Implementation of the Modern Monitoring Methods as the Main Stage of Digitalization of the Agrarian Enterprises

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Abstract*— Population is growing and, at the same time, the need for food requires new methods of agriculture. Modern technologies help agrarian producers to improve yields in conditions where suitable fertile lands are decreasing every year and climatic conditions become unpredictable. In addition to global problems, agrarian producers face the competitiveness of large agrarian giants when business exists in tough market conditions. The use of the modern tools for improvement of productivity has influence on the big number of agricultural enterprises. The main obstacle to the widespread dissemination of these tools is the lack of experience in using modern means and technologies, including monitoring. The article discusses the most available method for entering to a new level of digitization, namely, monitoring with the help of satellites and drones. This method of increasing yields is widely used in the world, but is only beginning to gain popularity in Ukraine. The information which is provided in the article will help agricultural producers to assess the need of implementation of these tools for their own businesses and to understand the benefits of a particular method of monitoring. The article explains in an accessible way the advantages and disadvantages of modern methods of monitoring, mechanism of its action and implementation; provides a comparison of the quality of information of satellites and drones, and considers the problems and prospects of these methods of monitoring in the future.

Keywords: agrarian business, drone, normalized difference vegetation index, satellite monitoring.

I. INTRODUCTION

Crop monitoring helps to gather key data on the future prospects of the crop. Monitoring can detect plant diseases, quality of seedlings, weeds in the field and more. You can also identify plant growth variations in different areas of the field, identify the causes of these deviations, and adjust further actions.

Monitoring is a time-consuming process. It needs to spend a lot of time regardless of the area of the fields.

In the particular case, the agronomist must inspect the condition of the crops on his own and circumvent the fields at least every few days. If the crops have reached more than a meter in height, then the analysis is complicated.

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Crop monitoring allows timely improvement of plant growth condition and increased yield at the final harvest stage.

Ukraine is one of the largest exporters of agricultural products due to the large number of fertile soils, good climate and water resources. All this defines the great potential of the country in the agricultural business. However, insufficient information on the crop can lead to loss of profitability for the agricultural business, even under favorable conditions.

The market offers a large number of modern monitoring methods, but the most common are the use of satellites and drones. These methods have made many agricultural producers competitive enough for the international agricultural market.

II. RESULTS

A. Modern monitoring methods as a tool for improvement of agriculture

Satellites and drones that have changed agriculture in recent years are considered to be the most available monitoring tools.

Monitoring is done with the help of satellite photos. When the satellite is above a certain area of the field, it makes a photo for further analysis (Table I).

Table- I: Available information of satellites and drones

Aim of monitoring	Satellite (10 m-250 m)	Satellite (60c m-1,5 m)	Drone
The real area of the field, its relief	-	-	+
Condition of the field, presence of puddles, salt marshes, waterlogging	-	+	+
Area of performed operations	-	-	+
Quality of performed operations	-	-	+
State and dynamics of vegetation on the base of Normalized Difference Vegetation Index (NDVI)	+	+	+
Presence on the field of weeds	-	-	+

These photos are a source of information for the agrarian companies that use it – installed spectral cameras help to calculate the vegetation indexes.

For example, the most common index is the NDVI (Normalized Relative Vegetation Index) [1].

It is calculated as the difference between the values of red and near infrared, divided by its sum. Due to its plant density characteristics, this index helps to define where to sow crops, where to apply fertilizers or pesticides.

Agrarians receive maps of crop condition and maps of productivity that are based on calculations of this index. This is required for precision farming and mapping tasks.

In recent years, a large number of satellites have been launched into Earth's orbit to take surface surveys. Different satellites have different parameters. This is also the frequency of the shooting, the passage over a certain field, as well as the resolution of the photo (Table II).

The following criteria should be taken into account when satellites for agrarian monitoring is choosing:

1. spatial resolution;
2. frequency of shooting;
3. the cost of photos.

Table- II: Comparison of Earth Remote Sensing satellites with free images

Criteria of comparison	SENTINEL -2	LANDSAT 8	MODIS
Spatial resolution	10 m per pixel	30 m per pixel	250-1000 m per pixel
Frequency of shooting	5 days	8 days	1 day
Retrospectivity	Since August, 2015	Since May, 2013	Since 2001
Number of photos per season	54 photos since May till October	34 photos since May till October	365 photos
What products can be got	Natural color images, NDVI	Natural color images, NDVI, soil temperature, snow cover	Natural color images, NDVI (change of field dynamics in comparison with other fields)

Today anyone has access to the data of some satellites which have been launched as research. Free photos are provided by next services: USGS Agency [2], NASA [3], Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub) [4], Digitalglobe [5], Land Viewer [6].

Although photos of some satellites are free, the quality of free photos is not the best and processing the data takes a long time.

The biggest advantage of using satellites is the retrospective peculiarity, that is, all the photos taken by the satellite since its launch are stored in its own database. This allows to see the history of the site for certain years. This information is very important, especially when buying a site, because it can help to evaluate its productivity. Also, it is possible to see what problems this site had and take immediate action to prevent its repeated appearance.

Advantages:

1. calculation of vegetation indexes which characterize the state of vegetation;
2. automatic data processing that eliminates subjective interference;
3. analysis of both individual fields and certain agricultural crops;
4. free data;
5. possibility to get historical photos of the field.

Disadvantages:

1. dependence on cloud weather;
2. possibility to get photo every 5-8 days;
3. quality of satellite' photos is worse than drones.

The use of drones greatly simplifies the collection of necessary information about the condition of crops. Unlike satellite, drones are more mobile and contain more details. Due to the fact that the height of the drone's flight is usually within 100 to 300 meters above the ground, it is possible to get images with a resolution of centimeters per pixel. Drones allow to gather a wealth of information in the shortest possible time. On average, one crew can handle up to 2500 hectares per day.

It should be mentioned here that different types of drones are used for agriculture: fixed-wing airplane type and copters with 4, 6, 8 screw. The main differences between a fixed-wing drone and a copter are the characteristics of range and flight stability, lifting weight, launch and landing method, price, etc.

According to the aim of use as well as to the size of the farm, it needs to make a right choice of drone before its buying. The collection process of information about the crops by both types of drones is almost the same.

In the practice, information is collected by drones in several stages of crop monitoring:

1. Selection of fields area and preparation of route for the drone;
2. Departure to the field and launch the drone;
3. Automatic flight and making photos;
4. Landing of the drone;
5. Import of collected data into a service (for example – Drone Deploy [7]);
6. Creation of orthophoto plan and vegetation indexes;
7. Analysis of the received information;
8. Development of recommendations.

A peculiarity of drones is the ability to use spectral cameras which allow to get near-infrared photos. NDVI are calculated on the base these photos. Conventional cameras can also be used for these purposes, but after some modifications or additional data processing.

The following advantages and disadvantages of drones, which are used in agriculture, can be noted:

Advantages:

1. high mobility and speed of shooting;
2. accuracy of 2 centimeters;
3. possibility of shooting in the conditions of cloud;
4. high efficiency.

Disadvantages:

1. dependence of photos quality on the weather conditions;
2. presence of "no fly zone" near the airports, military and other facilities;
3. the cost of the drone.

It is possible to make qualified monitoring with the help of satellites or drones starting from pre-sowing preparation of the soil and ending with the harvest.

For example, monitoring winter wheat consists of several steps:

1. Assessment of soil before sowing;
2. Analysis of germination during sprouting;
3. Winter monitoring during tillering;
4. Spring monitoring during the ear tube appearing;
5. Before harvesting to assess maturity.

Before sowing, the soil condition is mainly analyzed. The basic monitoring information of satellite or drones at this stage is the quality of the soil before sowing. Drones are also used to draw up an accurate terrain map, indicating all elevations, gullies and other natural objects.

When sowing is complete, similarity is monitored. At this stage the level of plant loss is analyzed, the need for sowing or resawing is defined. Satellite monitoring and the use of drones make it possible to identify problems most quickly. The main information that the agrarian receives is the maps with crop density and the area of heterogeneity of the seedlings. Thus, a comparison of all fields of the enterprise and the calculation of the total losses of the sprouts are conducted.

If we talk about winter crops, its productivity is largely defined by the nature of growth and development in the spring growing vegetation period, when the tillering phase is still underway. At the same time, the need for fertilizing is analyzed. The main goal is to optimize fertilizer application. For example, in the case with winter wheat, the first top dressing should be conducted in fields with good and satisfactory crop conditions. Drones or satellites help to identify the areas where should to apply high rates of fertilizer and create electronic task cards for technology. Such cards are used for differential fertilizer application.

Weeds is about 30% of the total crop losses because of pests, diseases and weeds. In this case, the total crop losses and the additional costs of clearing the fields from weeds double the total losses in grain production. The use of drones is ideally suited to assess the littering of the field. Due to its low altitude and powerful cameras, drones are able to gather information to create maps where can distinguish weeds from crops. As a result, the agronomist, in getting more accurate information, can make the correct rate of herbicide in time.

At the end of the vegetation season, monitoring is repeated before harvest. This allows to clarify the timing of the harvest and finally forecast the yield.

Every year the quality of the cameras increases, the capacity of the batteries increases too. Algorithms for processing the collected information are getting better and the use of drones is becoming more accessible. Commercial services continue to launch its remote sensing satellites into orbit. Landsat and Sentinel-2 programs make plan to launch new devices with more advanced technologies to capture and scan the Earth's surface. This contributes to the fact that monitoring with the use of drones and satellites in a few years will become as usual in the work of Ukrainian farmers, as today the use of GPS.

B. Sphere of implementation of the modern monitoring methods

Modern monitoring methods have several advantages and help to solve the following questions:

1. Land inventory and accounting.

The old maps are extremely inaccurate, so it is impossible to even talk about exact farming unless you really know how much land you have. A detailed inventory is the first and most important step to improve the efficiency of economy. Photos make it easy to learn about inappropriate use of land or to deal with unused areas.

2. Reduction of visits on field by up to 90%.

Syngenta (a Swiss company, one of the leaders in the field of plant protection products and seed production), recently announced such a high reduction in the need to visit fields when bought provider of satellite photos under the name of FarmShots [8]. Now the agronomist no longer needs "manually" to monitor the field, everything can be done due to satellite photos. A prerequisite is high resolution. Of course, it is not for a free.

3. Forecast of yields with the help of vegetation indexes.

Such advice is possible due to vegetative indexes. The most popular is the previously mentioned NDVI. The leaves of plants absorb electromagnetic waves in the red range and reflect waves in the near infrared. The more leaves mean the more chlorophyll, the more strongly the plants absorb the red light which hits them (and reflect less). Programs calculate the NDVI, which helps forecast the yield with use of this data. There are other indexes, for example, NDRI or RVI.

4. Retrospective data.

Many services have such an opportunity and can give photos of the field in a few years. This will help the agronomist deal with chronic field problems.

5. Possibility to assess negative factors.

Due to regular monitoring of the condition of the field, the influence of natural disasters can be more effectively controlled. If problem areas arise, the agronomist goes to this area and makes decisions to eliminate the problem. It is no longer need to travel around the field, looking for deviations in plant growth. That is, we are talking about operational monitoring of the state of crops.

The effectiveness of agricultural activities directly depends on the quality of the land bank. But often, experts have a lack of reliable data to make sure that the land is in good condition. In such cases, satellites come to help in its

collection and analyze this information about the actual characteristics of the fields.

Today, agricultural holdings and investors cannot afford to choose a land plot blindly. Such investments have many risks, so it is important to understand how promising the land is. Satellite monitoring provides many solutions for the analysis of the quality of agricultural fields, both nationwide and at the local level.

There are a number of problems that Ukrainian farmers face in assessing agricultural land.

The quality of the soil may differ from what is stated in the documents. It depends on whether previously used intensive technologies that led to soil degradation. On the other hand, if the area has not been cultivated for a long time and it "rested", then such plot, on the contrary, will be more productive.

In assessing the feasibility of investments, other factors must be taken into account: the location of the plot, the productivity of the field in previous years, the relief and communications that pass nearby. All these features have influence on the market value and profitability of land.

Such information is not always easy to obtain. It is often outdated or absent altogether. Because of this, accurately assessing the real potential of the site is often difficult.

The arrangement of land shares as well as the electronic cadastral map of Ukraine do not solve the problem. Often, they do not take into account afforestation of land and the presence of shrubs, power transmission towers and other communications, wetlands and salt marshes.

Such information is necessary not only for investors, but also for the owners of a land bank. They need to understand what areas are cultivated and whether they meet accounting; accurate land bank losses because of an inefficient management; how much land is not involved at all. Answers to these questions will help to clearly indicate the productivity of the fields, the effectiveness of its use and define the profitability per unit of area. In addition, it can perform such a really difficult task so as estimating the size of a land bank.

To answer these questions, agricultural holdings and investors conduct a general audit of an individual plot or land bank and assess the attractiveness of a particular agricultural land with its help.

The usual methods of field audit are not always justified. It is necessary to collect an impressive package of documents to conduct an audit of a land bank. It will require both the arrangement of land shares and yield data for the last 3-5 years, both by household and by district. At the same time, it is necessary to find yield information for typical crops in the area.

Also, it is needed the field registries and lease agreements. It is necessary to create electronic field maps with division into land plots. To do this needs to search in various data sources: a cadastral map of Ukraine and a map of shares which cannot be found online.

Conducting an audit, it is very difficult to establish the historical potential of the field, that is, its productivity over the past 5 years. All because of the lack of field history data. In ordinary Ukrainian realities, it is simply not known what was grown on the plot even two years ago, not to mention a long period.

For a modern agricultural producer introducing precision farming technologies, a yield map is a fundamental necessity. After all, it is important to have information about how productivity differs in different zones of the field. Therefore, auditors analyze archives, satellite data and also conduct chemical analysis of the soil.

A full audit is not possible without creating electronic field boundaries. It is important to make it accurate. In addition, it is needed to know for sure which areas are unsuitable because of waterlogging, afforestation or because to the location of other objects within the area of interest.

As a result, auditing often takes a lot of time and resources, but still does not provide accurate data. It should be taken into account how difficult for the company to independently realize all the tasks. It is necessary to look for competent employees, competently manage them and incur additional costs.

A standard assessment of agricultural fields is based on several components:

1. Electronic maps of field plots;
2. The arrangement of land shares;
3. Area of unsuitable fields;
4. Yield data;
5. Field registries;
6. Lease agreements.

C. Satellites VS drones

Audit with the use of satellite monitoring is much easier. Simply put, satellite monitoring is a method that is used in the agricultural industry to get information about the condition of fields and crops planted on them over the past few years and at the current moment due to satellite photos and its analysis through special platforms.

In Ukraine, satellite monitoring services are usually offered along with monitoring by drones. Satellite monitoring costs less because is not required the costs in collection of information.

For example, the company SmartFarming offers satellite monitoring services for 5 UAH per 1 ha and monitoring by drones for 20 UAH per 1 flight [9]. The company provides the client with NDVI-maps of the condition of crops, vector maps with indication of heterogeneous zones, a report on crops.

One of the world leaders in the provision of satellite monitoring services for agricultural territories is Cropio [10]. The company has offices in four cities of Ukraine, including Kyiv. The client provides the coordinates of its fields, information about crops grown, soil cultivation methods, fertilizers applied, etc. as well as retrospective information (crop rotation, yield, etc.). Due to this information, the company provides an individual analysis model with a daily forecast update.

AgroOnline, AgriLab and others provide maps of vegetation, sprout control, physical damage monitoring, analysis of land bank on the base of satellite monitoring.

Xarvio company offers the Field Manager phone application, which provides field management advice and risk information based on satellite photos processing. All information is received on a mobile phone [11]. The system identifies and calculates the possibility of the occurrence of characteristic diseases for wheat, barley, sugar beets, rape, potatoes; analyzes the risk of pests. The system helps to define the time and rate of application of fungicides, forms a differential application card. Reliable and economical plant protection is provided for the entire vegetation season.

Implementation of even one of the tools of precision farming, which includes satellite monitoring, leads to an economic effect of 7-10% at least [12].

Monitoring with the help of drones is better and more detailed than satellite monitoring, but this method is more expensive too. Therefore, with an integrated approach, it is best to combine the use of both methods depending on the monitoring task, since each approach has its own advantages.

Drones are good for its accuracy. At the same time, they cannot be used everywhere, since the number of territories where drones are prohibited is constantly growing. To conduct a flight, it is needed a special pilot who will have to physically go to the place.

One survey from a drone will cost in 4-5 times more expensive than data received from a satellite. And if one survey on the field is not enough and the drone has to be launched several times, then the price will be in 15-20 times higher.

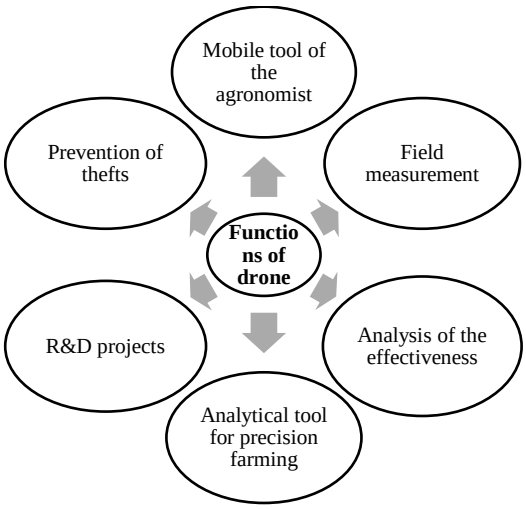

Fig. 1. Key directions of drone implementation in the agrarian industry

The main functions that drones can perform in the agricultural business are:

1. Mobile tool of the agronomist – when the agronomist uses a quadcopter to save his time;

2. Field measurement – the use of aircraft platforms to get the exact contours and areas of fields, taking into account the relief;

3. Analysis of the effectiveness – the use of aircraft platforms for 1-2 flights per season to analyze violations of production technology, identify problems with equipment, etc.;

4. Analytical tool for precision farming – the use of aircraft platforms and multispectral or RGB cameras to analyze the condition of crops and create task maps for differentiated fertilizer application, differentiated desiccation;

5. R&D projects (Research and Development) – the use of quadcopters and multispectral cameras for monitoring demo plots, the use of octocopters for ultra-low-volume application of plant protection products;

6. Prevention of thefts – the use of quadcopters with thermal cameras that is a favorite order of most security services of agricultural holdings.

Satellite data allow the calculation of vegetation indexes and automatic data processing. Satellites provide a much wider range of data. Agrarians always have information in their hands about the entire area and the coverage of additional territories will not increase the cost of inspection. Satellites win in mobility, since there is no need to put the satellite into orbit. It is already there, and agrarians can work on everything ready. Satellites allow to analyze the state of vegetation. Pictures are updated at a frequency of 3-5 days without any additional effort on the part of the user. In addition, there is access to historical data on the condition of fields and weather as well as forecasts for the future. Among the disadvantages is the fact that situational cloudiness can interfere with a full analysis. Photo resolution will also be lower than that of drones, but sufficient to define the condition of crops as accurately as possible.

Another important difference between drones and satellite data is that drones are more efficiently used in small areas when high resolution images are needed, and the satellites are better for working with large areas.

III. DISCUSSION

Agrarians need to pay attention to satellite monitoring to spend less resources, grow more high-quality crops and increase profit. This will help to achieve high results without high costs.

As for drones, its use still faces a number of problems:

1. Rules. For example, the provision on the use of the airspace of Ukraine regarding the regulation of drone flights and liability for violation of the Air Code [13].

2. Public opinion. There are still problems with drone safety, the issue of privacy and public inconvenience. The question of how to overcome these problems remains open.

3. Business value. We have yet to see a reliable return on investment in this business. The key question is: what kind of profit do drones and the collected by them information in addition to commercial use by agricultural companies.

4. The accuracy of the information. Until now, drone manufacturers have focused on image accuracy. To improve business performance, they need to focus on the accuracy of processing and the thoroughness of data analysis.

5. IT data management. This is especially true for drone inspections. One drone can collect from 50 to 100 gigabytes of data. Managing these large data sets is starting to become one of the problems that needs to be solved.

6. Automation. A lot of automation will come in software, including artificial intelligence (AI) or algorithms that minimize human efforts to filter information. But the massive industrial use of AI is still extremely new and requires human intervention in order to distinguish between too similar objects.

7. Durability. Manufacturers are still in search of efficiency, for example, the best sources of energy.

8. Wider acceptance of this business and industry. This acceptance is growing, but it is unstable. Factors that interfere are: fears of business risks, an invasion of privacy and the reluctance of many companies to share information about its successes.

By 2050, approximately 9.8 billion people will live on Earth and food demand will grow by 60% [14]. In parallel, the climate will change and the amount of resources (water and suitable land for agriculture) will continue to decline. In this regard, representatives of the agricultural industry around the world today have to look for ways to optimize all processes.

Precise farming and satellite monitoring may seem incomprehensible, inaccessible and optional today, but, in fact, the future lies with it. So far, only 10-20% of Ukrainian farmers use new technologies. There is reason to believe that they will occupy the top business positions in the future.

IV. CONCLUSION

The main aim to article to light profitability and prospective of modern monitoring methods. Drones and satellites are not often considered in scientific literature but today it is important to provide agrarian producers with all accessible information about it. Practically, the main problem of Ukrainian agrarians to understand that the modern methods of monitoring are not so expensive and complicated. Low price of land and labor are simpler method to increase profit of agrarians. It is not need of qualified specialists and no need to study something new. But today agrarian business goes on the new level of development and in the immediate future quantity of lands will not save without knowledges about scientific approaches to increase the yield. Digitalization as well as any process need to be implemented consistently, step by step. And the best decision is to start with the cheapest and the simplest way of digitalization that is implementation of the modern methods of monitoring.

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