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THE IMPACT OF UAV TECHNOLOGY IN AGRICULTURAL MONITORING

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Abstract

This paper aims to investigate the usage and impact of Unmanned Aerial Vehicles (UAVs), also known as drones, in agricultural land monitoring. The main objective of this research is to thoroughly examine the use of UAVs in agriculture, focusing on obtaining precise and up-to-date information about land conditions to support decision-making processes and implement sustainable management strategies. The contributions of this study include the identification of the advantages and limitations of UAV in monitoring and protecting agricultural land, as well as exploring how these technologies can optimize agricultural processes and support informed decision-making. The paper also addresses current challenges facing agricultural lands, such as soil degradation, crop loss, and climate change pressure, emphasizing the importance of precise monitoring and adequate protection for sustainable agriculture.

Throughout history, the evolution of drones has been analyzed, from early prototypes to modern models, highlighting the technological advancements that have led to the popularization of UAVs in agriculture. Presently, the use of UAVs in agriculture has become increasingly popular due to their ability to collect detailed data and provide relevant information in real-time, thereby contributing to increased efficiency and sustainability in agriculture. In the future, it is anticipated that UAV technology will become increasingly sophisticated and integrated into agricultural activities, contributing to the transformation of this sector and generating increased interest among younger generations of farmers and agricultural researchers.

The method used involved a review of specialized literature to assess the impact of this technology at the national level and the execution a drone flight using specific software to collect relevant data for monitoring agricultural land. Detailed mission planning was conducted beforehand, and during the flight, various techniques and strategies were applied for land mapping and data collection. The system also provided real-time information about weather conditions and air traffic, contributing to efficient operations management and ensuring safe flight. The results obtained consisted of precise and detailed data about the monitored land, which were subsequently analyzed and interpreted to identify potential threats or issues. The images processing included their transformation into 3D and 2D maps, as well as generating NDVI maps to assess the vegetation status of the land. These data allow the identification and evaluation of various aspects of agricultural land, including pest-related problems, nutrient deficiencies, or water stress, thereby contributing to informed decision-making and optimized crop management. The paper highlights the importance of UAV technology and demonstrates its potential in increasing efficiency and sustainability in agriculture. By integrating UAVs into agricultural workflows and using them in data collection and analysis, it is possible to more efficiently identify and manage the challenges and risks associated with agricultural activities, thereby contributing to the development of smarter and more sustainable agriculture.

Keywords: agricultural resource optimization, crop monitoring, multispectral mapping, precision agriculture, remote sensing.

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1. INTRODUCTION

Modern agriculture faces significant challenges, such as soil degradation, crop losses, and the pressures of climate change. These challenges necessitate the adoption of innovative solutions to support agricultural sustainability and productivity. In this context, Unmanned Aerial Vehicles (UAVs), or drones, have emerged as a valuable tool in precision agriculture. These technologies enable detailed monitoring of agricultural lands, providing precise and real-time data that can guide informed decision-making by farmers and agronomists.

UAV technology has rapidly evolved from early prototypes to modern models capable of delivering detailed and precise real-time data on the condition of agricultural lands (Ruwaimana et al., 2018; Lazzeri et al., 2021). These technological advancements have facilitated the integration of UAVs into agriculture, where they have become indispensable for accurate land monitoring and real-time decision support, enabling rapid interventions and optimal resource management. The use of drones in agriculture offers multiple advantages, such as detailed soil condition monitoring, moisture assessment, early detection of pests and crop diseases, as well as more efficient resource management (Santos et al., 2015; Anderson et al., 2017).

This research aims to investigate in detail the use and impact of UAVs on agriculture, focusing on optimizing decision-making processes and sustainable land management.

The specialized literature highlights numerous advantages of using UAVs in agriculture. To provide a comprehensive perspective, this research primarily relied on specialized literature from Romania, supplemented by several relevant international articles that offered a comparative context on the applicability of UAVs in precision agriculture globally. At the national level, studies by Lupu et al. (2022) and Ioja et al. (2023) explored the use of UAVs in agriculture, highlighting the impact of these technologies in crop monitoring and the application of phytosanitary treatments. Studies conducted in Romania emphasized the need to integrate precision technologies into local farms to combat soil degradation and optimize agricultural production. For instance, Simon et al. (2018) used UAV technology to detect spatiotemporal changes in areas designated for forage, underscoring the utility of photogrammetric data in land management. Casian et al. (2019) investigated the applicability of UAV photogrammetry in creating topographic and cadastral documentation, demonstrating the efficiency of this technology in obtaining precise 3D models for land monitoring. Similarly, Călina et al. (2022) explored the use of aerial scanning and GIS in the design of sustainable agricultural production works on an agritourism farm, offering an innovative solution for expanding agricultural production through the use of drones. Iagăru et al. (2023) analyzed the prospects for integrating miniature UAVs into horticultural agroecosystems, emphasizing the potential of these technologies in enhancing production and resource management in Romania.

At the international level, Zhang and Kovacs (2012) highlight that UAVs facilitate crop monitoring and vegetation health assessment through multispectral analyses, allowing for rapid interventions in case of deficiencies or pests. Additionally, Tsouros et al. (2019), Lu et al. (2022), Su et al. (2022), and Alsadik et al. (2023) emphasize the importance of this technology in optimizing irrigation and targeted fertilizer application, contributing to cost reduction and environmental impact. However, Tsouros et al. (2019), Dutta and Goswami (2020), and Climavision (2022) draw attention to the technological limitations, such as battery life and sensitivity to adverse weather conditions, which can affect the efficiency of flights.

Recent research demonstrates that UAVs have become an essential tool in precision agriculture, enabling real-time monitoring of agricultural lands and the integration of data directly into agricultural equipment, such as sprayers, for the precise application of phytosanitary treatments

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(Khan et al., 2021; Hanif et al., 2022; Aslan et al., 2022). For example, a study conducted in Brazil showed that the use of drones contributed to a reduction in herbicide use by up to 52%, thus optimizing resource management and reducing environmental impact (Pinguet, 2021).
This research explores the impact of UAV technology on agriculture, highlighting both the benefits and limitations of this emerging field. The primary objective is to demonstrate how integrating UAVs into agricultural activities can optimize the decision-making process and support sustainable land management.
In this study, an experimental UAV flight was conducted, collecting and analyzing detailed data on the agricultural land, using advanced software for generating 2D and 3D maps, as well as NDVI maps for vegetation assessment.

2. MATERIALS AND METHODS

To facilitate understanding and tracking of the research, we find it useful to divide the main stages into distinct sections: literature review, flight planning, flight execution, and data processing, to provide a clear overview of the applied methodology. This approach allows for an easy follow-up of the process from theory to practice and then to the analysis of the results.
The first stage of the research involved a review of the specialized literature from Romania, focusing on the impact of UAV technology in precision agriculture at the national level. Additionally, several relevant international articles were used to offer a comparison between global technological implementations and their adaptability in the Romanian context. Articles from major academic databases such as Google Scholar, MDPI, and SpringerLink were consulted, providing a solid foundation for understanding the advantages and limitations of UAVs in agricultural land monitoring. These studies highlighted the role of UAVs in optimizing the decision-making process and improving agricultural management, while also providing critical data for implementing sustainable strategies.
For the experimental drone flight, a senseFly eBee X UAV was used (figure 1), equipped with a multispectral camera capable of capturing detailed images in both the visible and near-infrared spectrum, essential for monitoring vegetation health and detecting issues related to crop health. The data obtained were important for monitoring the state of the vegetation and identifying problems associated with crop health.

Figure 1. UAV_senseFly eBee X

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The mission planning was carried out using the mission block assistance and planning functions available in the drone's software. This allowed for the automatic optimization of the flight plan based on the blocks from the selected area (figure 2) and the map quality settings. Additionally, the launch and landing zones (figure 3) for the aircraft were established. Thus, the software allowed the precise determination of flight routes, altitude, and image overlap degree, ensuring efficient and uniform coverage of the monitored terrain.

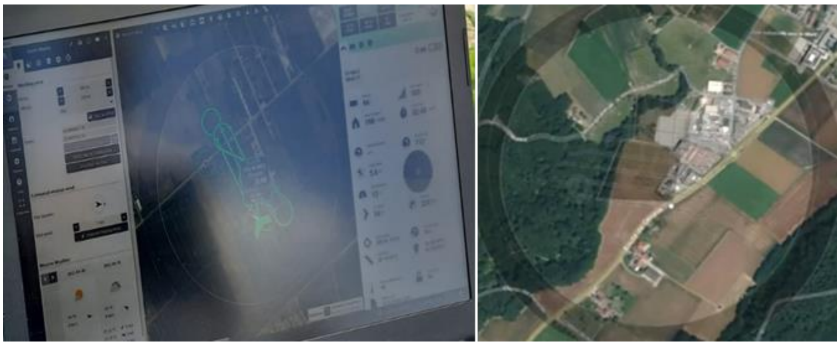

Figure 2. Establishing the area to be flown over

Figure 3. Establishing the launch and landing zones

During this planning, variables related to weather conditions and air traffic were taken into account to ensure the safe execution of the flight. The software provided the ability to simulate the mission, thus optimizing the UAV's route to cover the entire area of interest. After generating the route, the program displayed the number of photos that the multispectral camera would take and estimated the time required for the drone to complete the monitoring flight. Once the UAV's operating system confirmed the mission parameters, the drone was manually launched (figure 4). After completing the mission planning and simulation, the actual flight execution took place.

Figure 4. Manual launch of the drone

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The experimental flight was conducted to monitor a large agricultural field. The UAV transmitted real-time information about flight conditions, atmospheric status, and air traffic, contributing to the efficient management of operations. Data were collected during a single flight, and the captured images were later processed to generate detailed 2D and 3D maps of the agricultural field.
The collected data provided critical information for generating detailed maps and for efficiently assessing the agricultural land, thereby contributing to the overall objective of the study to optimize crop management through the use of UAVs.

3. RESULTS AND DISCUSSIONS

The flight data manager embedded in the software automatically prepared the images (figure 5) for further processing, ensuring that all data was suitable for post-production.

Figure 5. Photos taken during the mission

After completing the drone flight, the collected data were analyzed to assess the condition of the monitored lands and to identify any potential issues. The multispectral camera captured images in the visible and near-infrared spectrum, which were later processed to generate the NDVI map (figure 6). This map allowed for the evaluation of vegetation health, and problem areas were quickly identified through color variations, indicating either nutrient deficiencies or pest infestations.

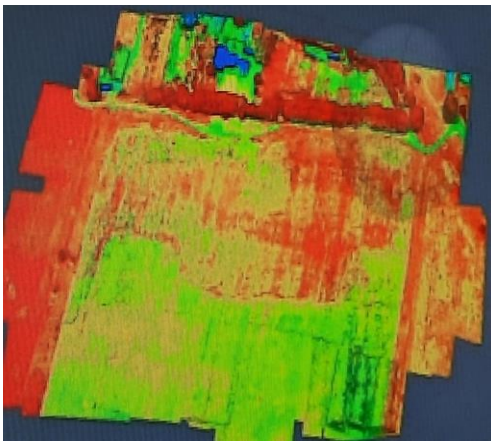

Figure 6. NDVI map – vegetation health of the monitored area

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The image presented in figure 7 illustrates the process of aligning and overlapping the images captured by the multispectral camera during the UAV flight. This step is important for generating detailed 3D models and creating accurate maps of the monitored area. Each individual image was processed and correlated with the other captured images to ensure perfect overlap and to allow precise analysis of the multispectral data. This technique enables the detailed identification of land features, including variations in vegetation and soil structure, contributing to a clear assessment of the agricultural land's condition.

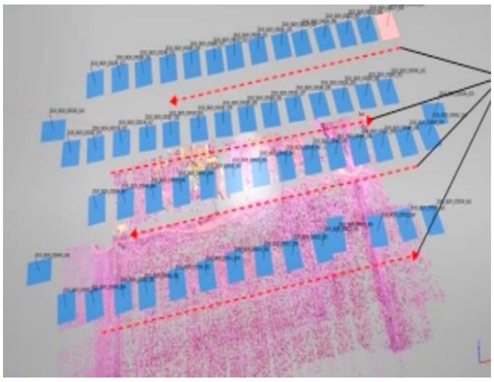

Figure 7. Alignment and overlapping of multispectral images captured during the UAV flight

The orthomosaic map generated from the processing of images captured by the multispectral camera during the UAV flight was obtained (figure 8). The areas colored in shades of purple and pink highlight different aspects of the soil surface and vegetation, allowing the identification of potential problem areas, such as variations in vegetation density or soil conditions. This information is essential for assessing crop health and implementing appropriate agricultural management measures.

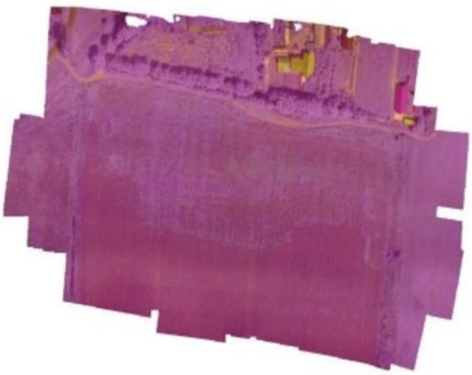

Figure 8. Orthomosaic map of the agricultural land obtained through the processing of multispectral images captured by the UAV

An NDVI map (figure 9) was generated from the processing of multispectral images captured during the UAV flight. This NDVI map indicates variations in vegetation health, where areas colored in green represent healthy vegetation, while those in red and orange indicate vegetation stress or potential issues, such as water or nutrient deficiencies or the presence of pests. The use of

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such a map is important for the early identification of agricultural problems and for making informed decisions regarding crop management.

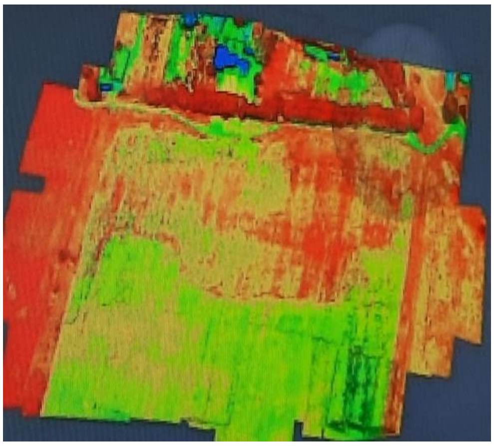

Figure 9. NDVI map generated by processing the multispectral data captured by the UAV for vegetation health assessment

Following the data analysis, several types of issues within the crops were identified. For instance, moisture deficiencies were observed in certain areas, which allowed for the optimization of irrigation systems to prevent losses caused by drought. Other areas showed signs of specific pest infestations, and the early identification of these problems enabled the rapid application of treatments, preventing further damage.

Another major contribution of the UAV analysis was the assessment of soil conditions and the identification of areas with nutrient deficiencies. The collected data were used to apply fertilizers in a targeted manner, thereby reducing costs and environmental impact through the precise application of doses.

Additionally, the NDVI analysis demonstrated the utility of this method for real-time crop monitoring, allowing for prompt and accurate interventions. This continuous monitoring capability has brought significant benefits in optimizing agricultural production, ensuring more efficient resource management and increased yield.

Following the analysis of the data collected using the UAV, the results highlighted the drones' ability to provide a precise and detailed view of vegetation and soil conditions. These findings align with the research conducted by Zhang and Kovacs (2012), which demonstrated that UAVs are effective tools for phytosanitary monitoring of crops. Additionally, Simon et al. (2018) emphasized the effectiveness of UAVs in identifying spatio-temporal variations in forage areas, underscoring their important role in agricultural land management.

In this research, NDVI maps provided a fundamental method for assessing vegetation health, allowing for the early identification of problem areas, such as nutrient deficiencies or water stress. This aspect is supported by studies conducted by Lu et al. (2022) and Su et al. (2022), which demonstrated that UAVs enable optimized adjustments to irrigation and fertilization by closely monitoring crop conditions in real-time.

Technological limitations, such as reduced battery autonomy and vulnerability to adverse weather conditions, highlighted by our experiment, are also reflected in the studies by Tsouros et al. (2019)

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and Dutta and Goswami (2020). These limitations can affect the efficiency of flights and should be taken into account when planning UAV missions in areas with unpredictable climatic conditions.

Casian et al. (2019) highlighted the ability of UAVs to generate precise 3D models through photogrammetry, and this finding is also supported by our results, which demonstrated the utility of these 3D maps in the detailed assessment of agricultural lands. The maps were useful not only for assessing the vegetation state, but also the efficient planning of agricultural interventions, similar to the conclusions of Călina et al. (2022), who used UAVs for the development of sustainable agricultural practices.

The results of this study are in accordance with existing research and demonstrate the high potential of UAV technology in precision agriculture. These technologies not only optimize the decision-making process but also contribute to increasing sustainability in agricultural resource management, while simultaneously reducing costs and environmental impact.

4. CONCLUSIONS

The experimental results confirmed the high potential of UAV technology in agriculture. By integrating these technologies into agricultural workflows, farmers have access to effective tools for sustainably monitoring and managing agricultural lands.

This study highlights the significant positive impact of using drones (UAVs) in the monitoring and protection of agricultural lands, demonstrating the benefits of this technology in precision agriculture. By analyzing the data collected by UAVs, farmers can make more informed decisions regarding resource management, such as irrigation, fertilization, and pest control. This contributes to increased efficiency and reduced production costs, making agriculture more sustainable and environmentally friendly.

The integration of drones in agriculture enhances not only productivity but also the precision of monitoring vegetation and soil conditions, allowing for rapid interventions in cases of infestations or nutrient deficiencies. UAV technology also contributes to reducing the use of environmentally harmful chemicals, promoting more eco-friendly agricultural practices.

As drone technology continues to evolve, these devices will become increasingly accessible and widely used in agriculture. New developments in sensor technology and artificial intelligence will further expand the capabilities of UAVs, contributing to the creation of a smarter and more sustainable agricultural environment. These findings can be applied to other sectors of agriculture and demonstrate great potential for expanding the use of these technologies across farms of various sizes.

The results indicate that drones will continue to be an important tool in transforming traditional agriculture into precision agriculture, capable of addressing current challenges related to climate change, soil degradation, and resource management.

5. ACKNOWLEDGEMENTS

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