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ASSESSMENT OF THE ECONOMIC EFFICIENCY OF USING UNMANNED AERIAL VEHICLES IN AGRICULTURE AND WAYS TO IMPROVE IT

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Annotation: This article analyzes the economic efficiency of using unmanned aerial vehicles in agriculture. The introduction of modern technologies into agricultural production can improve farming processes, reduce production costs, increase labor productivity, and ensure more efficient use of available resources. The use of drones makes it possible to monitor crop fields, identify problematic areas, conduct agricultural activities more precisely, and prevent unnecessary resource consumption. The article examines the direct and indirect economic effects of drone use, cost-forming factors, the advantages of service-based models, investment payback issues, and proposals for improving the efficiency of this technology under the conditions of Uzbekistan.

Keywords: unmanned aerial vehicle, drone, agriculture, economic efficiency, cost, investment, agricultural service, resource conservation, labor productivity, precision agriculture, agricultural drone.

Today, improving production efficiency in agriculture is directly related not only to achieving higher yields, but also to the rational use of available resources and the reduction of production costs. The limited availability of land and water resources, together with rising expenditures on fuel, mineral fertilizers, plant protection products, and labor, is encouraging agricultural producers to adopt new technological solutions.

Under the conditions of Uzbekistan, reducing production costs in such agricultural sectors as cotton growing, grain production, horticulture, vegetable farming, and other areas is considered one of the key economic priorities. In particular, carrying out agrotechnical activities in a timely and high-quality manner over large areas requires significant labor, machinery, and financial resources. Therefore, reducing unnecessary expenses through the automation and digitalization of production processes is of great importance.

The introduction of unmanned aerial vehicles (hereinafter referred to as UAVs) into agriculture is taking this process to a new stage. The economic efficiency of drones is determined not merely by their ability to fly or capture images of agricultural fields. Their main effectiveness lies in using the data they collect to prevent improper or excessive expenditures, plan agrotechnical activities more accurately, and ensure the targeted and efficient use of resources.

From this perspective, it is appropriate to assess the economic efficiency of drone use based on the following sequence: **"cost – technological result – saved resource – economic benefit."** (Figure 1)

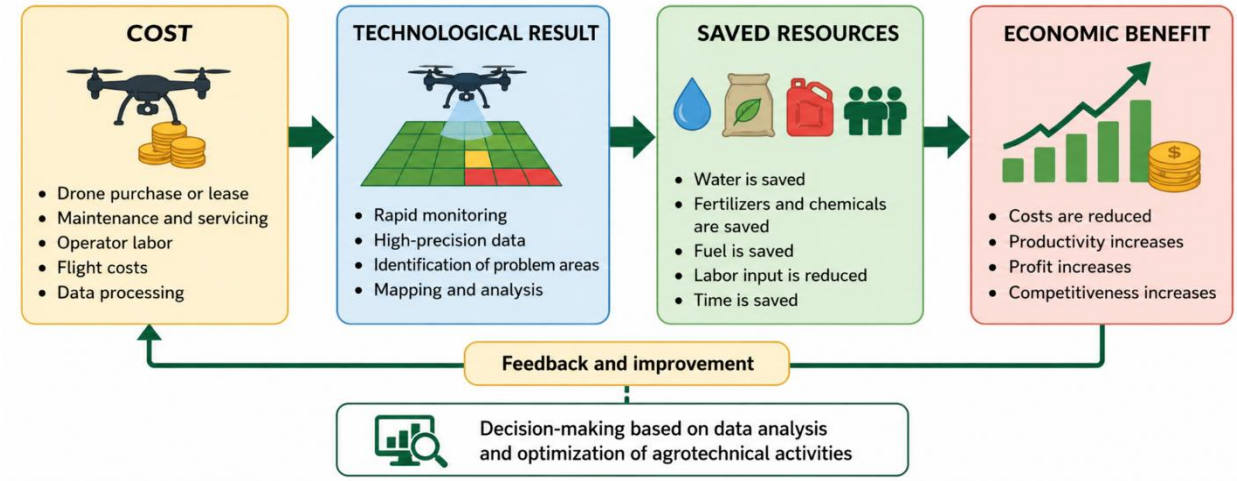


Figure 1. System for forming the economic efficiency of using UAVs.

In traditional agricultural production, monitoring large areas, observing crop conditions, and ensuring the implementation of agrotechnical measures require the use of a large workforce, transport vehicles, and other technical resources. Under such an approach, it may be difficult to monitor all parts of the field equally and regularly. This is especially true in large crop areas, where difficulties arise in the timely identification of problems such as plant diseases, pest infestations, moisture deficiency, or the need for fertilizers. As a result, some problems are detected late, which leads to additional expenditures of labor, time, fuel, and material resources to eliminate them.

The use of drones, however, creates opportunities for rapid and regular monitoring of agricultural fields, thereby increasing the efficiency of the control process. With the help of drones, it is possible to observe large areas from the air within a short period of time, assess the general condition of crops, and identify problem zones. When drones equipped with special cameras and sensors are used, the possibility of obtaining additional information about the level of plant development, water supply, and areas damaged by diseases or pests also expands.

For example, if a problem exists only in a certain part of a crop field, instead of applying the same agrotechnical measure to the entire field, it becomes possible to implement measures targeted specifically at the problem area. This contributes to the rational use of water, fertilizers, plant protection products, and other resources, reduces unnecessary costs, and helps maintain stable productivity.

In addition, the regular analysis of data obtained through drones makes it possible to monitor the condition of crop fields over time and to identify emerging changes at an early stage. From this perspective, the use of drone technologies can be considered one of the promising directions for digitalizing monitoring in agriculture, ensuring efficient use of resources, and improving decision-making processes.

In this case, the economic benefit is manifested in two main directions. The first is the **reduction of direct costs**, and the second is the **achievement of indirect economic benefits through the efficient use of resources**. **(Figure 2)**

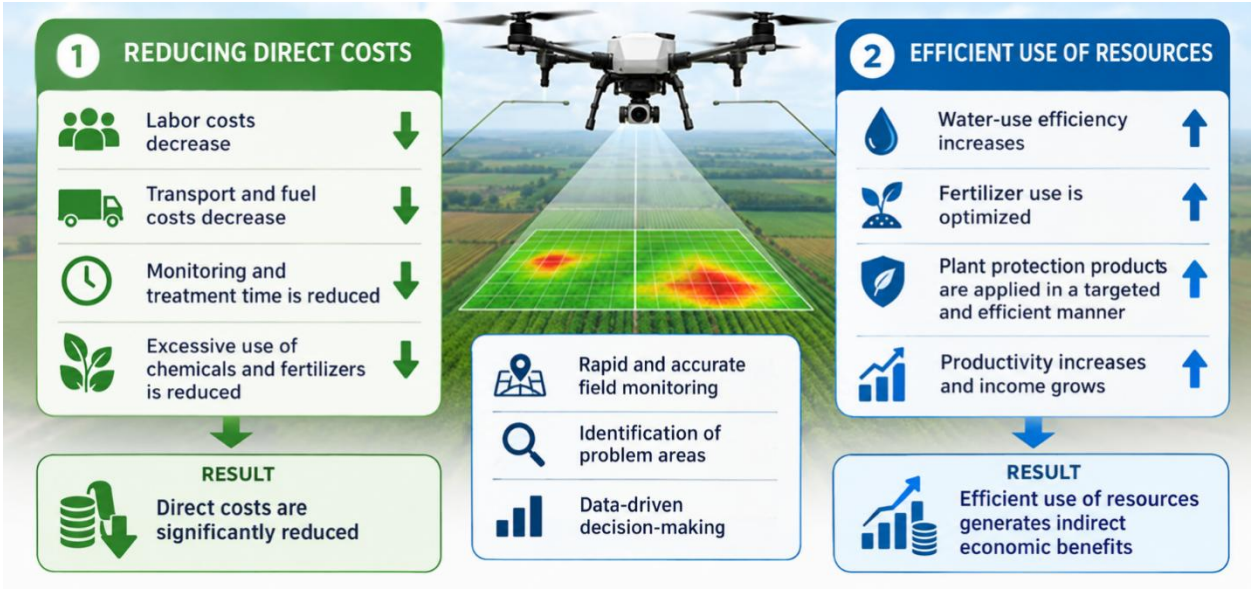


Figure 2. Reduction of costs and efficiency of resource use through the application of drones.

The main factors determining the economic efficiency of drone use are as follows:

first, reducing labor costs;

second, shortening the time required for the use of technical equipment;

third, reducing fuel and transportation costs;

fourth, ensuring the targeted use of mineral fertilizers and plant protection products;

fifth, preventing yield losses through the early detection of crop-related problems.

One of the most important economic advantages of using drones is the **increase in labor productivity**. Under the traditional approach, inspecting large areas, assessing crop conditions, and identifying problem zones may require several specialists and a considerable amount of labor. In such cases, field inspection, data collection, and data analysis require substantial time.

With the help of drones, however, it becomes possible to obtain the necessary information over a large area within a short period of time, monitor crop conditions remotely, and identify problematic locations. As a result, the amount of labor and time required to perform the same task is reduced. This not only increases the productivity of specialists, but also helps reduce transportation and other organizational costs.

In addition, the promptness of the data obtained through drones makes it possible to identify problems early and take timely measures. As a result, instead of spending specialists' time solely on monitoring activities, it becomes possible to redirect them toward crop care, the planning of agrotechnical measures, increasing productivity, and other important tasks. For this reason, the use of drones in agriculture is of great importance not only as a means of improving monitoring efficiency, but also as a modern technological tool that enhances overall labor productivity.

Furthermore, the use of drones can contribute to the reduction of **transportation and fuel costs**. Instead of constantly inspecting fields by means of ground vehicles, problem areas can first be identified through aerial monitoring. Only after that does it become necessary to direct machinery or specialists to the required locations.

Another of the most important factors affecting economic efficiency in agriculture is the **rational use of agrotechnical inputs**. For example, applying plant protection products or fertilizers

in the same quantity across the entire field is not always economically justified. Depending on the condition of the crops, some areas may require additional treatment, while in other areas it may be sufficient to limit intervention to a minimum.

Based on the data identified with the help of drones, the field can be conditionally divided into **"normal," "requiring observation," and "problematic"** zones **(Figure 3)**. This creates an opportunity to organize agrotechnical measures in a differential manner.

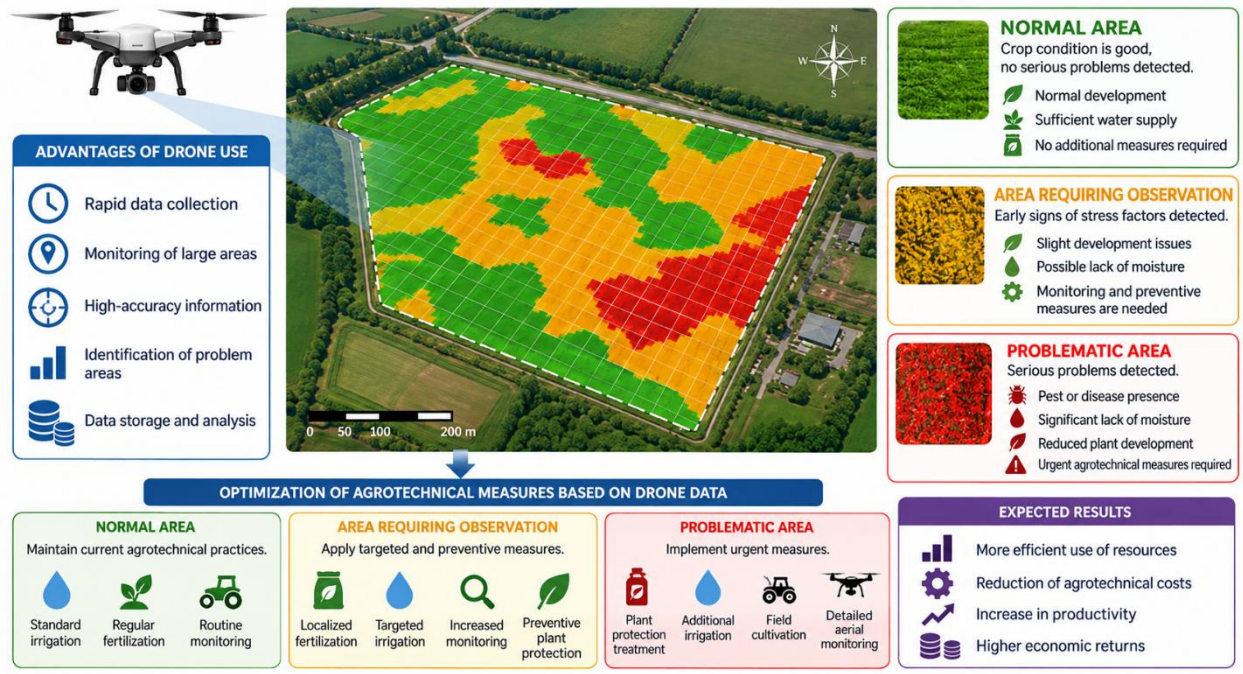


Figure 3. Zoning of crop fields based on economic efficiency.

The main advantage of this approach is that resources are not spent uniformly across the entire field. On the contrary, they are directed to specific areas based on the existing problems and needs. As a result, it becomes possible to prevent excessive expenditure of fertilizers, chemicals, water, fuel, and labor.

To evaluate the economic efficiency of using drone technologies, it is important to compare the **total costs and the economic results obtained**. In this process, such expenses as the purchase cost of the drone, maintenance, batteries, software, operator labor, flight organization, and data processing are taken into account.

Conventionally, economic efficiency can be expressed on the basis of the following formula:

$$EB = SC + PL - DC \quad (1)$$

Where:
EB – economic benefit;
SC – saved costs;
PL – prevented losses;
DC – costs associated with drone use.

If the costs are to be expressed in greater detail:

$$SC = LS + FS + FES + CS + WS + ORS \quad (2)$$

Where:
SC – saved costs;
LS – savings in labor costs;
FS – savings in fuel costs;
FES – savings in fertilizer costs;
CS – savings in chemical input costs;
WS – savings in water resource costs;
ORS – savings in other resource costs.

$$PL = DP + PP + WD + AD \quad (3)$$

Where:
DP – the portion of potential losses prevented as a result of early detection of plant diseases;
PP – the portion of potential losses prevented from pest damage;
WD – the portion of losses prevented due to water deficiency;
AD – the portion of losses prevented as a result of avoiding delays in agrotechnical measures.

$$EB = SC + PL - (DP + MC + BC + SWC + OC + FOC + DPC) \quad (4)$$

Where:
DP – drone purchase cost;
MC – maintenance costs;
BC – battery-related costs;
SWC – software costs;
OC – operator labor costs;
FOC – flight organization costs;
DPC – data processing and analysis costs.

The saved costs include reductions in expenditures on labor, fuel, fertilizers, chemical inputs, water, and other resources. Prevented losses, in turn, are associated with avoiding potential reductions in crop yield caused by diseases, pests, water shortages, or delays in agrotechnical measures.

When assessing the efficiency of drone use, it is advisable to calculate **one-time costs** and **recurring costs** separately. One-time costs include the purchase of the drone itself, additional equipment, and software tools. Recurring costs may include maintenance, repairs, operator training, battery replacement, and data processing.

Therefore, direct purchase of a drone is not always the most economically efficient option for every farm. For small farms, **using drone services** may be more cost-effective, whereas for large farms and agro-clusters, **establishing their own drone fleet** may produce different and potentially more favorable economic results.

In this context, the service-based model is of particular importance. Instead of purchasing expensive technical equipment, a farm can order a specific service from a specialized agricultural service center. In this case, the costs associated with the drone, operator, maintenance, and data processing are borne by the service provider.

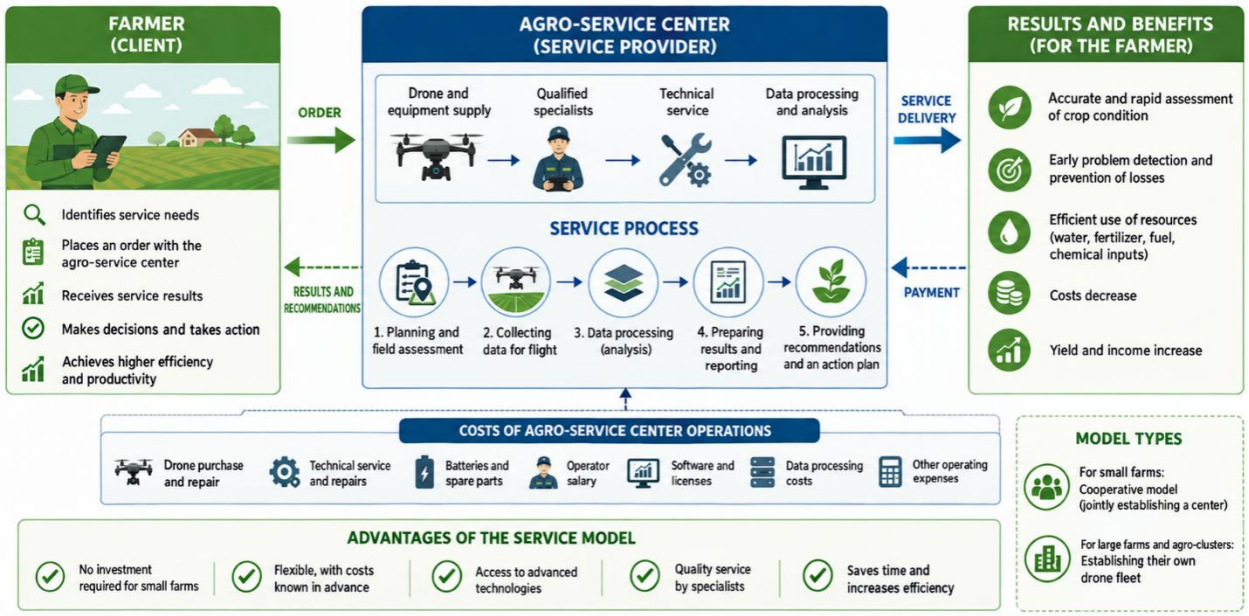


Figure 4. Service model for providing drone services in agriculture.

The main advantage of this model is that farmers can use modern technologies without making large initial investments. Drone service centers, in turn, are able to achieve a high level of equipment utilization by providing services to several farms.

In the future, organizing such services on a regional basis may become one of the effective mechanisms for promoting digital technologies in agriculture.

The economic efficiency of drone use is not limited only to cost reduction. Another important aspect is the **prevention of crop losses**. If problems such as crop diseases, pests, or water shortages are detected at an early stage, timely measures can be taken. This helps preserve potential yields.

The use of drones also improves the quality of planning agrotechnical measures. Farm managers or agronomists can make decisions based not only on general observations but also on accurate data. As a result, the justification and quality of management decisions are improved.

Under the conditions of Uzbekistan, drone services can also be specialized for areas producing cotton, fruits and vegetables, grapes, and other crops in addition to grain. For example, in horticulture, services can be organized to monitor the condition of trees, identify irrigation problems, and detect diseased trees.

At the same time, the development of a **local service and technical maintenance system** is of great importance for increasing the economic efficiency of drone technologies. If drone repair, spare parts supply, and software support are available locally, the costs associated with their use can be reduced.

The training of drone operators also has a direct impact on economic efficiency. A qualified operator can properly organize flight time, battery consumption, and the data collection process. This makes it possible to serve a larger area during a single working day.

Taking into account the existing opportunities and challenges in this field, the following proposals can be put forward to improve the economic efficiency of UAV use in agriculture.

First, it is advisable to develop a **unified methodology for assessing the economic efficiency of drone use in agriculture**. This methodology should take into account such indicators as drone purchase and operating costs, service costs, saved resources, labor productivity, and the economic benefits obtained from preventing crop losses.

Second, it is necessary to establish **drone-based agricultural service centers** in different regions. These centers can provide farms with monitoring, aerial photography, crop field analysis, mapping, and other services. This is especially important for small and medium-sized farms that have limited opportunities to purchase expensive equipment independently.

Third, it is advisable to introduce the practice of conducting an **economic efficiency assessment before purchasing drones** on farms. In this case, the frequency of drone use during the year, the size of the area to be serviced, operating costs, and the expected economic benefits should be compared.

Fourth, local production and service capabilities should be expanded. Localization of drone spare parts, batteries, software, and technical maintenance systems can reduce operating costs and contribute to the wider adoption of the technology.

Fifth, data obtained from drones should be **integrated with the economic management systems of farms**. In such a system, agrotechnical data, costs, crop yields, and resource consumption can be analyzed together. This makes it possible to assess how much a particular agrotechnical measure costs and what economic result it produces.

In conclusion, the economic efficiency of UAV use in agriculture depends more on the purpose for which the technology is used and the management system within which it is applied than on the technology itself. Proper use of drones makes it possible to optimize labor, fuel, water, fertilizer, and chemical input consumption, organize agrotechnical measures more accurately, and prevent crop losses.

Under the conditions of Uzbekistan, limited water resources, the need to reduce agricultural production costs, and the ongoing digitalization of the agricultural sector make the economically efficient use of drone technologies increasingly important.

Alongside the direct purchase of drones, the development of a service model through agricultural service centers is also an important and promising direction. Such an approach can expand access to modern technologies while reducing initial costs for farms.

Therefore, in the future, along with the development of drone technologies in agriculture, special attention should be paid to **assessing their economic efficiency, developing service infrastructure, training qualified specialists, and integrating drone technologies with digital management systems**. This will make it possible to transform the use of unmanned aerial vehicles from a simple technological innovation into an important tool for improving the economic efficiency of agricultural production.

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