

INCREASING THE PRODUCTIVITY OF THE AGRICULTURAL SECTOR USING NEW-GENERATION DRONES USING LIDAR AND GIS TECHNOLOGIES

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Abstract. *The article is devoted to the study of the possibilities of increasing the productivity of the agricultural sector through the use of new-generation drones and the integration of spatial digital technologies, in particular LiDAR and GIS, as a single intelligent platform for managing agricultural production. The scientific novelty of the work lies in the systematic combination of approaches to high-precision spatial measurement and analytical data management, which allows us to show how the integration of LiDAR and GIS creates an additional effect for increasing the productivity of the agricultural sector not only at the level of information collection, but also at the level of practical management decisions. The purpose of the article is a comprehensive analysis of the role of new-generation drones in increasing the productivity of the agricultural sector with an emphasis on the use of LIDAR and GIS technologies. The results of the study show that the main factors for increasing productivity using drones are the ability to monitor crops, estimate biomass and plant height, integrate data with GIS, differential input of resources, spraying and plant protection, as well as ensuring the efficiency and flexibility of production process management. However, the use of these technologies is not yet perfect, as it is resource-intensive and requires more efficient energy supply, and is accompanied by imperfect algorithms and models. Some of these limitations can be eliminated through the development of new technologies, in particular artificial intelligence, autonomous systems, cloud computing and sensor platforms. As a result, the practical significance of the study is to increase the efficiency of configuring and using drones with the involvement of new digital technologies to increase the productivity of the agricultural sector.*

Keywords: *drones, LiDAR, GIS, precision agriculture, agricultural sector productivity.*

Introduction

Global agriculture is currently operating under severe pressure, as the population is growing, climate change is intensifying, and natural resource degradation is deepening, which directly increases the risks to the stability of food systems. The problem of water resources is becoming particularly acute, as the areas with water shortages for agricultural production are predicted to expand, and therefore there is a need for more water-saving technologies and intelligent irrigation management. Current climate changes are already manifesting themselves in the form of a decline in



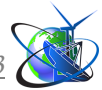
the yield of certain crops in a number of regions, and these trends may further intensify, so the agricultural sector needs adaptive approaches that quickly adapt to environmental changes [2]. Against this background, the technological state of the agricultural sector is best described by the transition to precision agriculture, where data-driven work and more targeted field management are becoming the basis [1]. Here, geoinformation technologies play an important role, because they collect spatial and technological data into unified databases and reduce information losses, and also allow for the coordination of technical, agronomic and economic indicators in a single information environment [5].

In this logic, new generation drones become a practical “bridge” between field condition measurement and management action, because they provide high-precision monitoring, high spatial resolution data collection and the possibility of more targeted interventions [2].

Literature Review

The topic of increasing agricultural productivity with the help of new generation drones using LiDAR and GIS technologies is widely studied in the scientific literature, the study used scientific works: H. Bartholomeus [10], Z. Chen [1], K. Chokmani [2], M. Chui [11], I. Durluk [4], S.M. Farhan [1], M. Ghasemi-Nejad-Raeini [8], R. Guebsi [2], O. Hloba [12], J. ten Harkel [10], L. Kooistra [10], A. Łobodzińska [4], S. Mami [2], D. Minaiev [5], T. Miller [4], F. Melnychuk [3], M. Mikiciuk [4], G. Mikiciuk [4], M.S. Memon [1], T. Mironchuk [12], L. Plichko [12], Y. Radelytskyy [5], R. Roberts [11], G. Rivera-Zárate [7], M. Safaeinezhad [8], S. Smit [11], M. Śnieg [4], G. Sylvester [9], M. Taki [8], V. Vorokh [12], L. Yee [11], J. Yin [1], V. Zatserkovnyi [12].

If we highlight works that are more devoted to GIS technologies in precision agriculture, then it is logical to rely on the approach of D. Minaiev, Y. Radelytskyy [5], on Esri's practical approaches to the use of GIS in farm management and precision agriculture [6], as well as on the work of V. Zatserkovnyi, V. Vorokh, O. Hloba, T. Mironchuk, L. Plichko, where GIS is considered together with GPS, remote sensing and AI in the context of studying soil characteristics, that is, as an analytical

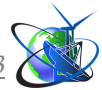


environment for spatial agricultural solutions [12]. At the same time, if we talk about LiDAR technologies, then the most targeted here are the works of S.M. Farhan, J. Yin, Z. Chen, M.S. Memon [1], G. Rivera-Zárate et al. [7] and the research of J. ten Harkel, H. Bartholomeus, L. Kooistra [10].

Future trends in the development of the agro-industrial complex using drones are most clearly outlined in the work of L. Yee, M. Chui, R. Roberts, S. Smit [11], as well as in the systematic review of T. Miller, G. Mikiciuk, I. Durlík, M. Mikiciuk, A. Łobodzińska, M. Śnieg [4]. If we talk about the most relevant and current studies, then, first of all, it is worth highlighting the work of M. Safaeinezhad, M. Ghasemi-Nejad-Raeini, M. Taki, which compares spraying drones with boom sprayers at an applied level and shows that, with correctly selected flight modes, drones can provide comparable protection efficiency and higher work productivity [8]. Secondly, it is worth highlighting the work of V. Zatserkovnyi, V. Vorokh, O. Hloba, T. Mironchuk, L. Plichko, where the combination of GIS, GPS, remote sensing, AI is tied to the tasks of soil analysis, that is, to the very basis without which productivity improvement through spatial management is poorly manageable [12]. In general, this literature became the basis for the research conducted, and through the use of scientific methods of cognition, synthesis, grouping and systematization, those aspects were highlighted that are not sufficiently detailed in individual sources, which forms the scientific novelty of the work. The key idea here is that LiDAR provides highly accurate three-dimensional measurement and description of the condition of crops and the field surface, while GIS provides integration, coordination, and practical interpretation of spatial data in the logic of agricultural production management, and it is their combination that gives the most applied effect for increasing the productivity of the agricultural sector, because it combines "precise measurement" with "precise management" in a single technological chain.

The purpose of the article is a comprehensive analysis of the role of new generation drones in increasing the productivity of the agricultural sector with an emphasis on the use of LiDAR and GIS technologies.

To achieve this goal, the **following tasks** will be performed during the study: 1)



to conduct a general review of modern approaches to the use of drones in agriculture, taking into account the trends of digitalization, automation and the development of precision agriculture; 2) to analyze the features of LiDAR technology as a tool for high-precision spatial measurement; 3) to summarize the main problems and limitations of the use of drone technologies, LiDAR and GIS in the agricultural industry.

Research Results

The role of drones in the modern agricultural sector is gradually moving from auxiliary to system-forming, because it is they who provide rapid data collection, their spatial detailing and the ability to quickly respond to changes in the field. According to S.M. Farhan, J. Yin, Z. Chen, M.S. Memon [1], precision agriculture is based on the use of modern technologies and data analysis to increase yields, resource efficiency and crop management quality, while traditional agricultural technologies have limitations in productivity and rational use of water, fertilizers and plant protection products [1].

Today, drones are closely integrated with geographic information systems, which form a single information environment of agricultural production. According to D. Minaiev, Y. Radelytskyy [5], modern technologies provide the formation of complex arrays of spatial and technological data, which are used for operational management, planning of technological operations and control of resource flows, and the integration of these data into single databases reduces information losses and increases the consistency of technical, agronomic and economic indicators [5].

A separate direction where drones are already demonstrating a practical effect is associated with spraying and differentiated application of plant protection products. According to M. Safaeinezhad, M. Ghasemi-Nejad-Raeini, M. Taki, unmanned sprayers may be somewhat inferior to traditional boom units in terms of uniformity of droplet deposition, but they provide comparable protection efficiency and significantly higher work productivity [8]. It can be said that drones form a new logic of agricultural production, where accuracy, speed and targeting of decisions become basic factors of productivity growth. The systematization of key factors that can radically improve the state of agriculture is given in Table 1.

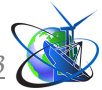


Table 1 – Contribution of new generation drones to increasing the productivity of the agricultural sector

Factor	Contribution of drones to productivity improvement
Crop monitoring	Provide rapid collection of detailed spatial data on plant conditions, terrain, and soil characteristics
Biomass condition assessment	Enable the generation of quantitative indicators of crop growth, which improves yield forecasting accuracy and planning of agrotechnical measures
Integration with GIS	Supply geographic information systems with up-to-date data, support the creation of digital field maps, and improve consistency in farm-level decision-making
Variable-rate input application	Allow targeted application of fertilizers and crop protection products
Spraying and crop protection	Ensure high operational efficiency, reduce pesticide use, and enhance the economic effectiveness of agricultural operations, especially on large areas
Responsiveness and management flexibility	Make it possible to quickly respond to changes in weather, crop conditions, and technological needs, which reduces crop losses and increases production stability

Based on sources: [1, 5, 8, 10]

According to S.M. Farhan, J. Yin, Z. Chen, M.S. Memon, the use of modern sensors and data analysis methods allows to increase yields, use resources more efficiently and improve the quality of crop management, and drones actually provide prompt receipt of this information without significant expenditure of time and human resources [1]. Unmanned platforms support monitoring of large areas, rapid identification of stress zones and adaptation of agricultural technologies to real field conditions, and this directly affects the stability and productivity of agricultural production [2]. That is, drones form a practical basis for more accurate and informed decisions, and at the same time reduce the risks associated with the human factor and late information.

If we talk about the features of modern drone solutions, they are based not on a single technology, but on the combination of a whole complex of digital tools that work as a single system. Firstly, agriculture is actively introducing sensor networks and the Internet of Things for continuous field data collection, GPS satellite navigation systems for spatially linking operations, remote sensing technologies for monitoring crop conditions, GIS geographic information systems for accumulating, integrating and analyzing spatial information, LiDAR laser scanning for generating high-precision



three-dimensional models of vegetation cover and relief, artificial intelligence and machine learning algorithms for automatically processing large data sets, as well as cloud platforms and big data analytics for storing, visualizing and supporting management decisions [4; 11; 12].

Among this entire set of technologies, LiDAR and GIS occupy a special place, because they form the spatial basis for most management decisions. According to S.M. Farhan, J. Yin, Z. Chen, M.S. Memon, LiDAR allows building high-precision three-dimensional models of relief, vegetation cover and soil characteristics, which increases the targeting of agronomic interventions and the quality of crop condition monitoring [1]. According to D. Minaiev, Y. Radelytskyy, geographic information systems provide accumulation, structuring and analysis of spatial data in a single information environment, which allows to coordinate technical, agronomic and economic indicators and reduce information losses [5]. Also, according to V. Zatserkovnyi, V. Vorokh, O. Hloba, T. Mironchuk, L. Plichko, the combination of GIS, GPS, remote sensing and analytical algorithms creates the basis for electronic field maps, differentiated resource application and more accurate forecasting, and it is drones that act as a key carrier of primary data for these systems [12].

In general, according to S.M. Farhan, J. Yin, Z. Chen, M.S. Memon, the use of LiDAR significantly expands the functionality of autonomous and robotic systems, in particular in crop monitoring, disease and weed detection, yield assessment, mapping, navigation and automated harvesting, and the combination of data from aerospace and ground platforms increases the accuracy of spatial analysis and supports site-specific management of agroecosystems [1]. At the same time, the authors draw attention to the need to systematize approaches and critically analyze results to avoid interpretation errors and ensure the stability of decisions [1]. That is, conceptually, LiDAR combines high spatial accuracy, work with three-dimensional models, dependence on data collection parameters and orientation on practical support of management processes in the agricultural sector.

If we compare GIS with LiDAR, the difference lies primarily in the functional role of each technology. As noted by S.M. Farhan, J. Yin, Z. Chen, M.S. Memon,



LiDAR acts as a source of high-precision primary spatial information in the form of three-dimensional models of relief and vegetation cover [1], while D. Minaiev, Y. Radelytskyy in their study show that GIS performs the function of a system for accumulating, structuring and analytical processing of this data within a single information environment of the farm [5]. That is, if LiDAR is more responsible for measuring and detailing space, then GIS is more responsible for the logic of data management, their interpretation and practical use in planning and controlling agricultural operations [1;5].

Table 2 – Main conceptual features of LiDAR technology in agriculture

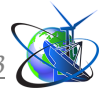
Conceptual feature	Content and practical significance
Three-dimensional laser scanning	enables the creation of highly accurate 3D models of terrain, vegetation cover, and soil characteristics to support decision-making
Plant height assessment	makes it possible to quantitatively determine crop development, though accuracy depends on plant structure and laser signal penetration
Biomass assessment	relies on the analysis of spatial distribution of points in 3D space, requiring proper model configuration and flight parameters
Sensitivity to data collection parameters	flight altitude, speed, and coverage density affect the number of scanning points and the quality of results
Integration with autonomous systems	supports monitoring, navigation, mapping, yield assessment, and automation of agricultural operations
Focus on site-specific management	allows a shift toward site-specific management of agroecosystems and resource optimization

Based on sources: [1, 10]

Table 3 – Main conceptual features of GIS technology in agriculture

Conceptual feature	Content and practical significance
Integration of spatial and technological data	combines different types of information into unified databases for comprehensive analysis of agricultural production
Support for decision-making	ensures planning, control, and optimization of agrotechnological operations
Spatial referencing of agro-operations	uses GPS for precise positioning and the creation of digital field maps
Analysis of spatial variability	identifies zones of differences in soil properties, crop conditions, and productivity
Integration with remote sensing and LiDAR	utilizes laser scanning data and satellite imagery to improve analysis accuracy
Formation of a unified information environment	aligns technical, agronomic, and economic indicators within the farm

Based on sources: [5, 12, 1]



So, LiDAR and GIS have in common the orientation towards working with spatial data, support for precision agriculture and the desire to increase the targeting of management decisions, but at the same time they differ in their role in the technological chain. According to S.M. Farhan, J. Yin, Z. Chen, M.S. Memon, LiDAR provides high detail and accuracy of primary measurements [1], and according to D. Minaiev, Y. Radelytskyy, GIS provides systematization, integration and practical interpretation of these measurements within the framework of economic activity [5]. According to V. Zatserkovnyi, V. Vorokh, O. Hloba, T. Mironchuk, L. Plichko, their combination allows creating multilayer electronic maps, supporting differentiated input of resources, predicting yield and increasing the consistency of technical and agronomic decisions, and it is this integration that forms the basis for a more stable and productive development of the agricultural sector [12].

To date, technologies for the use of drones in the agro-industrial sector are being improved through ongoing innovations. Among the key advances is the implementation of low-latency event-based cameras. Such cameras enable much earlier detection of obstacles, allowing drones to avoid potential collisions, including with animals present in the operational environment. Another important innovation is a propulsion system capable of elevating drone maneuverability to a fundamentally new level. Gimbal-mounted motors can direct the airflow in any direction, enabling smooth, serpentine maneuvers with precise control. As a result, the accuracy of approaching a target point increases, and the capability to operate in environments that are challenging for agricultural applications – such as flying between trees – also improves. With such propulsion systems, drones are able to perform tasks with surgical precision.

Verification of the compliance of models formed on the basis of drone data with the real state of crops shows a sufficiently high informativeness of LiDAR and GIS, but at the same time reveals a number of system limitations. According to J. ten Harkel, H. Bartholomeus, L. Kooistra, the accuracy of estimating plant height and biomass depends on the type of crop, leaf density, flight parameters and density of laser points, and under certain conditions both overestimation and underestimation of indicators are



possible [10]. The quality of the results is also determined by the level of sensor calibration and the correct processing of large data sets, and without this, even high-precision technologies can produce simplified or unstable models [1]. Also, errors can occur in GIS due to incompleteness or incompatibility of data sources, delays in updating information and different levels of accuracy of spatial reference, which complicates the correct interpretation of the results in practical management [5;12]. That is, the main challenge lies not so much in the technologies themselves, but in the quality of the data, the conditions of their collection, the standardization of processes and the readiness of the systems for integration with future digital solutions.

Table 4 – Potential errors in the use of LiDAR and GIS in the agricultural industry and possible directions for overcoming them

Problems	Manifestation	Possible ways to reduce or overcome
Errors in plant height measurement	overestimation or underestimation of height for crops with dense or uneven leaf structure due to limited laser signal penetration [10]	adaptation of models for specific crops; increasing scan density; use of combined sensors and machine learning algorithms [1;10]
Inaccuracy in biomass assessment	underestimation of biomass in cases of high plant density or mass; results depend on flight height and speed [10]	standardization of flight parameters; development of more robust analytical models; integration of LiDAR with multispectral data [10;1]
Sensitivity to data collection conditions	variation in result quality due to different flight path densities and number of laser scan points [10]	automated flight planning; use of autonomous control systems and predictive algorithms [11]
Incompleteness and incompatibility of GIS data	differing formats, varying source accuracy, and update delays can distort analytical outcomes [5;12]	development of unified data standards; cloud-based integration platforms; improved system interoperability [5;12;11]
Spatial referencing errors	GPS inaccuracies or coordinate shifts lead to incorrect maps and flawed management decisions [12]	use of high-precision navigation systems, correction signals, and automated coordinate validation [4;12]
Complexity in processing large data sets	system overloads, delayed analysis, and risk of partial data loss [1]	use of cloud computing, artificial intelligence, and scalable analytical platforms [1;11]
Limited staff readiness	insufficient training of specialists in interpreting complex digital models [5]	development of digital competencies; implementation of intuitive interfaces and decision support systems [5;11]

Based on sources: [1, 5, 10, 11, 12]



Future technologies can significantly enhance the efficiency of drones in the agricultural sector through deeper automation, better data quality and more intelligent information processing. The development of the Internet of Things, smart sensor networks and artificial intelligence allows for the automation of data collection, transmission and analysis, reducing dependence on manual operations and human errors [4]. Trends in digitalization, autonomy and scaling of big data analytics create conditions in which drones will be able to work as part of single digital platforms, process information faster and support forecasting in real or near real time [11]. Combining these solutions with a high-precision sensor base, in particular LiDAR, will increase the stability of models, the accuracy of biomass and crop condition assessments and the overall targeting of agronomic decisions [1].

Conclusions

Increasing the productivity of the agricultural sector using new-generation drones is primarily due to the ability to quickly obtain objective, spatially bound and detailed information about the condition of crops and the production environment, as well as to promptly convert this information into practical management decisions. The key factors for increasing productivity are regular monitoring of crops, accurate assessment of plant height and biomass, timely detection of spatial heterogeneity of the field, targeted application of resources, optimization of spraying and plant protection, as well as increasing the efficiency and flexibility of managing agro-technological processes. These factors allow reducing resource overspending, reducing technological risks and stabilizing yields. The use of LiDAR technology provides highly accurate three-dimensional measurement of relief and vegetation cover, which allows obtaining quantitative indicators of crop development and moving from visual assessments to substantiated data, and therefore increasing the accuracy of agronomic decisions. At the same time, GIS forms a single information environment within which data from drones, navigation systems and other sources are integrated, spatial analysis is provided, coordination of technological operations and planning support is provided. The combination of LiDAR and GIS allows you to combine measurement accuracy with management logic, that is, to transform detailed spatial data into practical



scenarios of actions in the field, which creates the basis for more effective, economically feasible and sustainable decisions in the agricultural sector.

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