Prospects and features of robotics in russian crop farming

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Abstract. Specificity of agriculture, low levels of technical and technological, information and communication, human resources and managerial capacities of small and medium Russian agricultural producers explain the slow pace of implementation of robotics in plant breeding. Existing models are characterized by low levels of speech understanding technologies, the creation of modern power supplies, bionic systems and the use of micro-robots. Serial production of robotics for agriculture will replace human labor in the future. Also, it will help to solve the problem of hunger, reduce environmental damage and reduce the consumption of non-renewable resources. Creating and using robotics should be based on the generated System of machines and technologies for the perfect machine-tractor fleet.

1. Introduction

The European Association of Agricultural Engineering forecasts the need to increase agricultural production by 2050 to 70\%, considering the growth in the number of hungry population of the planet [1]. Maybe in 35 years, the situation will be smoothed over by the decrease of the number of women of the reproductive age, the aging world population, urbanization [2], but the problem of hunger remains urgent. Food and Agriculture Organization of the United Nations (FAO) calls it the global food challenge [1]. Production of agricultural products is not unlimited. Currently, the total arable land area of the Earth is about 1.3 billion hectares, which represents 9\% of the land. This indicator has remained stable in recent years [3]. In all cases, the expansion of cultivated areas have the following consequences: changes in gas and water cycle, climate change, change of river flows, geographical, ecological, biocenotics change, possible natural habitat and population destruction, etc. According to K. Moebius, the change of at least one condition results in the changes in the number of species, i.e. changing biocenosis.

The crop production in Russia is connected with the global restrictions, as well as slow intensification, impoverishing of farms, neglected farmlands [4, 5]. To solve these problems, FAO proposes considering the intensification of crop as a strategy sustainable production. This allows getting a better crop yield from the same area of the land, while reducing its negative impact on the environment [4].

For over the last sixty years, the robots have been playing a fundamental role in improving industrial efficiency and reducing production costs. At the same time, automated production operations have been implemented in agriculture, and, during the last decade, there has been a tendency of robotics applications. Transition to the precise agriculture required application of new technologies.
The term “smart agriculture economy” has already been traced in foreign publications. It is regarded as a high-tech cluster intended to introduce innovative technologies, in particular, smart generation of agricultural machinery [6]. Market Analysis of the European agricultural machinery indicated that 70% of the machines that perform operations on fertilization and spraying, are already using smart technology [7]. It is also remotely possible to adjust the depth of tillage and seeding, to create interactive maps of fields, embedded smart irrigation systems, etc. Thus, new technology led to the creation of a large number of innovations that can afford to move towards sustainable development.

Relevant questions are: whether the Russian agriculture is ready to adopt, in particular crops, the use of agro robots; whether the robots meet farmers’ needs; whether it is currently effective in Russia to replace labor mechanics with agronomists robotic systems.

2. Materials and methods

The development of agricultural robotics is influenced by the following research areas: artificial intelligence; the Internet of things; Big data; cloud technologies; 3D-printing; the mobile Internet; new generation materials; biotechnology; bionics; neuroscience; microelectronics; mechanization and automation; nanotechnology; cognitive science.

The characteristic features of crops impose certain requirements on the robotics:
- dependability on the weather and climate conditions;
- use of agrolandscape zoning;
- territorial dispersion of fields and farms;
- seasonal work;
- use of crop rotation;
- soil and plants handling.

Creating machines that do not require constant attention and their administration is the most important task of modern technology [8]. Livestock production is the most developed field in the world in terms of robots implementation in agriculture. In 2013, 4790 robots for milking were sold; in 2014 – 5180. For crops the number was significantly smaller. Meanwhile, the demand for them will increase.

The interest of scientists and researchers in development and use of robots in crop farming is increasing (Table 1).

| Search queries | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | till August 2016 |
|----------------|------|------|------|------|------|------|------------------|
| Agricultural robotics | 2960 | 3320 | 4140 | 4290 | 4010 | 4280 | 2500 |
| Automated agricultural plant growth monitoring | 1350 | 1510 | 1580 | 1890 | 1870 | 2140 | 1250 |
| Automated plant species classification and maturation determination | 203 | 188 | 231 | 265 | 281 | 324 | 168 |
| Automatic vehicle guidance | 780 | 960 | 1020 | 1020 | 969 | 1130 | 625 |
| Autonomous seeding, phenotyping and weed removal | 17 | 11 | 13 | 12 | 26 | 35 | 25 |
| Automatic mowing plants | 600 | 650 | 790 | 792 | 764 | 776 | 490 |
| Agricultural harvest robots | 1970 | 2140 | 2580 | 2820 | 2960 | 3120 | 1870 |
| Robotic tillage | 65 | 89 | 89 | 94 | 115 | 116 | 62 |

In 2010, the number of articles about it on Google Scholar site has reached 2960, by the end of 2015, interest has increased 1.45 times (the authors note that the approach used, the results obtained
might have an error, but it can be used). Considering separate groups of operations, it is necessary to emphasize that the greatest academic interest of Russian and foreign scientists lies in the harvest, and automated monitoring of the plant growth. In their article, Z. Ying, Y. Wang, Z. Li explored the successful model of agricultural products e-commerce on the basis of analysing the characteristics of agricultural products circulation, and put forward the idea of developing agricultural products e-commerce [9]. In their research, Armstrong L.J., D. Diepeveen, R. Maddern aimed to assess these new data mining techniques and to apply them to a soil science database to establish if meaningful relationships can be found [10]. In Russia, the first work on the use of robot technology in agriculture appeared in 1984 [11]. The development of robotic technical devices for crop production in Russia is carried by the All-Russian Institute of Mechanization (VIM). First prototypes and preproduction models were created there [12].

The Russian agriculture sector has started using foreign and domestic autonomous operation system models, machines with multi-functional chassis, modern combines, unmanned aerial vehicles, special vehicles. Satellite positioning system technology, which has its disadvantages, such as problems with the GPS quality of coverage, is replaced or supplemented by the creation of an interactive map technology, using active RFID systems of radio-frequency identifiers, infrared, ultrasonic positioning and laser-guiding. Remote or autonomous means of controlling robotic equipment are currently used in crop production. The examples of robotic devices are autonomous systems (Autonomous Tractor, Kinze Manufacturing etc.); multifunctional chassis (Spirit, Cleorpath Robotics, Lynex, Hortibat etc.); harvesters (Argobot, Energid, Romobility Yoto etc.); unmanned aerial vehicles (Agribatix, SenseFly, Precision Howk etc.); specialized vehicles (VIM-ELEC 2.0, BoniRob, HoriBot, Vibrô Crop Robottii, Prospero, Spider Mini etc.). The application of these devices accumulated both positive and negative experience.

Mankind is on the way of solving the problem of hunger. Major trends in the creation of robots for agriculture are aimed at: transition from technical operations to the implementation of the entire production process; minimization of human labor costs; preservation of human health; a reduction of the consumption of natural resources; a reduction of environmental damage.

3. Discussion.
The expert-analytical PBK report gave an assessment of the impact of progress in various scientific fields on the development of industrial machinery in different sectors [13]. Grouping areas of economic activity allowed identifying three groups: with a high level of technological development, e.g., the army, care for the disabled, work at home, leisure and play; with a medium level of technology development, e.g. logistics, construction, health care. Currently, the areas with the lowest level of technological development are computer vision, speech understanding, sensory systems, bionic and navigation, power supplies, hardware miniaturization in creating robots in agriculture, industry, education, the extraction of minerals (Table 2).

| Technologies        | Application area |
|---------------------|------------------|
|                     | Industry | Mining | Agriculture | Education |
| Computer vision     | Medium   | High   | High        | High      |
| Speech understanding| Low      | Low    | Low         | High      |
| Sensor networks     | Medium   | Medium | Medium      | Medium    |
| Bionic system       | Low      | Low    | Low         | Low       |
| Navigation systems  | Medium   | High   | High        | Low       |
| Power supplies      | Low      | Low    | Low         | Low       |
| Microrobots         | Low      | Low    | Low         | Low       |

Currently, the lowest level of technological development is observed in computer vision, speech understanding, sensory systems, bionic and navigation, power supplies, hardware miniaturization in
creating robots in agriculture, industry, education, the extraction of minerals. This can be explained by the size of these areas, their characteristics as well as by the wide range of tasks. According to the forecast made by RBK, the greatest demand on the domestic Russian market can be expected for the purchase of military and special robotics for mining, operation of the infrastructure, logistics and health.

In March, 2016, during the meeting of the Presidium and the Board of scientific and technical council of the Ministry of Agriculture of the Russian Federation, the main directions of the Forecast for scientific and technological development of the agro-industrial complex of the Russian Federation for the period of up to 2030 were defined. The exhaustion of long-term effects of "green revolution" in 1960-1980 requires a transition to a new technological paradigm – the technology which is called «low external input sustainable agriculture» (LEISA). It includes biotechnology, precision agriculture, robotics, composite fertilizer, integrated biological protection, resource efficient local agriculture. There has been a growing contribution of platform technologies for multi-sectoral purposes [14]. As noted by V.I. Kiryushin in 2004, high technologies require modern software, including computer-aided design, electronic control and mapping [15]. But are Russian agricultural enterprises ready for them?

The analysis of the current situation in the Russian agriculture has shown that large agricultural holdings have a high potential for the introduction of robotic systems (Table 3).

Table 3. The potential for introduction of modern technologies which are interconnected with robotization of technological processes in crop farming (compiled on the basis of data [14]).

| Modern technology | Economy type | APH (subsistence farming) | K(F)/SP (semicommodity economy) | Average agricultural enterprises, agricultural production cooperatives (commodity production) | Large agricultural holdings (trade, export-oriented economy) |
|-------------------|--------------|---------------------------|-------------------------------|---------------------------------------------------------------------------------|----------------------------------------------------------------|
| Precise agriculture | Low          | Low                       | Medium                        | High                                                                            |
| Automation and computerization | Low         | Low                       | Medium                        | High                                                                            |

Medium and small agricultural enterprises still need to build up their technical and technological, information and communication, human resources and management potentials.

According to A.N. Ananiev, the application of robots in agriculture is profitable, provided that it replaces at least two employees with its full depreciation for over three years [16].

A low demand for agricultural robots intended for crop production can be explained, on the one hand, by their high price and, on the other hand, by the need for their further development, providing their compatibility. Farmers show great interest in robotics, but they are wary of their implementation. Most often their questions concern their efficiency, the cost of the technical systems, required personnel training, information and communications support, etc.

Apart from the readiness of agricultural produce, technical re-equipment of the agricultural machinery industry is required. Russia has an extensive network of such plants, but, as noted by Y.N. Plynsky, S.G. Shchukin, a lot of highly qualified scientific and engineering personnel left the country in the 90s, the indirect production costs increased and now there is a technological gap between Russian and foreign manufacturers [17]. The lag of Russian robotics is noticeable in basic control devices, drives, training and software systems [18]. At the same time, on the Russian market there are low import duty rates for foreign agricultural machinery. According to the All Russian Institute of mechanization, tractors of 78 modifications produced by 13 foreign companies are imported to the European part of Russia. According to the data from the State Technical Authority (Gostekhnadzor), 128 makes of tractors produced by 34 companies and 65 modifications of harvesters, produced by 23 companies, are imported to Novosibirsk Region. A number of farms has already purchased foreign
sowing complexes, which prove to be applicable in real production. According to the State of supervision in the Novosibirsk region supplied 34 tractors firms 128 brands, harvesters – 23 firms 65 modifications. A number of farms already purchased foreign sowing complexes, which proved to be inapplicable in real production.

One of the main reasons for this situation is the absence of federal and regional programs for technological and technical modernization of agriculture; an information gap among managers and farms specialists; deceptive advertising on the part of manufacturers and resellers. Mindless acquisition of foreign technological machinery (including robotics) creates a delayed-action bomb in the form of problems connected with operation of multi-brand equipment.

In addition, agriculture in comparison with other areas of economics can be called an outsider in terms of implementation of data support, engineering, animal veterinary, agronomical and other services, to say nothing of executive decision-making. Accountancy systems and legal information services are most commonly used in organizations.

Thus, in our view, the introduction and development of robotics in the Russian crop farming has the following problems:

- under-funded research and development in the robotic sphere;
- lack of the regulatory and methodological framework for measuring, testing and monitoring, as well as evaluation of the quality and safety of robotics;
- necessity of technological modernization and re-equipment of agricultural enterprises
- shortage of a highly qualified personnel to ensure the introduction, development and implementation of robotics, and eventually its management; the necessity to increase information and communication technology literacy among population;
- necessity of cost-effectiveness (which can be achieved by mass production, the replacement of human labor, the development of new materials, etc., that lower the costs);
- a low level of automation and data support of technological and control processes on the farms;
- the question of how networks will cope with the load of billions of connected devices still remains open; there is a growing problem of information security;
- necessity to create advanced technological and machinery System for agriculture, taking into account the introduction of robotics in manufacturing;
- development and implementation of government programs to support the entire cycle of the research work before putting prototypes into production and providing a unified intelligent control.

Due to the development of Russian information and communication technologies, we should expect the growth of computing power in the short term, reduction of components cost, standardization of platform technologies in robotics [19].

In our opinion, it is quite promising to expect robotic machines with electronic tracking systems to appear on Siberian fields performing the complex mineral fertilizing based on yield maps or maps of crops which need fertilizing elements.

The most demanded and compatible equipment will be robotic machines with the remote control system in the unit with a train in agricultural machinery, drills, sprayers for low-growing crops.

There is no possibility to create advanced robots without further development and improvement of the mobile Internet; artificial intelligence; the Internet of Things; cloud computing; new generation materials; storage, accumulation and use of renewable energy. It requires the state program to support the development of robotic systems and management systems.

4. Conclusion.

Thus, the creation of robotics applied to crop requirements of plant features: depending on weather and climate conditions; agrolandscape use zoning; territorial dispersion of fields and farms; seasonal work; the use of crop rotation; operations with soil and plants. Advanced robotic systems have to minimize human labor costs, go to the realization of the whole technological process, reduce harm to the environment, the consumption of natural resources. In the future, new technologies will enable
obtaining high yields of crops with a minimum total cash costs and the balance between the preservation of human activity and the biosphere. But it is necessary to solve a number of serious problems: to provide funded research and development activities in the field of robotics; to create a regulatory and methodological framework for measuring, testing and monitoring, evaluation of the quality and safety of robotics; to conduct technological modernization and re-equipment of enterprises of agricultural engineering; to improve personnel literacy in terms of use of information and communication technologies and robotics; to reduce the cost model (engineering); to create a modern information and communication structure in rural areas. It will also enable creating a System of progressive technologies and machines based agrolandscape zoning and the use of robotics, which is only possible with the support of the state. In the near future, in Siberia robotic machines will be of great demand in the sphere where fertilizers and aggregates with a train in agricultural machinery, such as drills, sprayers for low-growing crops, will be highly required.

References
[1] The Global Food Challenge. – URL: http://www.cema-agri.org/page/global-food-challenge (Accessed 09.09.2016)
[2] Antonov A.I. 2006 Dynamics of the population of Russia in the XXI century and the priorities of the demographic Publishing House "Key-C" 192
[3] Geography of the main branches of agriculture. – URL: http://www.geographyofrussia.com (Accessed 09.09.2016)
[4] Aletdinova A.A., Kurcheeva G.I. 2014 Factors innovative development of agro-industrial complex of Russia Cluster Structure of Industrial Economics Publishing House of SpbSTU 192-214
[5] Pimentel D., Hurd L.E., Bellotti A.C., Foster M.J., Oka I.N., Sholes O.D., Whitman R.J. Food 1973 Production and the Energy Crisis Science 182–411 443–449
[6] Enabling Smart Farming in Europe – URL: http://www.cema-agri.org/page/enabling-smart-farming-europe (Accessed 09.09.2016)
[7] Armagan Z. E. 2016 Global trends in agriculture and technological solutions Fifth World Summit on Agriculture Machinery 28
[8] Elyashiv N.N. 2016 Fundamentals of Robotics: A Training Manual (RGPPU p. 49
[9] Ying Z., Wang Y., Li Z. 2005 Research on circulation and e-commerce of Chinese agricultural products ICEC '05 Proceedings of the 7th international conference on Electronic commerce 846-850
[10] Armstrong L.J., Diepeveen D., Maddern R. 2007 The application of data mining techniques to characterize agricultural soil profiles AusDM '07 Proceedings of the sixth Australasian conference on Data mining and analytics 70 85-100
[11] Vasaynin V.I. 1984 Agricultural robots (Kolos) p. 224
[12] Hort D.O., Filippov R.A., Kutyrvev A.I. 2015 Multifunctional robotic vehicle with vision Innovations in agriculture 4 (14) 115-121
[13] RBC. – URL: http://www.rbc.ru/ (Accessed 09.09.2016)
[14] 2016 Forecast of Russian scientific and technological development of the agro-industrial complex for the period till 2030: global challenges Newsletter "Agrarian heart rate of a great country" 4 14-21
[15] Kiryushin V.I. 2004 Exact agricultural technology as the highest form of intensification of adaptive-landscape agriculture Agriculture 6 16-20
[16] A.N. Ananiev Problems of application of robots in agriculture. – URL: http://www.biz-for.ru/robotics/robotsprobl/robotsprobl.php (Accessed 09.09.2016)
[17] Blynzny Y.N. Schukin S.G. 2013 Agricultural Engineering Western Siberia Innovation and food security 1 67-76
[18] Maksimov P.L., Ivanov A.G., Mokhov A.A., Petrov V.A. 2015 Study of the possibilities of automation of farm work Bulletin of the Izhevsk State Agricultural Academy 3 3 (44) 32-38
[19] Potential of innovations Russian market automation systems and robotics. – URL: http://www.slideshare.net/tuknov/otchet-robotfinal291014 (Accessed 09.09.2016)