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DIGITAL TOOLS FOR MONITORING AND MANAGEMENT IN AGRICULTURAL PRODUCTION

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Abstract
The digitalization of agricultural production has led to the widespread use of mobile technologies for monitoring and managing agricultural processes. Applications and devices such as drones and satellites allow you to receive real-time data on soil conditions, humidity, plant growth, and pest threats. This data helps farmers to make quick decisions on irrigation, fertilization, and crop forecasting. Modern mobile solutions such as AgroMonitor integrate with various data sources and provide accurate information, which increases the efficiency of resource management and reduces production risks. The introduction of these technologies not only helps to increase yields but also ensures the sustainable development of agricultural operations, minimizing the impact of external factors. Thus, digital tools are becoming an important element of the modernization of the agro-industrial sector, contributing to its competitiveness at the global level.

Keywords Digitalization, agriculture, monitoring, resource management, mobile applications, AgroMonitor, drones, satellite data, yield forecasting.

INTRODUCTION

In recent years, the digitalization of agricultural production has become increasingly relevant against the backdrop of global changes in the agribusiness sector. Technological advancements open new opportunities for monitoring and managing agricultural processes, ensuring more efficient resource use and increased yields. Digital tools such as mobile applications, drones, and satellite data enable farmers and agronomists to monitor field conditions in real-time, significantly improving decision-making processes. The use of such technologies has become an important element of competitiveness in agriculture, especially in the context of climate change and the growing demand for food security.

The relevance of this research is driven by the increasing need to optimize agricultural processes, which requires the implementation of innovative monitoring and management methods. In the face of global climate changes and the depletion of natural resources, enhancing agricultural efficiency and minimizing the impact of external factors on agricultural processes have become increasingly significant. The adoption of digital solutions can not only increase yields but also reduce resource costs, making them a necessary component of sustainable development in the agricultural sector.

This work aims to study digital tools for monitoring and management in agricultural production and their impact on enhancing the efficiency and sustainability of agricultural processes.

1. Mobile Applications for Field Monitoring

In the agricultural sector, there is currently rapid development among large enterprises such as agribusiness holdings, which manage extensive areas of agricultural land. Modern technologies, such as satellite monitoring and the use of drones, are being actively applied for field diagnostics. These methods allow for the rapid acquisition of accurate data. Among other tools, leaf diagnostics and soil analysis are also actively used.

High-resolution satellite images, which are used for diagnosing crop conditions, provide farmers with the ability to analyze field status using spectral cameras. Spectral data enable the calculation of vegetation indices, such as NDVI, which is widely used in agriculture. Satellite data not only help assess the current state of crops but also analyze the development dynamics of fields over the past years. This allows agronomists to adjust crop rotation and identify errors from previous seasons to develop more effective work plans.

An undeniable advantage of satellite monitoring is the capability for retrospective analysis due to image archiving. This aids in analyzing the history of yield changes and other field indicators over extended periods. However, it is important to consider the dependence of data accuracy on weather conditions, such as cloud cover, and limitations on the frequency of imaging, which is typically conducted weekly.

The practical application of data obtained through satellites and drones requires knowledge of agronomy and geoengineering. The use of this data is effective at all stages of the production cycle, starting from assessing soil conditions before planting and ending with yield forecasting before harvest.

During the initial monitoring phase, the state of the soil and the terrain of the plot are assessed, helping to determine optimal cultivation methods. At the seedling stage, the density and uniformity of crops are analyzed, allowing for the identification of areas with losses and the implementation of appropriate measures.

Subsequently, fertilizer application is monitored, and weed control is conducted, as weeds are one of the main causes of yield loss. Drone images not only assess the concentration of weeds but also identify their types, aiding in the selection of the most suitable herbicides.

Leaf diagnostics and soil analysis are important tools for assessing crop conditions and determining the necessary measures for fertilization. Leaf diagnostics help evaluate the chemical composition of plant tissue, while soil analysis identifies the fertility level and contamination of the plot.

Thus, the use of modern field monitoring technologies contributes to the effectiveness of agronomic practices, improving yields and optimizing resource use. Digital data allow farmers to make more informed decisions. For instance, creating a unified database for fields that includes information on previous yields and agrochemical characteristics helps improve planning and reduce losses. Additionally, using yield maps allows for the optimization of fertilizer use, which is particularly relevant given the rising costs.

Digital technologies also provide farmers with the ability to quickly assess crop conditions. For example, through geospatial analysis, problematic areas can be identified promptly, allowing for the adjustment of agronomic practices. Monitoring systems, such as the Cropwise platform, provide nearly ready data on plant conditions, enabling farmers to respond swiftly to changes and make informed management decisions. Table 1 below describes the functionality of mobile applications for monitoring field conditions.

Table 1. Functionality of mobile applications for monitoring the state of fields [5].

Functionality	Description
Soil Moisture Monitoring	Applications receive real-time data from sensors regarding soil moisture, helping to optimize irrigation.
Temperature Monitoring	Applications track current and forecasted temperatures, enabling the planning of agronomic activities.
Plant Condition Analysis	Using data from drones and satellites, applications assess plant health, including greenness and stress levels.
Light Level Control	Applications measure sunlight levels affecting plant growth and provide agronomic recommendations.
Satellite Data Processing	Applications integrate with satellite systems to obtain field images and analyze conditions over large areas.
Weather Condition Notifications	Applications send alerts about weather changes (rain, drought, frost), helping to take prompt action.
Irrigation Management	Applications allow remote management of irrigation systems based on soil moisture data and weather forecasts.
Pest and Disease Detection	Through image analysis and sensor data, applications identify pests or diseases at early stages.
Yield Forecasting	Applications use historical data and current indicators to create forecasts of expected yields.
Geolocation and Field Mapping	Mobile applications provide maps of fields indicating current conditions and various treatment zones.
Resource Management	Applications help track the use of fertilizers, herbicides, and other resources, increasing their efficiency.
Reporting and Analytics	Applications generate reports based on collected data and offer recommendations for improving fieldwork.
Compatibility with Drones and Sensors	Applications integrate with drones, IoT sensors, and other devices for more accurate field monitoring.

Thus, digital solutions assist farmers not only in managing their fields more effectively but also in conserving resources by making more accurate and informed decisions.

2. Mobile Solutions for Resource and Operations Management in Fields

Digital solutions for the agribusiness sector are becoming key tools for ensuring high productivity and accuracy in agricultural management. Modern applications allow for the effective tracking of

production processes in real-time, minimizing human error and significantly reducing the risks of mistakes. They process vast amounts of data, contributing to increased productivity of agricultural lands.

The functional capabilities of these applications include:

- comprehensive monitoring of crop and land conditions, soil analysis, fertilizer application, management of planting campaigns, and harvest collection;
- use of vegetation maps;
- satellite monitoring of field properties;
- monitoring of pest and weed infestations;
- mapping of land plots, sampling of soil and plants for phytopathological and agrochemical studies;
- monitoring of harvest collection, from loading in the field to storage.

These digital tools allow for the automation of many routine operations, reducing time and labor costs. The applications facilitate process optimization, significantly lowering management expenses for agricultural operations.

Some technologies enable enterprises to monitor the condition of their equipment and conduct preventive maintenance. This is particularly relevant for essential production assets, such as technological lines, boilers, and electrical networks. Specialists conducting inspections focus on inventory management and diagnostics, identifying defects, and troubleshooting, which allows for quick responses to any technical issues.

Typically, such inspections at enterprises are organized manually, which can lead to time and resource losses. Traditional methods using notebooks and logs often result in errors and delays. To address these shortcomings, mobile solutions, such as applications for monitoring equipment conditions, are increasingly being used to automatically record data and resolve issues more quickly. If discussing the elements of this system, they are reflected in Table 2.

Table 2. Elements of the mobile system [7].

Element	Purpose	Suitable Automation Solution
Data Collection Terminal	The device is used as a mini-computer for data entry during inspections and for sending data to external accounting programs	Any data collection terminal from the catalog or an Android smartphone
Field Worker Application	It records information about fixed assets, manages work orders, plans routes, and more	DM.TOIR
Information System (Accounting Program)	It allows for the accounting of fixed asset objects and repair activities, registers defects, plans teamwork, and creates orders. It integrates with the application on the data collection terminal, sends tasks to it, and remotely receives data.	"1C Enterprise Management"

Thus, such applications ensure comprehensive monitoring of crop conditions, soil analysis, pest, and weed monitoring, as well as equipment condition management, and preventive maintenance. The integration of satellite data, vegetation maps, and other information sources contributes to more effective management of agricultural operations and increased productivity.

3. Application of Mobile Technologies for Yield Analysis and Forecasting: The Case of AgroMonitor

The application of mobile technologies for yield analysis and forecasting has become an important aspect of agricultural digitalization. In recent years, the rapid development of mobile applications and digital solutions has significantly enhanced the efficiency of managing agricultural processes. The use of mobile technologies not only simplifies access to data but also enables timely decision-making based on the information obtained. This section describes the AgroMonitor project—an application that enhances the efficiency and sustainability of agricultural operations through modern technologies. AgroMonitor provides farmers with digital tools for monitoring, managing, and analyzing agricultural resources. The application allows users to receive real-time data on field conditions, manage irrigation and fertilization, and forecast yields. It integrates with various data sources, such as sensors, drones, satellite imagery, and meteorological services, ensuring precise management of agricultural processes.

One of the key advantages of this application in agriculture is its ability to integrate with various data sources. This data includes information on soil conditions, moisture levels, nutrient content, and weather forecasts, enabling timely adjustments to crop management actions.

The use of this application also facilitates the automation of yield forecasting processes. Through machine learning algorithms and the analysis of historical data, farmers can predict potential yield volumes, taking into account the influence of climatic conditions, soil types, and applied agronomic methods. This significantly enhances the accuracy of forecasts and minimizes risks associated with crop failures or surplus production.

Additionally, the use of mobile applications streamlines interactions among various participants in the agricultural process. Farmers can exchange information in real-time with agronomists, consultants, and suppliers, which accelerates decision-making and supports more flexible resource management. Thus, mobile technologies are becoming an essential tool for increasing yields, improving planning, and optimizing costs in the agricultural sector. Table 3 describes the capabilities of mobile technologies for yield analysis and forecasting.

Table 3. Possibilities of mobile technologies for yield analysis and forecasting [8].

Application Aspect	Description
Real-Time Data Collection	Mobile technologies enable agronomists and farmers to collect data from fields in real-time using sensors, drones, and GPS devices. This includes monitoring soil conditions, moisture, temperature, and light levels.

Use of Satellite Data	Mobile applications integrate with satellite monitoring systems to obtain data on field conditions, plant greenness, and other indicators, aiding in yield forecasting.
AI and Machine Learning-Based Forecasting	Mobile applications utilize artificial intelligence algorithms to analyze collected data and create yield forecasting models based on climatic conditions, agronomic practices, and historical data.
Irrigation Management	Through mobile applications, farmers can monitor irrigation systems and optimize water usage based on soil conditions and weather data, enhancing crop cultivation efficiency.
Disease and Pest Analysis	Mobile applications enable the detection of early signs of diseases and pest invasions through images from drones or smartphones, helping to prevent yield reduction.
Weather Condition Monitoring	Mobile applications provide accurate weather forecasts and recommendations for agronomic practices, assisting in better planning for planting, fertilization, and harvesting.
Yield Forecasting	Based on collected data, mobile applications can predict yield levels by analyzing climatic factors, soil conditions, and the current state of plants.
Integration with Financial Systems	Mobile technologies can integrate with platforms that help farmers forecast financial outcomes based on expected yields and production costs.
Feedback and Recommendations	Mobile applications provide personalized recommendations for optimizing field operations based on data analysis, improving processes, and increasing yields.
Resource and Inventory Management	Mobile technologies enable tracking and management of fertilizer, seed, and other resource usage, facilitating more accurate planning of agronomic practices and reducing costs.

Based on the above, it can be stated that the application of mobile technologies for yield analysis and forecasting improves the management of agricultural processes by providing farmers and agronomists with access to real-time data and the ability to make timely decisions. The automation of the forecasting process using machine learning algorithms minimizes risks associated with yield fluctuations and promotes more effective planning and resource management. Modern mobile applications, such as AgroMonitor, enable agronomists and farmers to obtain real-time data from sensors, drones, and satellites. This is achieved through integration with various data sources, such as sensors, drones, satellite imagery, and meteorological services, ensuring precise management of agricultural processes.

CONCLUSION

Digital technologies play a crucial role in modernizing agriculture, enabling efficient management of production processes and minimizing risks. Mobile solutions that integrate data from various sources, such as drones, satellites, and sensors, provide farmers and agronomists with tools for timely analysis and decision-making. The implementation of such technologies enhances the monitoring of field conditions and resources, ultimately contributing to increased yields and the sustainability of agricultural production.

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