Using digital technologies in horticulture

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Abstract. The article deals with the development of horticulture through the use of state-of-the-art technology including digital one. The results of scientists' research on the effectiveness of intensive gardens are analyzed. It was revealed that the technology of artificial neural networks is used to optimize processes in horticulture. Smart technologies in agriculture, which can be applied in intensive gardening, were studied.

1. Introduction

The soil and climatic conditions of a number of subjects in the Russian Federation meet the requirements for the effective cultivation of the main types of multiple fruit and berry crops (apple, pear, plum, currant, etc.), however, to make a serious breakthrough in Russian horticulture, an increase in intensive gardens, which output high quality and competitive products in the world market, is required [1].

The up-to-date agriculture is currently on the cusp of a second Green Revolution. The introduction and use of digital and information technology in agriculture including horticulture, precision farming and the Internet of Things (IoT) should lead to a significant increase in yields, and, consequently, to food import independence of the country.

The agricultural sector has traditionally been influenced by a large number of factors that negatively affect overall productivity, such as inaccurate forecast data, poor soil quality, faulty planting and harvesting practices, inappropriate irrigation, etc. Therefore, the use of IoT and other digital technology in agriculture, in particular in horticulture, will significantly reduce the influence of these factors.

The need to use progressive digital technology in the production of fruit products determines the relevance of this study.

2. Materials and methods

The research used the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials and Food Markets, the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2025 (FSTP), information from the leading scientific and educational institutions of the Russian Ministry of Education and Science, scientific and educational institutions of the Ministry of Agriculture Russia, and from a number of Russian and foreign organizations, where the results of research and information on the effectiveness of intensification of horticulture were presented.
3. Results

The development of intensive horticulture provides for the use of progressive technology for growing fruit crops. With the right organization, the economic efficiency of the site will be several times higher than that in the case of using traditional technology. In countries such as Israel, Italy, Spain, Bulgaria, Poland, Moldova, intensive gardening is predominant. One of the most widespread fruit crops is the apple tree. There are 22 countries in the world that produce apples on an industrial scale [2].

Mandatory elements of intensive horticulture technology are an automated monitoring and control system, liquid fertilization, and a drip irrigation system. In recent years, more and more attention has been paid to such promising projects as Smart Garden, which is an intelligent system (artificial intelligence, neural networks, etc.) for the preparation, execution and control of all the process steps for growing horticultural products using robotic / unmanned vehicles and units. In the minimum version, the control system has a fairly simple architecture, the key elements of which are various sensors, actuators and an automated workstation (WS) of the process operator. All information from the sensors is sent to the base station, and then to the operator's workstation, where it is processed, archived, visualized in a convenient form for the operator, as well as recommendations are output to the operator on the implementation of drip irrigation, fertilization and other activities [3].

Scientists from the Tambov State Technical University (TSTU), Michurinsk State Agrarian University, Lomonosov Moscow State University, Moscow Institute of Physics and Technology, Federal Research Center of Nutrition and Biotechnology, Institute of Biomedical Problems of the Russian Academy of Sciences, Derzhavin Tambov State University and other leading research centers and universities in the country and abroad are working on improving the Smart Garden control system based on artificial intelligence for industrial gardens [4].

Russian scientists have formulated the concept of a control system for biological and production processes in horticulture based on digital and intelligent technology, which implies the development of horticultural process systems at the level of a plant organism (molecular, genomic, cellular and tissue one), agroecosystem and industry. It is proposed to use the artificial neural networks for the collection, transmission, accumulation, storage and transformation of information in the form of feedback. The existing technical capabilities allow forming a concept of risk control and optimization of processes based on the tasks to be solved by the artificial neural networks, while handling data from all stages of horticulture where digital indicators are used. A system of control modules in the process chain of production, preservation and sale of horticultural products, which allows differentiating information coming to the decision-making system, has been developed [5-6].

Using unmanned aerial vehicles, scientists continuously monitor the condition of the soil, plants and climatic features, which allows for an accurate analysis of the territories studied.

When managing processes in intensive horticulture, the water potential of the soil and its salinity are determined, the moisture and temperature of the soil, the amount of precipitation, the humidity and temperature of the ambient air, the level of illumination, the wind speed are monitored, phytomotoring is performed, i.e. the parameters of the tree are measured (root system, trunk thickness and height, fruit size, etc.). Intensive gardens are characterized by the fact that they are located on rather large territories, therefore, to collect information from a large number of geographically distributed sensors, it is rational to use wireless communication channels (self-contained power supply is provided for several years). Using these wireless sensors, process operators will be able to obtain accurate data in real time from their garden plots. Based on the information received, the control system will be able to make key decisions, e.g. when to irrigate, how much fertilizer to apply, when to harvest, etc. Organized in this way around the clock access to all the necessary information minimizes numerous risks and allows gardeners to make more accurate decisions, and not only in the production process, but also in planning. In addition, the automated control system may have additional capabilities: in the event of emergencies for technical or process reasons, this control system automatically provides SMS-notification to employees of the relevant services [1].

With the development of industrial gardening, more and more devices are equipped with standard network protocols using the Internet of Things. In the last 20 years, a lot of wireless networks have
emerged in an ever-growing data communication size, such as 4G, GSM, GPRS, LTE, Wi-Max, Wi-Fi, ZegBee, that meet the requirements for rate, coverage range, and energy efficiency.

Smart technologies in agriculture can be divided into four large clusters (table 1) [7].

| Clusters | Decision groups | Advanced technology from major players |
|----------|----------------|---------------------------------------|
| Precision agriculture as a crop productivity management system based on the use of a system of satellite and computer technology | - Navigation and telemetry systems (systems for precise positioning of the unit in the field, parallel driving, yield mapping)  
- Earth’s Remote Sensing, e.g. operational acquisition of satellite images from Formosat-2 (NSPO, Taiwan), RapidEye (RapidEye AG, Germany) and aerial photographs  
- Geographic information systems (GIS)  
- Technology of differentiated fertilization | - GreenStar system from John Deere (USA)  
- CAM PILOT parallel driving system from Claas (Germany)  
- Parallel driving systems from Trimble, Inc. (USA)  
- Raven Cruizer system from Raven Industries (USA)  
- CenterLine 220 parallel driving system (heading indicator) developed by TeeJet Technologies (USA)  
- Leica mojoMINI system from Leica Geosystems (Switzerland)  
- TRACK-Leader system in the range of field navigators from Muller-Elektronik (Germany)  
- Azimut-1 navigation panel from Rateos LLC (Russia) |
| Agricultural robots | Unmanned vehicles / aircraft; UAVs for monitoring the state of fields and harvesting; smart sensors; automated systems for growing crops; automated control systems for dairy farms | - Jonh Deere AutoTrac 200 innovative system for automatic driving of any vehicle  
- Claas GPS PILOT system for automatic steering of agricultural machinery  
- AgGPS® Autopilot™ from Trimble, Inc. (USA)  
- SteerCommand® system from AG Leader (USA)  
- Topcon ACU direct steering system from Topcon Corporation (Japan)  
- AT400 Spirit modular robotic tractor without a control cabin from Autonomous Tractor Corporation (USA)  
- Innovative tools for managing precision farming production data and services from Farmers Edge (Canada)  
- AFS CONNECT up-to-date farming system from CNH GLOBAL  
- Iteris, Inc. (USA) provides consulting services through the ClearAg® leading high-precision farming platform and mobile application  
- CropX Ltd., an agricultural analytical company (Israel), develops cloud software solutions |
| AloT platforms / AloT applications allow automating the entire cycle of agricultural operations for growing plants or animals | - Peripheral equipment (sensors, transducers)  
- Navigation / communication channels (GPS / GLONASS, LPWAN, LTE, 3G, 4G, GPRS, GSM)  
- AloT platforms (web platforms for creating industry applications)  
- AloT applications (applications for IT platforms, standalone applications for | - Innovative tools for managing precision farming production data and services from Farmers Edge (Canada)  
- AFS CONNECT up-to-date farming system from CNH GLOBAL  
- Iteris, Inc. (USA) provides consulting services through the ClearAg® leading high-precision farming platform and mobile application  
- CropX Ltd., an agricultural analytical company (Israel), develops cloud software solutions |
A technology has recently been developed in Russia that is mainly related to the needs of machine-to-machine communication and data transfer within the framework of the Internet of Things concept. Connecting to a cloud service via wired/wireless Internet gives the monitoring and control system the ability to remotely access the system from anywhere. The user accesses the cloud service using a web interface from any computer or tablet. A distinctive feature of the automated control system is the presence of an intelligent decision support system that provides recommendations to the operator on irrigation, fertigation and other activities, as well as the widespread use of a wireless method of data collection based on the LoRaWAN network LoRa technology. LoRa is a state-of-the-art wireless technology for transmitting small data over long distances. It was just this technology that was chosen as the main communication technology in the Smart Garden pilot project. It provides a data transmission range of up to 15 km in the line of sight; ultra-low power consumption (the sensor can operate up to 10 years from a single 3,400 mA·h alkaline battery); scalability (the base station can serve up to five thousand sensors per square kilometer), and the star topology without the use of repeaters makes it easy to expand the network; high data protection and security that are provided by the 64-bit Extended Unique Identifier [EUI 64], 128-bit network connection key [AES 128] and 128-bit network application key [AES 128] [8].

To build the Smart Garden control system, preference was given to Vega-Absolute (Novosibirsk), whose main profile is the production of equipment and software as part of the Smart City concept, which supports LoRa technology. The Smart Garden installation were used, as test elements, sensors for measuring air temperature on the soil surface and in the crown of a tree: a temperature sensor using LoRaWAN protocol (TD-11); sensors for measuring soil moisture (DP-11) having an output signal of 4-20 mA; sensors for measuring the amount of water for irrigation fitted with a tachometer liquid meter with a pulse output signal, and with a VEGA pulse counter (SI-12). The base station (BS-2) is designed to deploy the LoRaWAN network at a frequency range of 863-870 MHz. The base station is powered and communicated with the server via the Internet, and can be powered via the server and the 3G channel. The workplace of the process operator is built based on the domestic MasterSCADA system [9].

The joint research of the North Caucasian Federal Scientific Center for Horticulture, Viticulture and Winemaking, Dokuchaev Soil Institute Federal Research Center and Space Research Institute of the Russian Academy of Sciences (SRI RAS) used space sounding of lands occupied by gardens in order to determine the prospects for their use by optimality degree. Based on the research results, relief maps of the Krasnodar Territory and the North Caucasus were elaborated in terms of height above sea level, steepness and exposure of the slope, as well as soil maps for 2005-2010 by 13 indicators. The geographic information system used in the research makes it possible to exclude manual graphic compilation of integrated agroecological maps. The use of such geographic computer ecological maps allows making the right decision about where in the garden (field) one can harvest a larger or smaller crop. New digital technology is needed in fruit growing, which will increase the profitability of fruit production by 50-100% while minimizing the risks associated with the placement of crops and varieties. In fruit growing, an important task is to create a new revised version of the digital geographic system for the rational placement of fruit crops and varieties. This will minimize the risks
of reducing the productivity of crops and varieties in conditions of climate fluctuations and changes in the growing environment. The innovative digital technology developed by scientists will allow for: selection and monitoring of growing areas for given crops and varieties in accordance with various requirements for environmental conditions; selection of varieties, the genotype of which corresponds to the growing conditions in terms of ontogeny phases; selection of agricultural technology that ensures the specified quantitative and qualitative results of growing fruit crops in a specific place [10].

4. Conclusions
The development of high-precision monitoring using the achievements of the space industry, the aviation industry, information and digital technology is one of the elements of a complex system that allows receiving online high-precision data on the state of soils, fertilization, amount of water, physiological state of plants, climatic situation, and analyzing and making operational and organizational decisions on the application of agricultural and process methods.

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