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Increasing the Level of Management Efficiency: Using Unmanned Aerial Vehicles for Monitoring Pasture Lands

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ABSTRACT

Increasing the level of efficiency of land use management of pasture lands is one of the most important modern problems in the context of the agro-industrial policy of Kazakhstan. Using the method of content analysis of scientific literature, the authors analyze the utilization state of the unmanned aerial vehicles in agriculture, as well as the possibilities of their use for monitoring pasture lands. The authors assess the possible economic benefit of using this technology for land management. To assess the feasibility of using unmanned aerial vehicles for monitoring pasture lands, a SWOT analysis is conducted. The results of the study allow concluding that using unmanned aerial vehicles for monitoring pasture lands leads to an increase in the level of land use management by providing a wide range of opportunities and achieving an economic benefit for all agricultural production entities.

1. INTRODUCTION

Recent years have been characterized by an increase in the technological effectiveness of agricultural production, which uses the most advanced technologies to improve the efficiency of environmental and economic processes management [1]. Precise land use is the area of agricultural development that opens up new opportunities for increasing the productivity of each land plot by considering its specific features of soil and agro-climatic conditions [2]. The ideology of precise land use assumes a spatially differentiated approach to the application of land use technologies depending on the properties of the soil, the availability of nutrients and moisture to plants, and the condition of plants at a certain stage of their development [3].

A necessary condition for accurate land use management is a detailed and dynamic assessment of the spatial heterogeneity of the soil and vegetation state, which ensures the timely application of adequate agricultural measures exactly in those areas which need it [4]. An indispensable source of information for accurate land use management is the data of high-resolution remote monitoring observations, for which unmanned aerial vehicles (UAVs) are increasingly being used [5].

According to experts [6, 7], the UAV market is one of the fastest-growing in the world. The number of civilian UAVs sold to individuals and legal entities is increasing from year to year. Thus, according to Global Market Insights Inc., the volume of the commercial UAV market in 2020 exceeded $20 bln and is estimated to grow further from 2021 to 2027 by about 15% per year. It is expected that by 2027 the total volume of industrial supplies of UAVs will exceed 16 mln units [8].

Agriculture is traditionally considered one of the most promising branches of UAV use today. So, according to estimates [9], UAVs will have the greatest impact on the agricultural sector. The profit from using UAVs in the US agricultural sector is estimated by experts at $75 bln by 2025 due to the creation of new jobs and optimization of existing processes [10]. In China, the agricultural application of UAVs will grow at an average annual growth rate of more than 20% until 2027 due to the increasing use of unmanned technologies in agriculture, which provide farmers with an understanding of the decision-making process through big data analysis [8].

Although, according to experts [11], despite the expectations, the demand for UAVs in the agricultural industry is now significantly less than for commercial video filming, surveying, inspection, and control. Accurate land use, however, is one of the most significant segments of the UAV services market. At the same time, according to estimates [11], by 2025, agricultural UAVs will occupy about 80-90% of the total use of UAVs.

Even now, using UAVs for agriculture is actively promoted on the market. However, like every new tool, using UAVs for monitoring pasture lands to improve the efficiency of accurate land use management requires research and justification of the capabilities of UAVs application in monitoring pasture lands, understanding the economic benefit of employing UAVs, as well as the main areas of using UAVs when monitoring pasture lands.

2. LITERATURE REVIEW

The works [12, 13] are devoted to the analysis, classification, purpose, contemporary developments, design, and evolution of UAVs. The works [14-16] present a systematic analysis of the use of various types of UAV models for aerial surveys of agro-industrial territories for mapping.

Having studied the literature on this topic, it can be argued that today there are many opportunities for using UAVs in agriculture. The prerequisites for the widespread use of UAVs in the latest land-use technologies have been investigated in [17-19]. Technical support tasks were analyzed, as well as laboratory and field studies were conducted to determine the rational parameters of the UAV [20-22]. The issue of determining the main characteristics and rational parameters of UAVs for monitoring the condition of lands, as well as the effectiveness of their use, is also relevant in scientific circles [23-25].

As a rule, UAVs equipped with cameras [25] that take pictures in the visible range, or multispectral sensors [23] are used for monitoring pasture lands, which allow shooting both in the visible and near-infrared range, and further calculating the NDVI (Normalised Difference Vegetation Index), which is traditionally used to assess the state of vegetation cover. Certainly, multispectral photography is more informative due to the possibility of more detailed meaningful decryption of images [26], including through calculations of auxiliary indexes. However, according to Kamelkhan et al. [27], even shooting with a conventional high-resolution camera allows obtaining good results in assessing the condition of the grass cover of pastures.

Besides, it is possible to equip the UAV with thermal imaging cameras [21], which allow shooting in the thermal wave range (usually 8-14 microns). The results of such a survey are used to assess the morbidity of plants [22]. Certain attempts are made to assess soil moisture based on thermal imaging data [20].

However, to date, there are no comprehensive studies, devoted to the problems and prospects of using UAVs for monitoring pasture lands in terms of improving the efficiency of precise land use management.

The purpose of the present article is to analyze the problems and prospects of using UAVs for monitoring pasture lands to improve the efficiency of precise land use management.

Research objectives:

- determining the possibilities of using UAVs to monitor pasture lands;

- assessing the possible economic benefit of using UAVs to monitor pasture lands;

- carrying out a SWOT analysis of using UAVs for monitoring pasture lands.

Research hypothesis: using UAVs for monitoring pasture lands leads to an increase in the level of land use management by providing a wide range of opportunities and achieving an economic benefit for all entities of agricultural production.

Based on the study results, it can be concluded that the goal, set in the study has been achieved.

3. METHODS

To achieve the set goal and prove the research hypothesis, a qualitative study of the problems and prospects of using UAVs for monitoring pasture lands was carried out to improve the efficiency of precise land use management.

Structurally, the study consisted in the successive implementation of the following steps:

- at the first stage of the study, based on the method of content analysis of scientific literature on the problem of monitoring pasture lands using UAVs, the source base of the study was updated;

- at the second stage, based on an expert survey, an analysis of the reliability of the source base of the study was carried out;

- at the third stage, based on the analysis of the source base using the methods of theoretical generalization and comparative analysis, the possibilities of using UAVs for monitoring pasture lands and the main areas of application of UAVs for monitoring pasture lands were determined, and a qualitative assessment of the possible economic effect of using UAVs for monitoring pasture lands was given;

- at the fourth stage, a SWOT analysis of the use of UAVs for monitoring pasture lands was carried out, and an assessment was made of the significance of the characteristics of the SWOT analysis using the ranking method based on the assessments of factors received from experts.

At the first stage, the method of content analysis of scientific literature on the problem of monitoring pasture lands using UAVs was applied.

The source base of the study consisted of scientific research on various aspects of using UAVs in agriculture (articles from scientific peer-reviewed journals included in Scopus and Web of Science).

Table 1. Map of expert assessment of the source base

	Source base assessment parameters	Score (points)
1	**Compliance with the objectives of the study**	
1.1	Complies completely	5
1.2	Complies partially	3
1.3	Does not comply	0
2	**Practical value of the study**	
2.1	The results of the study have cross-sectoral significance	5
2.2	The results of the study are applicable in several industries	3
2.3	The results of the study can be applied to enterprises in the same industry	2
2.4	The results of the study are intended for use only in a particular enterprise	1
2.5	The results of the study have no practical value for the economy and society	0
3	**Scientific novelty of the study**	
3.1	Unique study, fundamentally new results	6
3.2	Some general patterns and methods allowing obtaining fundamentally new results	4
3.3	Positive solution based on simple generalizations, analysis of factor relationships, extension of known principles to new objects	2
3.4	Description of individual factors, dissemination of previously obtained results	0
4	**Presence of a scientific background and experience of the authors of the study**	
4.1	The authors have significant scientific potential and experience in the research topic	4
4.2	The authors have a certain (insignificant) background and experience in the research topic	2
4.3	The authors have no background and experience in the subject of scientific and technological revolution	0

The search for scientific sources on the research problem was carried out in the ScienceDirect database (https://www.sciencedirect.com/) using the proper keywords, namely, "monitoring", "agricultural lands", "land management", and "unmanned aerial vehicle (UAV)" to get a link to the corresponding article. The source base has been updated by the time of publication, from 2010 to the present, and was also limited by the requirement of free access to the necessary materials.

The search results allowed obtaining 154 scientific articles and monographs.

At the second stage, to increase the reliability of the research results, it was decided to analyze the reliability of the source base through an e-mail survey of 15 Kazakhstani experts in the field of UAV use in agriculture. The experts were sent the same email at the same time with a request to evaluate the sources according to four parameters (Table 1) and given an equal number of calendar days to fill it out, which allowed providing equal conditions for all experts.

The results of the expert survey limited the source base to 28 sources and allowed assessing its reliability based on the generalized desirability function on the Harrington scale (average results of the reliability of information sources were 0.73 points, meaning a high value).

At the third stage of the study, the collected information was processed using the methods of theoretical generalization, comparative analysis, and quantitative content analysis, which allowed determining the possibilities of using UAVs for monitoring pasture lands, the economic benefit of using UAVs, the main areas of using UAVs.

The quantitative content analysis was aimed at numerical estimation of mentions (in %), significant for the conducted study, in the analyzed literature, in particular, mentions of various opportunities and main areas of using UAVs for monitoring pasture lands, as well as mentions of various types of economic effects from their use, depending on the party to a relationship.

At the final stage, a final SWOT analysis of the use of UAVs for monitoring pasture lands was carried out in relation to the conditions of Kazakhstan. The SWOT analysis procedure provided for the step-by-step implementation of the following actions:

1. identifying the strengths and weaknesses of using UAVs for monitoring pasture lands in Kazakhstan and entering them into a table;

2. identifying opportunities and threats (risks) of using UAVs for monitoring pasture lands in Kazakhstan and entering them into the table;

3. comparing the strengths and capabilities of using UAVs to monitor pasture lands in Kazakhstan with weaknesses and threats, and formulating conclusions about further actions based on the data obtained.

The quantitative assessment of the significance of the characteristics of the SWOT analysis was carried out using the ranking method based on the assessments of factors received from experts. The peer-review procedure included e-mailing 15 Kazakh experts who participated in the assessment of the reliability of the source base of the study with a request to rank the strengths and weaknesses, as well as opportunities and threats obtained in the SWOT analysis.

4. RESULTS

As shown by the scientific literature analysis, using UAVs in agriculture is reduced to the performance of two main functions: transport (32.5% of sources) and monitoring (67.5% of sources). In the first case, in relation to use in cattle breeding, it is mainly urgent delivery of medicines [25] or, for example, spare parts to sites located in hard-to-reach areas [24].

The monitoring function of UAVs in managing the use of pasture lands is much broader (Table 2). Depending on the equipment used, UAVs provide ample opportunities for both producers and institutions to control the use of pasture lands.

Based on the results of Table 1, it can be argued that in the field of precise land utilization management there are several main areas in which it is difficult to do without using UAVs when monitoring pasture lands (Table 3).

The analysis of scientific literature has also shown that using UAVs for monitoring pasture lands has an economic benefit, which is important both for agricultural producers and insurance companies, as well as regulatory state bodies (Table 4).

To assess the feasibility of using UAVs to monitor pasture lands in Kazakhstan, a SWOT analysis was made (Table 5).

The results of assessing the significance of the characteristics of the SWOT analysis using the ranking method based on the assessments of factors received from experts are presented in Table 6.

Table 2. Possibilities of using UAVs for monitoring pasture lands

UAV with an ordinary camera	Number of sources, %
Conducting inventory and mapping of grazing land (including the preparation of cadastral plans and creating projects of land management)	61%
Measuring the chemical composition of the soil, creating and updating soil maps	52%
Planning livestock grazing, including the timing and sequence of using pastures	48%
Conducting monitoring of grass cover (evaluating growth, identifying outbreaks of disease, assessing the infestation, freezing, damage, rodents, etc.)	43%
Protecting against fires and other damage	65%
Conducting monitoring of soil conditions, including their erosion, deflation, dehumidification, and salinization	52%
Monitoring of grazed herds	57%
Monitoring of pasture conditions and preventing overgrazing	30%
UAVs with multispectral sensors	
More effective, compared to a conventional camera, monitoring the grass cover condition of (evaluating growth, identifying outbreaks of disease, assessing the infestation, freezing, damage, rodents, etc.)	56%
Monitoring of soil moisture	45%

Note: Compiled based on the analysis of scientific literature

Table 3. The main implementation areas of UAVs in the monitoring of pasture lands

UAVs implementation areas	Characterization	Number of sources, %
Area or representative air photography and analysis of the data obtained	Area air photography is an integral part of the range of works for obtaining topographic maps, plans, and digital terrain models using materials of photographing terrain from UAVs [14] Using UAVs allows obtaining the maximum amount of data on the condition of the pasture within a short time. There are currently several methods for analyzing data obtained from UAV images [25]	51%
Soil survey	There are three main categories of cases requiring aerial photography of pasture soils: when surveying an area with a high complexity of the soil cover of the studied territory [20]; in cases, requiring detailed soil characteristics [18]; and when conducting any soil reclamation and soil erosion studies, requiring constructing three-dimensional maps with data [21], which can only be obtained using UAVs	42%
Protection of pastures	UAVs can guard pastures and provide real-time transmission of information about fires and other unforeseen circumstances that may occur. In this case, the speed factor is very important: the rapid movement of the UAV in space allows for tracking any changes while maintaining high image quality [24]. Besides, given their operating speed, UAVs can fly over a larger number of pastures; installing thermal imagers on drones allows monitoring at night [12]	33%

Note: Compiled based on the analysis of scientific literature

Table 4. The economic benefit of using UAVs to monitor pasture lands

Entity	Economic benefit	Number of sources, %
Agricultural producers	Optimizing production costs and improving the quality of planning the production activities of agricultural enterprises	54%
	Clarifying expected profit from the sale of products	61%
Insurance companies	Preventing risks in the insurance of agricultural enterprises	44%
	Obtaining reliable estimates of expected products	32%
State regulatory authorities	Preventing lending to unscrupulous producers	26%
	Monitoring over compliance with land and environmental legislation and preventing timely violations and the application of penalties	28%

Note: Compiled based on the analysis of scientific literature [15, 16]

Table 5. SWOT analysis of using UAVs for monitoring pasture lands in Kazakhstan

Strengths	Weaknesses
High economic efficiency (reduction in price by dozens of times); accuracy; mobility; ease of controlling; productivity; high efficiency; environmental cleanliness of flights	Short flight time; dependence on weather conditions (inability to use in strong wind and rain); the need for constant monitoring; high price; the need to obtain a permit for use
Capabilities	**Threats**
Operational monitoring of pastures from a height of tens and hundreds of meters; identifying problem areas, which cannot be done by traditional methods; measuring pastures considering the terrain with high accuracy and GPS communication; animal monitoring	The limited use of additional devices due to the geometric dimensions of the UAV; the complexity of control in certain situations; the complexity and high cost of repair or replacement

Table 6. The results of assessing the significance of the characteristics of the SWOT analysis

Factors	Rank	Weight
Strengths		
high economic efficiency	1	0.28
mobility	2	0.21
ease of control	3	0.15
accuracy	4	0.13
high efficiency	5	0.11
performance	6	0.08
environmental cleanliness of flights	7	0.04
Weaknesses		
high cost	1	0.34
dependence on weather conditions (inability to use in strong wind and rain)	2	0.28
need for constant monitoring	3	0.18
short flight time	4	0.12
need for permission to use	5	0.08

Opportunities		
operational monitoring of pastures from a height of tens and hundreds of meters	1	0.35
animal observation	2	0.29
identification of problem areas that cannot be done using traditional methods	3	0.21
measurement of pastures considering the relief with high accuracy and GPS-connection	4	0.15
Threats		
complexity and high cost of repair or replacement	1	0.33
complexity of control in certain situations	2	0.33
limited use of additional devices due to the geometric dimensions of the UAV	3	0.13

5. DISCUSSION

As the results of the conducted SWOT analysis on the possibility and prospects of using UAVs for monitoring pasture lands show that this technology has more benefits than disadvantages, which indicates its prospects and effectiveness. Thus, benefits include high economic efficiency, accuracy, mobility, ease of management, productivity, lack of a complex procedure for approving flights, high efficiency, environmental cleanliness of flights, operational monitoring of pastures from a height of tens and hundreds of meters, identifying problem areas which cannot be done by traditional methods, scaling the dimensions of pastures with consideration of the terrain, ensuring high accuracy and GPS communication; observing animal herds. At that, disadvantages concern short flight time, dependence on weather conditions, the need for constant monitoring, high price, the requirement to obtain a permit for use, limited use of additional devices due to the geometric dimensions of the UAV, the complexity of control in certain situations, complexity and high cost of repair or replacement.

Besides the above capabilities of UAVs, the study [20] noted that when monitoring pasture lands they can detect the appearance of pests on time. If there are problem areas damaged by pests in the pasture, they can be identified using a UAV, set the exact coordinates, and then spray this particular area with the necessary preparation. Employing ultrasonic echolocation, UAVs adjust the flight altitude, scan the terrain and evenly spray the necessary amount of agrochemicals and pesticides to destruct pests.

Moreover, as noted in [18], UAVs can be used to monitor herds of animals directly, i.e. to identify sick, injured animals and even the beginning of parturition, as well as to monitor and control the work of workers and equipment.

The study [15] notes that the peculiarity of UAV-made photography is their high, even ultra-high spatial resolution and the ability to plan and shoot at the most convenient time to achieve a given goal, which is a significant advantage of UAV-made photography over satellite imagery.

In addition, in our opinion, using UAVs can positively affect the demographic structure of rural areas, since the latest technologies will make work in the agro-industrial complex more prestigious and interesting in the eyes of recent graduates of colleges and universities.

Today, Kazakhstan already has a fairly wide market of proposals for using UAVs. In Kazakhstan, UAVs and their services for monitoring, aerial photography, and cartography in the field of agriculture, including pasture lands, are offered by TerraPoint, KazUAV, and QAZDRON companies. However, both the purchase of UAVs and the provision of services are quite expensive. Besides, there is poor practical experience in using UAVs to convince land users that the employment of UAV is necessary for successful business development. According to S. Krytsky, Director of Geoscan-Kazakhstan, the main orders come for the rendering of electronic maps of fields, although the potential of the UAV technology is much wider [28].

The experience of developing countries shows that today mainly large enterprises can afford UAVs. They create special divisions for their use. By optimizing the production management provided by the UAV, the company returns the money invested in the UAV in a month, a maximum of three months [10]. Therefore, most medium-sized enterprises need to reconsider their strategy and show interest in implementing technology such as UAVs. This will lead to significant savings in monitoring costs, and allow gaining time compared to other types of monitoring, such as ground survey, satellite photographs, and using manned aircraft [10].

Certainly, using UAVs is associated with certain objective problems, related to the technical aspects of their use [22] and processing of survey results [12], the economic component [10], and the cost [15]. Besides, in our opinion, there are subjective problems associated with the difficulties of perception and implementation of new technologies in the management of territories. These aspects cause the passivity of management bodies responsible for the implementation of innovations. Thus, the whole set of existing problems associated with the implementation of UAVs into the processes of terrain management can be divided into objective and subjective, and their solution requires the involvement of qualified specialists who can increase the level of efficiency of terrain management.

6. CONCLUSION

For agricultural production to become truly competitive, it is necessary to apply specific and effective measures that relate to internal development and improvement of the level of efficiency of land management. In particular, the conditions for its development need to be improved through implementing innovative approaches to economic activities, one of which is UAV remote sensing.

UAVs are becoming more and more in demand every day in all sectors of agricultural production.

Due to the possibility of installing various equipment on UAVs, they are becoming an effective tool for modern agricultural monitoring. Using UAVs provides an opportunity for a detailed analysis of agricultural lands, including pasture lands.

Using UAVs allows cattle breeders to monitor the soil condition, the quality of grass cover, including problem areas, damaged by pests, protect lands against fires, timely report their occurrence, and even point-by-point improve the soil condition by spraying with the necessary preparations of a specific land plot.

Despite the rather high price, using UAVs for monitoring pasture lands is cost-effective, since it allows increasing the

productivity of enterprises in the agricultural sector by reducing time and human labor, which contributes to increasing their economic efficiency in general.

Thus, the hypothesis was confirmed that using UAVs for monitoring pasture lands leads to an increase in the level of land management by providing a wide range of opportunities and achieving an economic benefit for all entities of agricultural production.

The limitations of the conducted study concern a methodology constrained by just the analysis of existing scientific literature. In this regard, further study may be associated with an expert survey on the concerned problem.

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