Features of digital phytosanitary monitoring of agricultural crops

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Abstract. The subject of the study is digital phytosanitary monitoring of agricultural crops. The object of the study is agricultural crops of the Russian Federation. The following main research methods are used: monographic method; method of analysis and synthesis; method of observation; method of comparison; method of expert assessments. As a result of the scientific research, the following result was obtained. The concept and essence of digital phytosanitary monitoring of agricultural crops are considered. We have determined that digital phytosanitary monitoring of agricultural crops is understood as a high-tech process that includes monitoring the state of growth and development of plants in order to protect them from harmful organisms and the influence of environmental factors. Three options for conducting phytosanitary monitoring of agricultural crops in the Russian Federation are considered: the use of satellite systems; the use of aviation equipment; the use of sensors and devices of agricultural machinery. The differences between digital phytosanitary monitoring of crops and the traditional method are determined by the following five characteristics: the time of monitoring; access to information; the possibility of physical damage to the studied plants; spatial and temporal analysis of vast, remote territories and interaction with each other; obtaining final results.

1. Introduction
In order to accurately monitor the growth and development of agricultural plants, it is necessary to obtain timely high-quality information from the cultivated areas by using technologies that are completely safe for agricultural crops. Today, life requires agricultural producers to develop in modern technological formats [1].

A new progressive direction in the issue of plant protection is digital phytosanitary monitoring of crops. The object of the study is agricultural crops of the Russian Federation. The subject of the study is digital phytosanitary monitoring of agricultural crops. The purpose of the study is to study and analyze the features of digital phytosanitary monitoring of agricultural crops.

The goal is achieved using the following tasks:
- to consider the concept and essence of digital phytosanitary monitoring of agricultural crops;
- to study options for conducting digital phytosanitary monitoring of agricultural crops in the Russian Federation;
- to identify the distinguishing features of digital phytosanitary monitoring of agricultural crops from the traditional method.

The following main research methods are used in the work:
- monographic method;
- method of analysis and synthesis;
- method of observation;
- comparison method;
- method of expert assessments.

2. Literature review

Based on the studied scientific literature, we have identified the following concept of digital phytosanitary monitoring of agricultural crops [2–4].

Digital phytosanitary monitoring of agricultural crops is understood as a high-tech process that includes monitoring the state of growth and development of plants with the help of technical devices in order to protect them from harmful organisms and the influence of environmental factors.

Digital phytosanitary monitoring of crops is based on the use of modern technical means and is carried out in a continuous mode for the analysis, assessment and forecast of the phytosanitary situation in a certain territory, and to determine the cause-and-effect relationships between the state of agricultural plants and the impact of environmental factors on them [5].

There are 3 main options for conducting digital phytosanitary monitoring of agricultural crops: the use of satellite systems; the use of aviation equipment; the use of sensors and devices of agricultural machinery.

2.1. Phytosanitary monitoring of crops from satellite systems

Satellite images are used to monitor the state of vast agricultural areas, and their processing allows for phytosanitary monitoring of the state of agricultural crops in specific fields. Competent interpretation of satellite image data allows the user to make decisions on the spot application of the necessary fertilizers, irrigation of agricultural crops and other activities [6].

The advantage of conducting phytosanitary monitoring of crops from satellite systems is the wide coverage of the cultivated area.

The disadvantage of conducting digital phytosanitary monitoring of crops from satellite systems is the insufficiently high accuracy of the data obtained.

2.2. Application of aviation tools for obtaining data on phytosanitary monitoring of crops

One of the promising areas for conducting phytosanitary monitoring of crops is aerial photography. Aerial photography is the process of photographing the earth's surface from airplanes, helicopters, unmanned aerial vehicles, and other types of vehicles [7].

The demand for the use of aviation equipment is due to the high accuracy of the data obtained and is more relevant in comparison with satellite images. However, they are inferior to the latter in the scope of coverage of the sown territory [8].

The advantage of using aerial photography on agricultural land is efficiency, since the time difference from the moment of shooting to the moment of receiving the image is relatively small compared to receiving satellite images, and agricultural crops are not hidden by anything and are well obtained in the images.

The disadvantage of conducting digital phytosanitary monitoring of crops using aerial photography is the high economic costs that hinder the use of aerial photography for agricultural purposes. In this regard, the use of aerial photography is unprofitable when shooting small agricultural fields, since the cost of organizing work per unit of captured area is significantly higher than similar indicators when shooting large acreage.
2.3. Use of sensors and devices of agricultural machinery to obtain data on phytosanitary monitoring of crops

To obtain data on phytosanitary monitoring of crops, optical devices with non-contact sensors are installed on agricultural equipment, which allow obtaining information about the content of food elements in plants [9]. The advantage of conducting these surveys is the ability to work in fog and rain conditions, which is a frequent occurrence during spring and autumn agricultural field work. The disadvantage of conducting digital phytosanitary monitoring of crops using sensors and devices of agricultural machinery is the possibility of physical damage to plants.

3. Results

Digital phytosanitary monitoring of agricultural crops includes 5 main stages (Figure 1):

Stage 1. Planning of shooting works. At this stage, the route, the height of the shooting, the number of shots, the maximum exposure time, the intervals between exposures, the number of routes and the distance between them are set. These parameters are determined based on the tasks that agronomists or crop monitoring specialists face.

Stage 2. Survey of agricultural crops. The survey of agricultural crops is carried out by the areal method by laying straight parallel routes. For continuous shooting of the terrain, the overlap of the images between each other (transverse) should be at least 60%, and between the routes (longitudinal) - 40%. It is necessary to choose the optimal timing that coincides with the main phases of plant development in sowing.

Stage 3. Preliminary processing of the results. Pre-processing of the results includes editing the photos, as well as checking the specified overlap values between the images and routes.

Stage 4. Creating a plan. Creating a plan involves transforming the resulting photos and combining them. The transformation is caused by the geometric distortion of the primary images.

Stage 5. Creating a forecast and evaluating its accuracy. At the final stage, the forecast is created and its accuracy is evaluated. The forecast is based on indicators based on the tasks of conducting phytosanitary monitoring of agricultural crops.

Figure 1. Main stages of digital phytosanitary monitoring of agricultural crops
Based on the analysis, it can be concluded that digital phytosanitary monitoring of agricultural crops, in contrast to traditional phytosanitary monitoring of crops, has a number of advantages [10–12].

Traditional methods of crop research, based on sampling of agricultural crops, their physical and chemical analysis in the laboratory, take a lot of time, are quite time-consuming and not always timely.

The main distinguishing features of digital phytosanitary monitoring of crops from the traditional method are reflected in table 1.

Table 1. Distinctive features of digital phytosanitary monitoring of crops

| Distinguishing features | Traditional phytosanitary monitoring of crops | Digital phytosanitary monitoring of crops |
|-------------------------|----------------------------------------------|-----------------------------------------|
| 1. Time of monitoring   | Long process; time-consuming                 | Quick process                           |
| 2. Access to information| Not always convenient access; often not timely| Convenient access; timely               |
| 3. The possibility of physical damage to the studied plants | High probability of damage                   | No damage (or with minimal damage when using agricultural machinery devices or with minimal damage when using agricultural machinery devices) |
| 4. Spatial and temporal analysis of vast, remote territories and interaction between them | There is no possibility                      | There is a possibility                   |
| 5. Getting the final results | Long process; time-consuming                 | Quick process                           |

In table 1, five distinctive features are considered: the time of phytosanitary monitoring of agricultural crops; access to the information obtained; the possibility of physical damage to the studied plants; spatial and temporal analysis of vast, remote cultivated areas and interaction with each other; obtaining the final results of phytosanitary monitoring of agricultural crops.

As a result, the advantages of digital phytosanitary monitoring of crops in comparison with the traditional method were revealed for all the listed features.

4. Conclusion
As a result of the conducted research, it can be concluded that with the use of digital phytosanitary monitoring of agricultural fields, it becomes possible to obtain the latest and reliable information about the state of agricultural crops, using space satellite systems, aviation equipment, sensors and devices of agricultural machinery.

Despite the variety of ways to obtain digital data, the use of each of them allows you to quantify the areas occupied by agricultural crops, determine the phases of development of agricultural plants, problems with the state of crops (uneven maturation, infection with pests and diseases, lack of nutrients, death from adverse meteorological conditions), which are important indicators for predicting yield.

Based on the obtained digital data, it is very convenient to analyze, make estimates and make a forecast of the phytosanitary situation in a certain area, as well as to determine the cause-and-effect relationships between the state of agricultural plants and the impact of environmental factors on them.
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