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AN ANALYSIS OF RESEARCH AREAS IN PRECISION AGRICULTURE

A.S.Gusev [a*], G.A.Beznosov [a], N.V. Ziablitckaia [b], M.V. Kholmanskikh [a], L.A. Novopashin [a], L.V. Denyozhko [a], A.A. Sadov [a]

[a] *Federal State Budgetary Educational Institution of Higher Education «Ural State Agrarian University» (FGBOU VO Uralsky GAU) Ekaterinburg, ul. Karl Liebknecht, 42, RUSSIAN FEDERATION.*
[b] *South Ural State University, Chelyabinsk, pr.Lenina, 76, RUSSIAN FEDERATION.*

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ABSTRACT

This article discusses the key research areas in precision farming and precision agriculture. The bibliographic method is used as a research tool. The average level of precision farming technologies in the USA is 30-50%, in the Russian Federation 10%. Despite the fact that precision agriculture technologies are aimed primarily at reducing costs by increasing the intensity of production and the level of resource output, the studies show that the resource intensity of agricultural production in Russia is still too high to speak about success in resource conservation. The 2014-2018 articles contents in the bibliographic database Web of Science are analyzed, totaling 4662 articles. In the most highly cited articles native English speakers (USA, UK, Australia) often use the term “precision farming”, while other countries scientists (China, India, EU, Iran, etc.) use the term “precision agriculture”. The considerable leaders in the total number of publications on the subject are countries with traditionally developed agriculture, such as the USA (20.0% of the number of articles reviewed), Brazil (8.8%), China (17.5%), and Spain (7.3%). The leader among scientific journals with publications on the problem is “Computers and electronics in agriculture”; it has 4.9% of all articles. The leading research organizations include the US Department of Agriculture (USDA), the Chinese academy of Sciences, Consejo Superior de Investigaciones Cientificas CSIC (Spain). The average level of introduction of precision farming technologies in the USA is estimated at 30-50%, while at large farms the level of technology use is twice the small ones. Its most common elements are: a computer with high-speed Internet access, an analysis of soil samples (98%); yield maps, yield monitors, GPS navigation systems (about 80%); differential fertilization technologies (60%); satellite images and a vegetative index analysis - (no more than 30%) of farmers. All the listed technologies should be developed intensively both in the world and in Russia, with the increased investments in precision agriculture research.

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*Corresponding author (A.Sanusi Hassen) E-mail: sanusi.usm@gmail.com ©2019 International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies. Volume 10 No.10 ISSN 2228-9860 eISSN 1906-9642 CODEN: ITJEA8 Paper ID:10A12D http://TUENGR.COM/V10A/10A12D.pdf DOI: 10.14456/ITJEMAST.2019.154

1. INTRODUCTION

Entrepreneurship in the agrarian sector is making significant efforts to reduce the costs of major resources. One of the solutions based on various technological breakthroughs in the digital industry is precision agriculture technologies.

There is an opinion that the concept of “precision agriculture” is associated with the concepts of “precision farming” and “precision livestock farming” (PLF). The scientific literature uses the following synonyms of the category “precision farming”: coordinate farming, information technology, GPS technologies, etc. For the first time, there were the elements of the precision farming system with GPS to determine the position to which any measured parameter of the field should be linked [1]. Precision farming technologies began to be used in the late 1980s in the United States and Australia [2,3,4]

The application of the precision farming system became possible due to advances in such technologies as global positioning systems (GPS), geographic information systems (GIS), remote sensing and simulation modeling, and robotics. These technological breakthroughs have made opportunities for assessing and managing spatial and temporal variability using various methods. The combination of these concepts is traditionally referred to as precision farming (precision agriculture) or crop and soil management.

Precision animal husbandry can be defined as “the application of principles and methods of technological design in animal husbandry for automatic monitoring, modeling, and management of animal husbandry” [5]. These technologies in animal husbandry make the production more cost-effective [6], socially and environmentally sustainable, and this can be achieved by observing, interpreting the behavior [8] and, if possible, individual control after animals [9].

2. METHODOLOGY

The relevance of precision farming has resulted in an increase of publications in recent years. However, there is no structured analysis of this published material. This study attempts to analyze the scientific results of research on problems of precision agriculture published in 2014–2018. With the bibliometric method, mainly based on the use of network analysis tools, it became possible to explore the main aspects of this research area. This will discover the trends in publications and areas of research, as well as their geographical distribution. In the Web of Science database, 4,662 scientific publications were found over a specified period. The number of publications has increased after 2014 significantly, which underlines the relevance of the research topic.

The study aims to determine the directions and prospects for the use of precision agriculture systems by analyzing the publications on this topic.

The bibliographic method was used as a methodological research tool. At the first stage, the content of publications on the systems of precision agriculture was analyzed. The review of publications was carried out on the basis of a system approach. A literature screening was performed and the text was analyzed to clarify whether the selected articles were relevant to the research problems. As a result, the most relevant publications in peer-reviewed research journals were chosen. The rest of the publications were irrelevant to the research problem, as they were related to the precision agriculture indirectly and, thus, were excluded from further analysis. The review concerns a comparison of the research areas of “precision farming” and “precision agriculture”, the specific nature and frequency of occurrence of particular research sub-areas in the world scientific literature according to the Web of Science database.

The results of the study can be used by the executive authorities in the development of programs on innovative agricultural development and technical modernization of the industry.

3. RESEARCH RESULT

The concept of “Precision agriculture” can be defined as a characteristic of soil conditions at the field level for land management [10]. There are other approaches, in particular, “Precision Agriculture”, that is a management concept based on observation, measurement, and response to variability within fields in crops [11].

There are three main stages in the precision farming system. Firstly, it is a primary exploratory analysis, which is collecting information about the economy, field, culture, and region. Secondly, there is an analysis of the results of monitoring, followed by the adoption of relevant management decisions. And the third stage is the development of a field treatment strategy for a specific agrarian operation or in general for the next year, and relevant agro-technological operations [12, 13].

There are various estimates of the level of introduction of precision farming systems into agricultural production. The average level of introduction of precision farming technologies in the USA is estimated at the level of 30-50%, while at large farms the level of technology use is 2 times higher than at small ones. Its most common elements are: a computer with high-speed Internet access, an analysis of soil samples (98%); yield maps, yield monitors, GPS navigation systems (about 80%); differential fertilization technologies (60%); satellite images and a vegetative index analysis - (no more than 30%) of farmers.

The precision livestock farming is a kind of precision agriculture; its essence is the economical and accurate use of material resources: fuel, seeds, feed, electricity, introduction of the latest scientific advances in the production of animal origin products using modern technical equipment with electronics for optimal results with the best cost recovery with the products. Moreover, if in precision farming, the implementation of the technology requires not only electronics but also spatial positioning with space navigation systems, in precision livestock farming this task is simplified due to the use of electronic animal identification systems. The effectiveness of precision animal husbandry is in the availability of a complex of precision technologies and technical means with electronic control.

According to scientists’ opinion, a key requirement to precision machine technologies in animal husbandry is providing the specified parameters for the implementation of technological processes and living conditions in rooms and in choosing modes of interaction of machines with biological objects to produce a high-quality product with desired properties. They include such operations as preparation of balanced feed mixtures, individual feed dosing systems, automatic milking machines and equipment, means for deep cooling of milk, systems for automatic control of climate parameters in livestock housings, systems for sorting and packaging finished products.

For this reason, precision agriculture is widespread only in large areas of the United States, Germany, Denmark, the Netherlands, and the United Kingdom. Such technologies are beginning to be introduced in Russia.

There is a serious difference in the assessment of the current level of application of precision farming technologies in Russia. So, according to the Ministry of Agriculture of Russia, the elements of precision farming are used in 1591 farms of the country on an area of 7521 thousand hectares. According to the Ministry of Agriculture, the leading regions in terms of the number of farms are the Lipetsk, Oryol, Samara, Kurgan, Voronezh, and Tyumen regions. The share of coverage with various communication technologies of agricultural land in 2018 was at the level of 10% [14]. At the same time, there are assessments of scientists of the Kuban State Agrarian University (Figure 1).

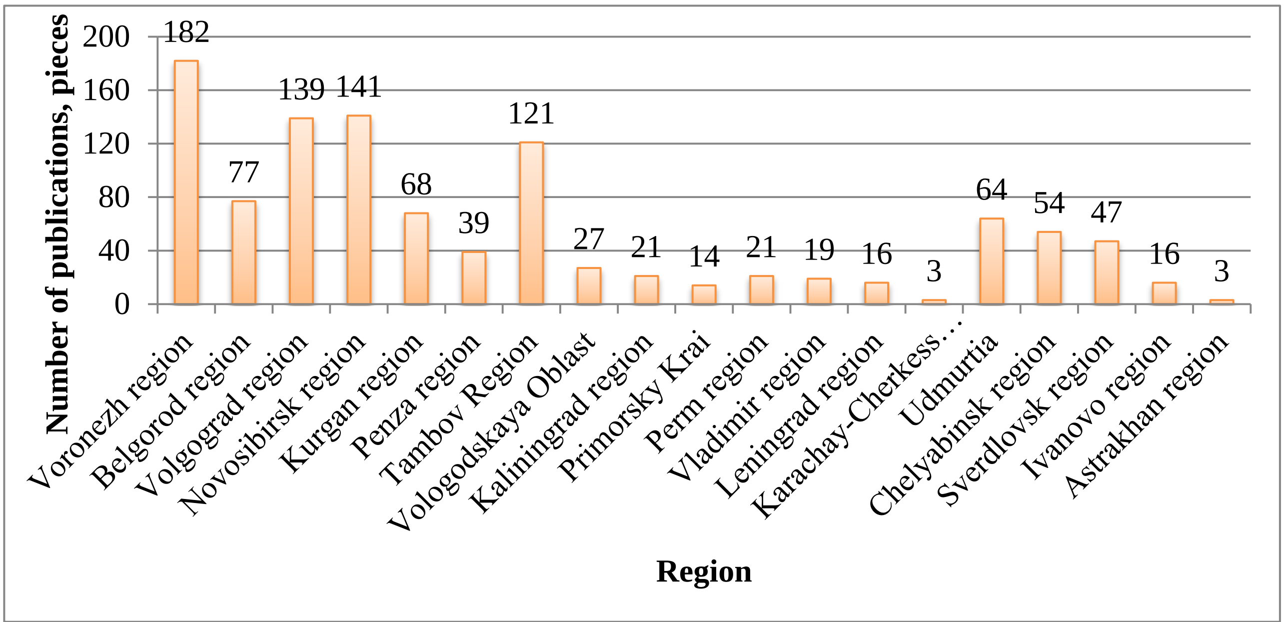

Figure 1: Region of Russia applying precision farming technology.

According to the Ministry of Agriculture, the leading regions by the number of farms are the Lipetsk, Oryol, Samara, Kurgan, Voronezh, and Tyumen regions. The share of coverage of agricultural lands with various communication technologies in 2018 is at the level of 10%.

At the same time, the concept of "Scientific and technological development of digital agriculture "Digital Agriculture", developed under the Ministry of Agriculture of the Russian Federation by such competent organizations as the Russian Academy of Sciences, Moscow State University by M.V. Lomonosov, "Higher School of Economics" and others reports that the share of agricultural enterprises which use the Internet of things, precision farming, digital herd, and smart greenhouses by the end of 2018 is less than 1%. But the target indicators have an ambitious goal to increase this number in 20 times by 2021, and 60 times by 2024. Regional Departments and Ministries have already joined the implementation of these plans, at least through increasing the share of such enterprises by considering certain technological operations as precision farming technologies, which can hardly be considered justified. Such work gave a leading position in the application of precision farming technologies in agriculture to the subsidized Kurgan region, Lipetsk, Oryol, Samara, Voronezh and Tyumen regions. This proves the absence of a fundamental scientific and regulatory framework and may result in distortion of the real situation in the development of precision farming technologies that are dangerous for the Russia economy as a whole.

Despite the fact that precision agriculture technologies are aimed primarily at reducing costs by increasing the intensity of production and the level of resource output, the studies show that the resource intensity of agricultural production in Russia is still too high to speak about success in resource conservation. Table 1 exhibits resource intensity for the Kurgan region of Russia.

Table 1: Resource intensity of production by the example of agricultural enterprises of grain specialization in the Kurgan region.

№	Total resources	Gross Production		Resource intensity	Considering			
		thousand rubles	Specific		Land intensity	Labour intensity	Capital intensity	Materials intensity
1	0.533	47091	0.108	4.943	0.849	0.204	2.820	1.071
2	0.138	13563	0.031	4.435	1.369	0.472	1.261	1.334
3	0.095	8298	0.019	4.976	1.779	0.974	0.501	1.722
4	0.364	35564	0.081	4.468	1.190	1.231	1.160	0.887
5	0.029	2235	0.005	5.706	1.641	1.507	1.540	1.018
6	0.979	152546	0.349	2.802	0.756	0.640	0.565	0.841
7	0.221	16929	0.039	5.711	0.974	2.526	0.947	1.263
8	0.154	11483	0.026	5.846	1.684	2.948	0.238	0.977
9	0.124	6941	0.016	7.801	1.799	3.178	1.845	0.979
10	0.126	9300	0.021	5.898	1.352	1.630	1.700	1.217
11	0.182	9860	0.023	8.067	1.588	4.184	0.993	1.302
12	0.046	3479	0.008	5.795	2.057	1.888	0.832	1.019
13	0.280	32032	0.073	3.815	1.228	1.109	0.313	1.165
14	0.124	15447	0.035	3.510	1.055	0.654	0.774	1.028
15	0.138	10425	0.024	5.763	1.248	2.067	1.274	1.173
16	0.074	7693	0.018	4.178	1.170	0.350	1.767	0.891
17	0.185	29298	0.067	2.760	0.577	0.655	0.594	0.934
18	0.130	14777	0.034	3.832	0.793	0.684	1.354	1.001
19	0.079	9674	0.022	3.578	1.254	0.714	0.554	1.056
Total	4.000	436636	1.000	–	–	–	–	–

To determine the level of regulatory resource intensity with consideration of the qualitative characteristics of the soil and intensity of resource use, we use the following formula,

$$P_{norm} = 12.39 – 0.08x_1 + 1.39x_2 + 0.83x_3 - 3.63\ x_4,$$

where

x_1 – soil assessment grade,

x_2 – the intensity of labour use, thousand-person – hour/ha;

x_3 – intensity of fixed production facilities use, thousand rubles/ha;

x_4 –intensity of material resources use, thousand rubles/ha.

The coefficient of regulatory resource intensity development shows an average level of resource use in the analyzed agricultural enterprises of grain specialization depending on the soil quality, intensity use of labour, fixed capital and material resources (Table 2).

Ranking of the analyzed agricultural enterprises of grain specialization by a degree of development of the regulatory resource intensity shows that the first nine of them do not develop the possible level of resource intensity. thus. having large reserves for the production of additional products (Table 3).

Table 2: The ratio of physical and regulatory resource intensity of production (by the example of agricultural enterprises of grain specialization in the Kurgan region)

Number of agricultural organization in order	Resource intensity		A degree of development of regulatory resource intensity	Gross production. thousand rubles	Additional GP. thousand rubles
	Physical	Regulatory			
1	4.943	4.472	0.905	47091	-4488
2	4.435	3.603	0.812	13563	-2546
3	4.976	3.531	0.710	8298	-2410
4	4.468	5.364	1.201	35564	7138
5	5.706	5.849	1.025	2235	56
6	2.802	3.881	1.385	152546	58756
7	5.711	6.052	1.060	16929	1011
8	5.846	6.196	1.060	11483	687
9	7.801	7.527	0.965	6941	-243
10	5.898	5.571	0.945	9300	-515
11	8.067	7.256	0.900	9860	-991
12	5.795	5.935	1.024	3479	84
13	3.815	3.776	0.990	32032	-324
14	3.510	3.458	0.985	15447	-230
15	5.763	5.635	0.978	10425	-231
16	4.178	4.648	1.112	7693	864
17	2.760	2.828	1.025	29298	718
18	3.832	4.377	1.142	14777	2104
19	3.578	3.925	1.097	9674	938

Table 3: Ranking of agricultural enterprises by a degree of development of the regulatory resource intensity (by example of the enterprises of grain specialization in the Kurgan region)

Rank	N*	Resource intensity		A degree of development of regulatory resource intensity	Gross production. thousand rubles	Additional GP. thousand rubles
		Physical	Regulatory			
1	3	4.976	3.531	0.710	8298	-2410
2	2	4.435	3.603	0.812	13563	-2546
3	11	8.067	7.256	0.900	9860	-991
4	1	4.943	4.472	0.905	47091	-4488
5	10	5.898	5.571	0.945	9300	-515
6	9	7.801	7.527	0.965	6941	-243
7	15	5.763	5.635	0.978	10425	-231
8	14	3.510	3.458	0.985	15447	-230
9	13	3.815	3.776	0.990	32032	-324
10	12	5.795	5.935	1.024	3479	84
11	5	5.706	5.849	1.025	2235	56
12	17	2.760	2.828	1.025	29298	718
13	7	5.711	6.052	1.060	16929	1011
14	8	5.846	6.196	1.060	11483	687
15	19	3.578	3.925	1.097	9674	938
16	16	4.178	4.648	1.112	7693	864
17	18	3.832	4.377	1.142	14777	2104
18	4	4.468	5.364	1.201	35564	7138
19	6	2.802	3.881	1.385	152546	58756

Note: N* = Number of agricultural organization.

The other enterprises in this ranking make full use of the existing potential. which is due to the getting of additional gross production thanks to the most efficient use of production resources.

Problems and prospects of using precision agriculture are the subjects of many studies (Figure 2).

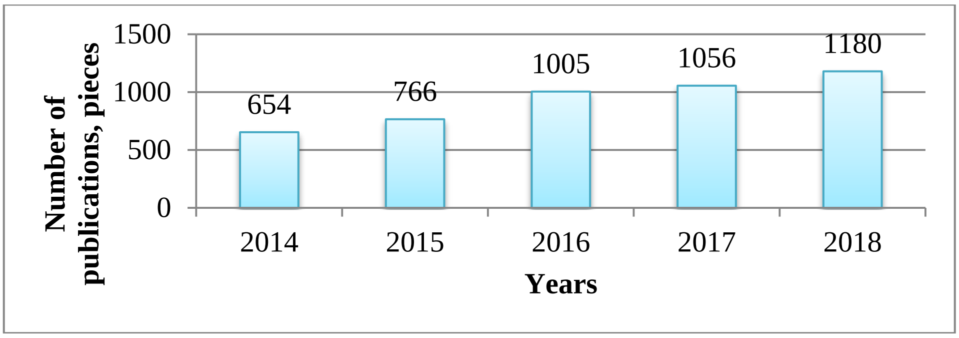

Figure 2: The number of publications by years

As the figure shows. the greatest interest in these issues arose after 2014. For the studied period, 4662 articles were found. which proves the urgency of the problem.

The analysis of the Web of Science publications over the past 5 years shows that the areas of animal husbandry, food production, and veterinary medicine are within the precision farming, while such unique areas as plant science, computer science, and mathematical computational biology are characteristic for precision agriculture (Figure 3).

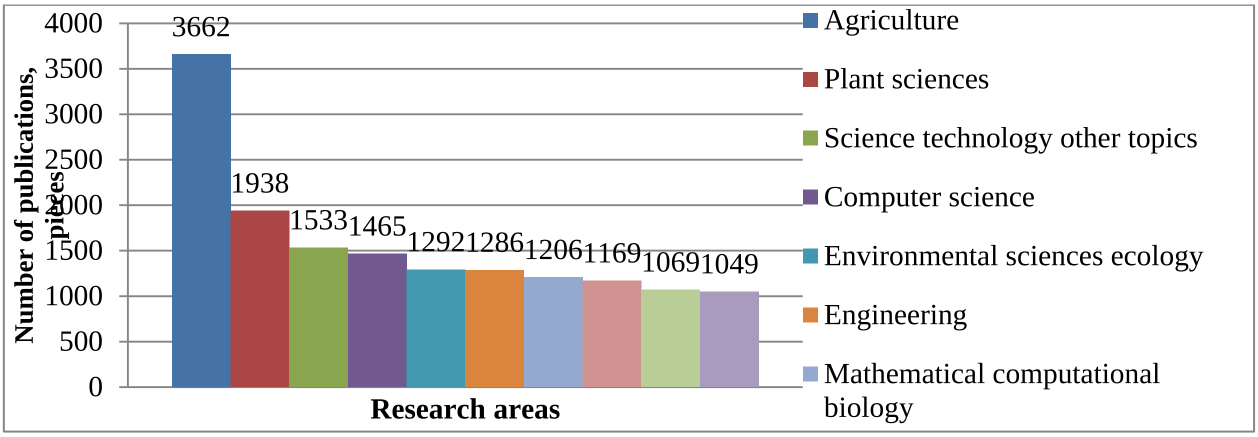

Figure 3: The main areas of studies on precision agriculture.

A comparison of publications with the keywords “precision farming” and “precision agriculture” shows that in the most highly cited articles native English speakers (USA. UK. Australia) often use the term “precision farming”. while scientists from non-English speaking countries (China. India. EU. Iran. etc.) in similar cases use the term “precision agriculture”.

A keyword analysis allows identifying key publications on issues of precision agriculture. They include “Computers and electronics in agriculture”; it is 4.9% of all articles (Figure 4).

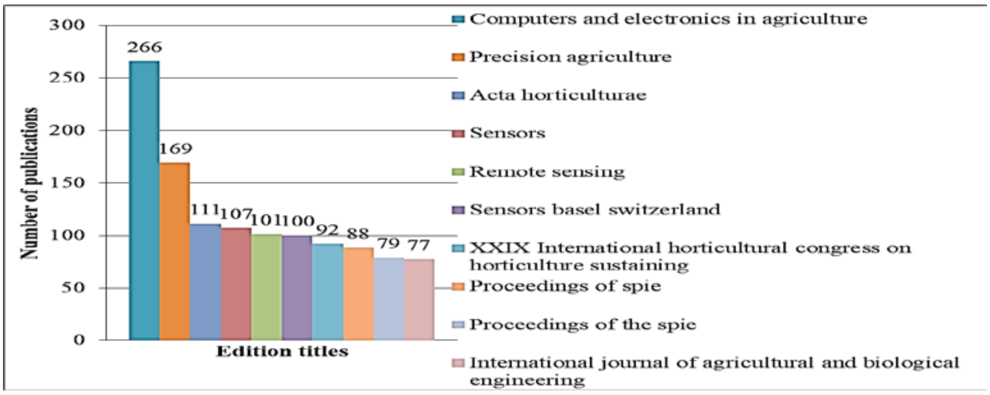

Figure 4: Scientific editions with the most number of publications on precision agriculture.

"Precision agriculture" takes second place. which has 3.6% of publications in the studied period.

Many countries study the problems and prospects of the introduction of precision farming and animal husbandry in agriculture. These are the countries with traditionally developed agriculture. such as the USA. China. Brazil. Germany. Italy. and Spain (Figure 5).

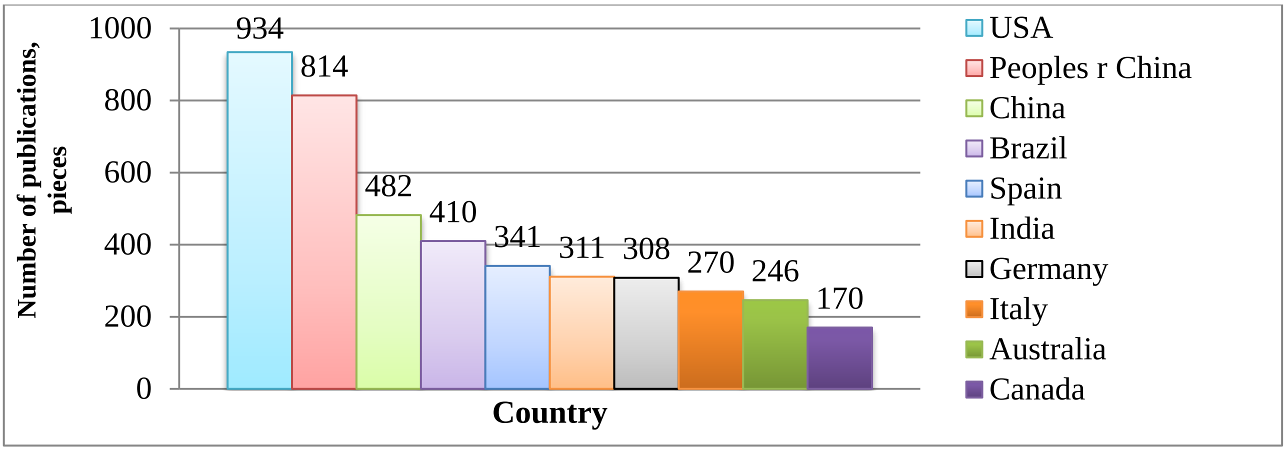

Figure 5: Countries with the largest number of publications on precision agriculture.

The leaders are the United States (20.0% of articles). Brazil (8.8%). China (17.5%). and Spain (7.3%).

Many scientific organizations are engaged in the research of precision agriculture technologies. The leaders are the United States Department of Agriculture (USDA), the Chinese Academy of Sciences (China), the Consejo Superior de Investigaciones Cientificas (CSIC, Spain), the State University System of Florida (USA), the China Agricultural University (China) and others (Figure 6).

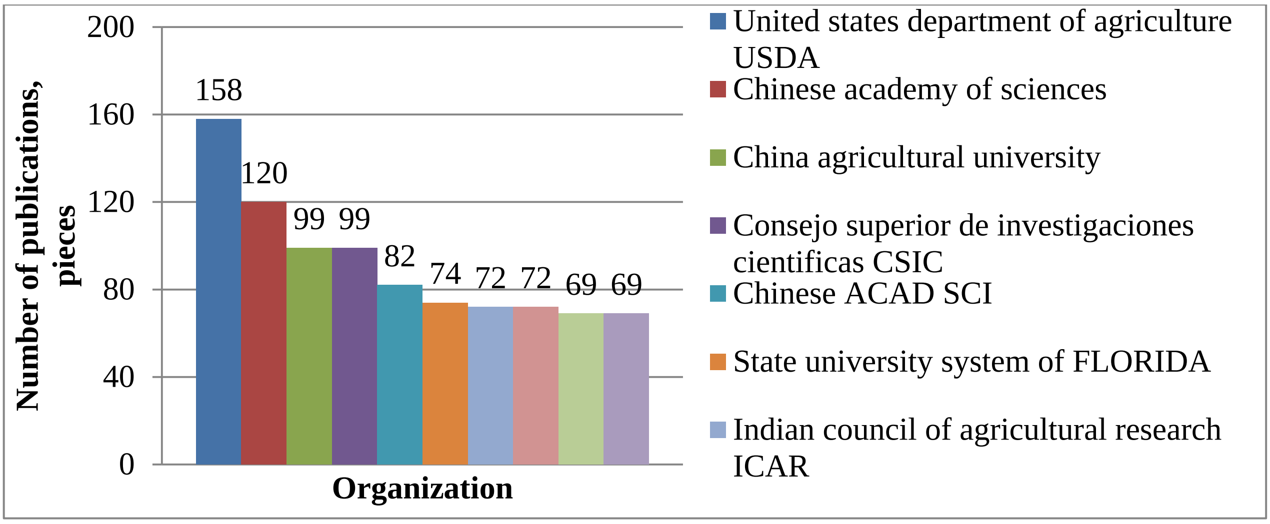

Figure 6: Scientific organizations with the largest number of publications on precision agriculture

4. DISCUSSION

The article deals with the financing of R&D mainly through foreign funds and scientific organizations. which take a leading position in the open "grant market".

The use of advanced technical tools and achievements in precision farming allows predicting crop yields. determining the level of normalized difference vegetation index (NDVI) plants.

performing analysis and considering the variability of the level of moisture supply. which is of great importance in crop growing. Modern large-scale agricultural production cannot be imagined without precision farming technologies. which are possible on the basis of the use of indicator systems, sensors, and lidars, various prediction algorithms and artificial intelligence.

The development of precision farming technologies is associated with ever-increasing demands for economic efficiency and ecological safety of farming. There is a need to reduce the cost of expensive fertilizers and plant protection products as well as fuel and lubricants.

5. CONCLUSION

The use of the elements of precision agriculture makes a huge commercial market for the development of the agro-industrial sector throughout the world. We have been proposed the coefficient of regulatory resource intensity development shows an average level of resource use in the analyzed agricultural enterprises of grain specialization depending on the soil quality. intensity use of labour. fixed capital and material resources. In recent years. the leading countries have invested great amounts of money and have made great efforts to take advantage of this industry. The leaders in these studies are the countries with developed agriculture such as the United States, China, Brazil, Spain, etc. It is obvious that all these technologies should be developed intensively in Russia but this should be associated with increased investments in research in the field of precise agriculture.

6. AVAILABILITY OF DATA AND MATERIAL

The data used is included in this article. No data is generated from this study.

7. CONFLICT OF INTERESTS

The authors confirm that the revealed information does not contain a conflict of interest.

8. ACKNOWLEDGMENT

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Dr.A.S. Gusev has a Ph.D. in Biological Sciences. His research interests are Land Management, Economic and Mathematical Modeling of Economic Processes and Phenomena in the Precision Farming System, Land Management based on Modern Digital Technologies.

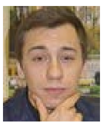
Dr.G.A. Beznosov has a PhD in Economics. His research includes Development of the Economic Mechanism of Resource Conservation, Economic and Mathematical Modeling of Economic Processes and Phenomena in the Precision Farming System, Development of the Organizational and Economic Mechanism of Sustainable Land Management based on Modern Digital Technologies, Profitability of Agricultural Production.

Professor Dr.N.V. Ziablitckaia is Professorat South Ural State University, Chelyabinsk, Russia. She holds the Doctor of Economics degree. Her research interests encompass Business Planning, Competitive Advantages of an Organization, Lean Manufacturing, Development of Petrochemical clusters, Petrochemical Industry.

M.V. Kholmanskikh is a Lecturer. Precision Farming Technologies, Lean Manufacturing, Economic and Mathematical Modeling of Economic Processes and Phenomena in the Precision Farming System.

L.A. Novopashin is a Candidate of Technical Sciences, Associate Professor. His scientific interests are problems of starting Transport and Technological Machines, Digitalization of Agriculture, research of Alternative Types of Energy.

L.V. Denyozhko is a Candidate of Technical Sciences, Associate Professor. Her scientific interests are research of Working Processes in Internal Combustion Engines, the use of Digital Technologies in the Study of Processes in Thermoelectric Thermometers, Research of Alternative Types of Energy.



A. A. Sadov is a Post-graduate Student. His research interests are research on renewable alternative types of Energy, Processes of Digitalization of Agriculture, Development of Robotic Complexes for Agricultural Needs.

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