The choice of mechanism for collecting big data in digital agriculture: soil and weather sensors

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Annotation: Agriculture plays a significant role in ensuring food security of countries, and improving the efficiency of the agricultural industry is an important aspect in the world with a growing population. Collecting and analyzing big data in agriculture can help a farmer make more accurate decisions, save resources and increase yields. This article discusses aspects of choosing a mechanism to collect data on the state of the soil and weather conditions. The research was based on the results of a survey of farmers in the Astrakhan region and the author's experience in realizing projects for the collection and analysis of data in the field of crop production. The article gives recommendations on the choice of sensors for data collection.

Keywords: digital agriculture, soil sensor, weather sensor, big data, data science, precision farming, data collection, digital economy

Introduction

Agriculture has always played an important role in ensuring food security of the country [1]. In a world with a growing population, this aspect is particularly relevant. There is a need for more active implementation of digital technologies in agriculture and the use of data to support decision making to improve the efficiency of the agricultural sector as part of the transition to a digital economy. Practice has shown that the use of big data helps to improve business performance in various industries [2]. One of the sources of data in the agricultural industry (in particular, in the field of crop production) is data on the state of the soil, which affects the level of yield. Constant soil monitoring and timely identification of problems can help a farmer maintain an optimal level of environment for cultivated crops and quickly respond to possible problems. Additional monitoring of the moisture level, temperature and salinity of the soil can help the farmer save resources and improve the ecological compatibility of the products. Such approaches in precision farming involve the use of soil sensors. In addition, it is

necessary to consider weather data, which also affects the doing of the agricultural business.

Materials and methods

This study used the results of a survey of farmers in the Astrakhan region conducted in 2017, an overview of the relevant literature, and the author's experience in introducing technologies for data collection and analysis in the agricultural fields of the Astrakhan State University. A set of methods used in this study has helped to identify the most popular areas of agriculture, where data collection can help to increase efficiency, as well as to make recommendations on the selection of sensors to collect data in agriculture.

Literature review

In the last decade, the use of sensors to collect data from agricultural fields attracted much attention from research teams. Ruiz-Garcia, Lunadei, Barreiro, and Robla [3] studied wireless sensor technologies and applications in agriculture. It also focused on wireless sensor networks and radio frequency identification, presenting recent developments and examples of applications. Garcia-Sanchez, Garcia-Sanchez, and Garcia-Haro [4] also found that wireless sensor networks became a dominant option of monitoring different parameters of a crop thanks to low-cost and low-power consumption deployments. Hybrid terrestrial underground wireless sensor networks can be used to show the environmental parameters of soil and monitor it in real-time [5].

In their study, Keshtgary and Deljoo [6] described and compared several topologies of wireless sensor network depending on the size of the sensor mounting zone. Ojha, Misra, and Raghuwanshi [7] analyzed wireless sensor networks with regard to communication standards, networking technologies, and hardware. The authors also showed the perspectives and challenges of the existing

framework. The problem of energy efficiency of sensors was investigated by Sahota, Kumar, Kamal, and Huang [8] who proposed a scheme of the sensor network model. A review of existing wireless sensor system frameworks in agriculture domain was conducted by Abbasi, Islam, and Shaikh [9] who additionally described and compared different sensors used in agriculture. According to their study, there are several types of sensors used in agriculture: soil sensors (temperature, moisture, dielectric permittivity, rain/water flow, water level, conductivity, salinity), leave/plant sensors (photosynthesis, moisture, hydrogen, wetness, CO2, temperature), weather sensors (temperature, humidity, atmospheric pressure, wind speed, wind direction).

Results and discussion

According to the data of the questionnaire, the most popular data sources for farmers are soil condition (including soil moisture, temperature, and level of salinity), weather data (and its forecast), and vegetation condition (see Fig.). Within the framework of this study, aspects of the selection of sensors of soil and weather conditions are considered.

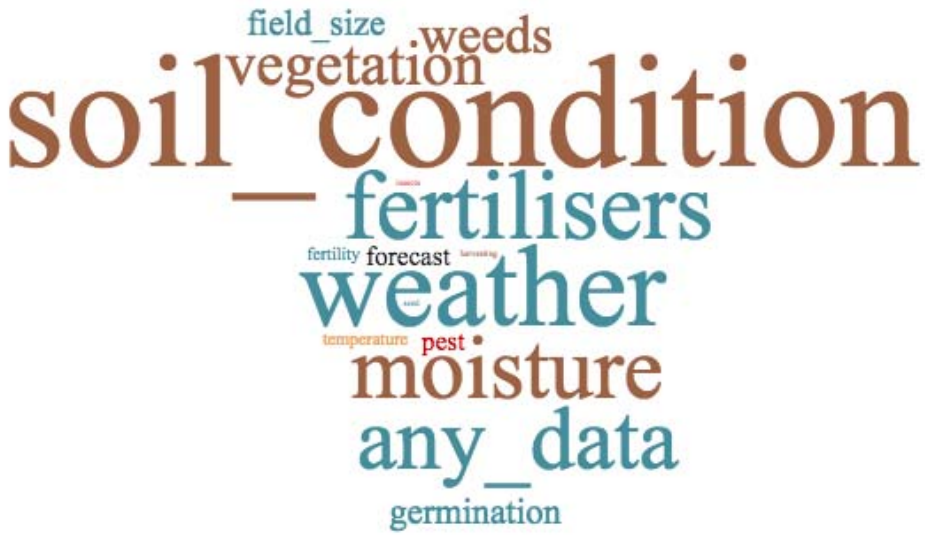

Fig. Wordcloud of data sources

Soil sensors can be used to collect soil condition data. It is popular to do that due to low-cost and low-power consumption deployments. The identified preferences of farmers include the following soil parameters: moisture, temperature, and level of fertilizers (salinity).

In simple words, the wireless soil sensor is an electronic device consisting of a rod with chips that plugs directly into the soil, and a mechanism (data logger / reader) that reads the required values and sends them to the base station for further processing [4]. Since wireless data transmission technologies are promising, the use of sensors in the future is likely to be based on this.

As for the standards of wireless communication in agricultural applications, the most popular are the following: ZigBee, WiFi, Bluetooth, WiMAX (Worldwide Interoperability for Microwave Access), and GPRS/3G/4G/5G [7].

Sensors also differ in their functionality. To select a data collection system, a farmer can implement a ready-made solution into their business, or it is possible to build the system independently, depending on the needs of their business.

For the collection and analysis of weather conditions, sensors are used for ambient temperature, atmospheric pressure, wind speed, precipitation level, air humidity. Often such sensors are produced as a set in the form of a small weather station. Such meteostations can additionally play the role of the base stations for the network of soil sensors and the gateway nodes for transferring the collected data to the database and the server for their storage and subsequent processing.

To use meteorological sensors in agriculture, it is necessary to analyze similar aspects as when selecting soil sensors: the type of data required, the data format, the way data is transferred to the farmer, the station's mobility, the cost of a weather station, the possibility of using a weather station in conjunction with soil sensors (as a base station for soil sensors), the complexity of implementation of the device and its maintenance, power sources, the lifetime of the station, and the software for processing and visualizing weather data and weather forecasting.

It should also be noted that in certain cases a farmer needs only a few indicators of the weather conditions (for example, only the temperature and humidity of the air). In such cases it will be enough to have separate sensors or to receive weather data in the farmer's region from open sources on the Internet.

The station for collecting weather data, moreover, can be designed and configured by the farmer independently and at a lower cost (e.g. [10]). The efficiency of such a station is comparable to popular commercial solutions.

Analysis of the sensor specification has revealed several common drawbacks that can limit their use by farmers: high cost, limited distance with wireless data transfer, the need for periodic calibration of sensors, limited power reserve for autonomous operation, low power, small internal memory and lack of information encryption mechanisms.

The general scheme of using a wireless sensor network for data collection in agriculture is as follows:

1. The distribution of the sensors in the fields and configuring the wireless network.
2. Data collection and monitoring of soil condition. Setting triggers and alerts to quickly identify problem areas.
3. Analysis and visualization of data using specialized software and corresponding algorithms.
4. Interpretation of the results and taking action if necessary. With the rapid identification of problem areas of the soil, the farmer can quickly take action, reducing possible losses and saving the future harvest. Some aspects of this process can be automated.

The choice of sensors

The results of the questionnaire showed that it is important for farmers to know the condition of the soil and the state of vegetation during the agricultural

season. Monitoring the condition of the soil and vegetation allows the farmer to identify problems in advance and solve them in a timely manner. There are many varieties of sensors and the farmer should select the soil sensors correctly.

Literature review, analysis of the specifications of sensors and the work experience of the author on the use of soil sensors in agriculture showed that the choice of soil sensors should begin with the answers to the following questions:

1. To determine the purpose of using sensors in the agricultural business, what parameters need to be measured and monitored for more effective soil management? The most common characteristics are: soil moisture, salinity, soil temperature, dielectric permittivity, water level, and conductivity [9]. There are sensors that measure only one of these parameters or several (for example, soil moisture, temperature, and salinity).
2. How can the type of soil affect the choice of the sensor? Not all soil sensors are universal and they may show inaccurate results under certain conditions (e.g. soil types).
3. How can a particular type of crop affect the choice of sensors? For example, plants can have different root lengths (this may require reading the values at several levels), agricultural fields can be treated with machinery in different ways (these can be a tractor with plows or manual work).
4. What methods of data transfer from the sensor to the base station are the most optimal at this stage of business development? Sensors can use both wireless data transmission technologies and data transmission via wires [3] It should be considered when processing the soil by mechanical tools. In addition, there are portable sensors that involve manual reading of data [9]. They can be used by farmers for periodic reading of indications.
5. What level of accuracy is needed? For example, for certain plant types, it is necessary to maintain a certain level of soil moisture. To improve measurement accuracy, most sensors need to be calibrated depending on the

type of soil and its structure [11]. For this purpose, a special calibration device can be packaged with sensors.

6. What is the expiry date of the sensor (the period of effective use)? How reliable is the sensor? The expiry date of the sensors can vary from 2-5 years, up to 20 years.
7. What is the price of the sensor / sensors and the payback period? Costs include the price of the device itself and the costs of its implementation and maintenance. The introduction of new technologies should also imply financial benefits. This can be expressed in reducing costs due to increased production efficiency or in increasing the number of crops, the scale of production and sales.
8. How many sensors are required for a particular field? The answer to this question depends, in particular, on the size of the field, the condition of the soil at the moment, the level of details required, the financial possibilities, and the power of the sensors used.
9. Is the sensor compatible with other farm systems used by the farmer? For example, a soil moisture sensor should be compatible with an automatic watering system [12]. If other sensors are already used, then the new sensors should be compatible with the existing system.
10. In what format will the data be provided and how will it be used in the future? It can be numeric values in the table and additional visualization in the form of graphs and diagrams. Additional software can be supplied with the sensor.
11. Is it possible to implement a network of sensors by the farmer? How difficult is it to do? What maintenance does it require? Does the seller provide training on the introduction of sensors?

To monitor weather conditions, data from regional weather stations can be used via the Internet or these data can be collected using weather sensors as part of a small mobile weather station. Such a station can become a base station for a wireless network of sensors to transfer data to the server and database. The use of public weather data practically does not require additional financial costs, but may not be accurate enough to monitor the dynamics of meteorological conditions in agricultural fields. The farmer should find a compromise based on financial possibilities and the necessary accuracy of the data.

Conclusion

Data collection and the use of digital technologies can improve the efficiency of agribusiness management and help the farmer save resources. Soil and weather sensors used in digital agriculture are one of the mechanisms for collecting data for further processing and analysis. The introduction of new technologies into agribusiness involves investing money in infrastructure and technology, and it is important for a farmer to understand the benefits of such innovations and the criteria for selecting appropriate mechanisms to minimize their risks.

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