sustainability of agricultural production.

It was found that the steady increase in the number of monographs and books reflects high demand for knowledge consolidation and the development of a modern methodological framework for agricultural engineering. At the same time, patent activity and the substantive focus of research indicate an increase in the applied nature of scientific research and its greater focus on the needs of the real sector of the economy.

Overall, the study's results confirm that science is a crucial factor in the technological modernization of the agro-industrial complex. The effective development of agriculture in the near future will be determined by the ability of scientific, educational, and research organizations to create, adapt, and implement innovative engineering and digital solutions that meet the challenges of increasing productivity, reliability, economic efficiency, and technological sustainability in the industry.

References:

[1] Agriculture in Russia. 2025: Stat. collection/Rosstat. – M., 2025. pp.81, [Online]. https://rosstat.gov.ru/storage/mediabank/S_x_2025.pdf (Accessed Date: January 10, 2026).

[2] Report of G.L. Fominoyo, Director of the Department of Economics and State Support for the Agro-Industrial Complex of the Ministry of Agriculture of the Russian Federation, at the annual seminar-meeting for heads of accounting and financial-economic services of the governing bodies of the agro-industrial complex of the constituent entities of the Russian Federation and agricultural producers. Moscow, Link to the original source, [Online]. https://disk.yandex.ru/i/rovVzmS4mPoyqw (Accessed Date: January 10, 2026).

[3] Rennings, M., Baaden, P., Block, C. et al. Assessing emerging sustainability-oriented technologies: the case of precision agriculture. Scientometrics 129, 2969–2998 (2024). https://doi.org/10.1007/s11192-024-05022-2.

[4] Global Challenges and Barriers to Sustainable Economic Growth in the Agribusiness Sector, R. A. Migunov, A. A. Syutkina, N. F. Zaruk [et al.], WSEAS Transactions on Business and Economics. 2023. Vol. 20. pp.923-930. https://doi.org/10.37394/23207.2023.20.85.

[5] Shen, Y.; Yang, F.; Wu, J.; Luo, S.; Khan, Z.; Zhang, L.; Liu, H. Advances and Future Trends in Electrified Agricultural Machinery for Sustainable Agriculture. Agriculture 2025, 15, 2367. https://doi.org/10.3390/agriculture15222367.

[6] Digitalization of agriculture as a factor of sustainable economic growth of the agrarian sector in Russia / R. A. Migunov, A. A. Syutkina, E. S. Kolomeeva [et al.], AIP conference proceedings : International Scientific and Practical Conference "Innovative Technologies In Agriculture". Volume 2921, Issue 1, Orel, 23–24 марта 2022 года. – AIP Publishing: AIP PUBLISHING, 2023. – P. 090003. – DOI https://doi.org/10.1063/5.0164565.

[7] Moroz, Oksana, and Dmitriy Medvedsky. “High-tech agricultural tools as a determinant of dynamic rationalization of business processes in Russian agriculture.” BIO Web of Conferences 179 (2025): 16002. Moscow. https://doi.org/10.1051/bioconf/202517916002

[8] Jinghui Zhao, Liyou Xu, Mengnan Liu, Official tests of MFWD tractors based on wheel force transducers and validation of tractor performance prediction model, Computers and Electronics in Agriculture, Volume 248, 2026, https://doi.org/10.1016/j.compag.2026.111831.

[9] Wantong Zhang, Fa Song, Jiyu Sun, A review of strategic enhancement of pollination with smart agriculture to counteract the decline of natural pollinators, Biosystems Engineering, Volume 261, 2026, ISSN 1537-5110, https://doi.org/10.1016/j.biosystemseng.2025.104344.

[10] Mkuna, E. (2025). Review of Socio-Technical Innovation Bundles for Agri-Food Systems Transformation: By Christopher B. Barrett, Rebecca J. Nelson, Karen Cooper, Steven James, Quinn Marshall, Cynthia Mathys, Kamakhya Misra, Lindiwe Majele Sibanda, and Philip Thornton (Eds.). London: Palgrave Macmillan, 2022. 347 pp. ISSN 2523-3092 (electronic): ISBN 978-3-030-88802-2 (eBook). https://doi.org/10.1007/978-3-030-88802-2.

[11] Lovakov, A., Chankseliani, M. & Panova, A. Universities vs. research institutes? Overcoming the Soviet legacy of higher education and research. Scientometrics 127, 6293–6313 (2022). https://doi.org/10.1007/s11192-022-04527-y/.

[12] Cao, Z., Shang, Y., Zhang, L. et al. The role of artificial intelligence in scientific research: a classification framework with case-based empirical insights. Scientometrics (2026). https://doi.org/10.1007/s11192-026-05620-2.

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