MODERN TECHNOLOGIES IN CADASTRE: A REVIEW OF UAV AND GIS APPLICATIONS

C. A. MINEA[1], S. KIAJI[1], Maroua DAHBI[1], A. ȘMULEAC[1], R. PASCALAU[1]
[1] University of Life Sciences "King Mihai I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania
Corresponding author: adrian_smuleac@usvt.ro

***Abstract**: The use of new technologies in cadastre work has changed old land management systems, making data gathering and handling more correct and efficient. Among these technologies, Unmanned Aerial Vehicles (UAV) and Geographic Information Systems (GIS) are important for solving tough problems with land surveying and mapping. UAVs give high-quality aerial pictures and can quickly collect data over large spaces, while GIS has strong tools for viewing and understanding spatial data. This mix not only makes cadastre tasks more precise but also helps in making better decisions in city planning, environmental checks, and managing resources. In addition, the cooperation of UAV and GIS technology opens doors to new uses in different areas, as shown by their vital part in good land management plans. To show these ideas, the diagram included demonstrates how GIS applications can cover different management areas, underlining the importance of modern technologies in current cadastre work. A good understanding of cadastre is important for good land management and administration today. The cadastre is a detailed record of land and property rights, including information on who owns land, where the boundaries are, and the value of land parcels. This makes it an important tool for governance, urban planning, and managing resources. A well-kept cadastre is important because it provides legal security for land ownership, aids in efficient tax collection, and helps resolve disputes regarding who owns land. New technologies like UAVs and GIS have changed how cadastral data is gathered, analysed, and managed, improving the accuracy and ease of access to this important information.*

Key words: cadastre, Unmanned Aerial Vehicles (UAV), Geographic Information Systems (GIS)

INTRODUCTION

The use of new technologies in cadastre has changed old land management methods, making data collection and handling more efficient and accurate. With improvements in Geographic Information Systems (GIS) and Unmanned Aerial Vehicles (UAVs), professionals can now gather high-quality spatial data, which makes land registration better. Before, traditional methods relied a lot on ground surveys; however, the quick growth of remote sensing technologies, like those mentioned in studies cited by (Asiama et al. 2021), has shown that aerial and satellite images can work well alongside standard methods. In addition, the rise of digital tools allows for constant updates and immediate analysis of land data, meeting the growing need for complete and interchangeable land information systems, as pointed out in ('MDPI AG').

Thus, the ongoing connection between these new technologies not only demonstrates their practical use in cadastre but also highlights their validity in tackling current land management issues, leading to new solutions in this area. An example of GIS use in land management illustrates this change by showing different sectors that benefit from spatial data, helping us to understand how these technologies are integrated into daily practices in cadastre. For example, using these technologies allows for quick mapping of land parcels, making the cadastre more responsive to changes in urban settings and the varied needs of land use planning (Williams et al. 2018).

These advancements show how important the cadastre is for handling the complexities of modern governance and achieving sustainable development. Moreover, visual

examples of GIS applications in management areas demonstrate the many uses of the cadastre, reinforcing its essential role in today's land administration.

MATERIALS AND METHODS

This review aims to look closely at the progress made in combining Unmanned Aerial Vehicles (UAV) and Geographic Information Systems (GIS) in cadastre work. By examining the background and development of these technologies, this study tries to set up a clear framework that shows how they help improve efficiency and accuracy in land management. Previous studies note that the use of photogrammetry and remote sensing has been crucial since they started but is often not fully valued (Asiama et al. 2021). Additionally, this review will outline the current research landscape, responding to the push for Land Administration 2.0, which calls for new methods to be used in cadastre processes ('MDPI AG'). In summary, this review seeks to compile existing literature, find research gaps, and encourage discussion on the need for updated technological systems, which will ultimately enhance land management practices. To visually support this discussion, effectively shows the various uses of GIS in land management, highlighting the importance of these technologies in cadastre improvements.

The use of Unmanned Aerial Vehicle (UAV) technology in cadastre systems brings clear improvements in efficiency and data precision. Drones, with their advanced sensors, enable land surveyors to quickly gather high-quality images, which helps in making detailed orthophoto maps and digital terrain models. This aerial view provides a better understanding of spatial relationships and land features that ground surveys might overlook. Additionally, UAVs greatly lower the time and expense needed for large surveying projects, making them a sensible choice for land administration tasks. The use of UAV technology in cadastre systems not only improves data collection methods but also simplifies workflows, encouraging broader use in land management practices. For visual context, an image showing common UAV uses in surveying and data gathering supports these ideas. To further show UAV capabilities, illustrates how GIS applications can effectively manage various environmental sectors, highlighting the role of UAVs in today's land surveying practices. In the end, these UAV uses represent an important change towards more flexible and responsive cadastre systems, effectively showing the operational advantages of UAVs in various management situations and enhancing the discussion on their use in cadastre.

RESULTS AND DISCUSSIONS

I. UAV Technology in Cadastre

As mentioned, the changing field of photogrammetry and remote sensing is increasingly accepted in land administration, highlighting the value of UAVs as reliable data collection tools, which supports their use in current cadastral methods (Casian et al. 2019; Pascalau et al. 2020). These approaches not only improve workflows but also help in managing land resources sustainably, thus boosting the overall effectiveness of cadastre systems (Croitoru et al. 2023). The importance of UAVs is even more apparent in GIS applications, as illustrated in, which shows how they assist in handling complicated geographical data.

A. Principles of UAV Operation and Data Collection

In land administration, Unmanned Aerial Vehicles (UAVs) have become an important tool for collecting data, thanks to their ability to gather high-quality images and spatial information quickly. The basics of how UAVs work include knowing about flight mechanics, combining sensors, and processing data. To run successful UAV missions, careful planning is crucial, which involves choosing the right altitudes, ensuring overlap, and placing ground control points to achieve accurate positioning. These essential operations help in identifying

geospatial features and play a key role in cadastre applications, as noted in recent studies (Herbei et al. 2018; Smuleac et al. 2017, 2020). Furthermore, UAVs can use many kinds of sensors, from standard RGB cameras to sophisticated LiDAR systems, meeting various project needs ('MDPI AG').

B. Advantages of UAVs in Land Surveying

Using Unmanned Aerial Vehicles (UAVs) in land surveying brings big improvements in efficiency and accuracy. Unlike older methods that can take a lot of work and time, UAV technology allows for quick data collection across large areas, which can greatly shorten project timelines. The ability to take clear images and create detailed maps helps surveyors gather data that leads to better planning and decision-making. Additionally, UAVs make it possible to access tough terrains that could be dangerous for ground workers, improving safety and increasing the area that can be covered. A key benefit is that they can easily work with Geographic Information Systems (GIS), updating land administration databases with current geographic information, which some researchers call Land Administration 2.0 ('MDPI AG'). This modern method not only helps improve accuracy but also meets the changing needs of the land administration field (Herbei et al. 2013; Barliba et al. 2014).

C. Case Studies of UAV Applications in Cadastre

Questioning the usual reliance on ground surveys, recent case studies showing the use of Unmanned Aerial Vehicles (UAVs) in cadastral work show clear improvements in surveying speed and accuracy. With the use of UAV technology, data collection has increasingly moved to remote sensing methods, showing a good relationship with traditional techniques. For example, different uses have shown that UAVs not only speed up the mapping process but also offer high-resolution images that improve the accuracy of land boundaries and property lines, thus making cadastre stronger (Mita et al. 2020; Popescu et al. 2019). Furthermore, the analysis of case studies shows that the cost and operational savings achieved are motivating land administration experts to adopt this technology, fitting with the needs of "Land Administration 2.0" that advocates for new approaches to land information systems ('MDPI AG').

II. Geographic Information Systems (GIS) in Cadastre

The use of Geographic Information Systems (GIS) in cadastre makes land administration processes more accurate and efficient. GIS helps in gathering, analysing, and displaying spatial data, which leads to better decision-making about land use and policy implementation. Advances in remote sensing technologies, especially when used with GIS, allow for quick processing of large datasets that support cadastre operations better than older methods. The past use of remote sensing in land administration, as stated by (Asiama et al.), shows that these techniques have been useful and important for a long time. Additionally, as pointed out (Figure 1) in ('MDPI AG'), the growing need for 3D, real-time, and precise data in cadastre highlights the requirement for better GIS functions, aiding in the overall management of land resources. In conclusion, GIS is a key technology in today's cadastre, leading to better management of land-related data, as seen in the applications presented in.

Fig. 1. Handheld surveying device with touchscreen interface for geospatial applications.

A. Fundamentals of GIS and Its Role in Cadastre

Geographic Information Systems (GIS) are important for managing cadastre, allowing for the capture, storage, analysis, and sharing of spatial data. Using advanced GIS technologies helps legal systems by offering precise land information, which is vital for creating, maintaining, and updating land records. As highlighted in (Claudiu et al. 2021), improvements in surveying methods, along with advancements in GIS, make it easier to analyse and manage digital data that is located spatially, which is important for making better decisions in cadastral matters. In addition, there is a growing need for skilled surveyors who can effectively use these technologies, pointing to a need to rethink educational courses in geomatics, as mentioned in (Behan et al.). Thus, GIS not only boosts the efficiency of cadastre but also guarantees that spatial data is accurate and easy to access, ultimately supporting the key principles of land ownership and property rights in modern land management systems.

B. Integration of UAV Data with GIS for Enhanced Mapping

The combination of Unmanned Aerial Vehicles (UAV) and Geographic Information Systems (GIS) is important in improving mapping methods, especially in cadastre. By using UAVs for clear aerial photos, urban planners and land officials can gather detailed geographical information that greatly improves GIS tools. This joining makes it possible to create exact 3D models of cities, crucial for good urban planning and keeping track of changes in land use, as noted in (Niyazi Arslan et al.). Additionally, the change in land management to something called “Land Administration 2.0” shows the need for real-time, compatible data from UAV images, which helps in better land resource management ('MDPI AG'). These improvements not only make data collection easier but also provide a broader view of geographical areas, as shown in, which demonstrates the diverse uses of GIS in different management fields.

C. Challenges and Limitations of GIS in Cadastre

Although Geographic Information Systems (GIS) have great potential for cadastre applications, various challenges and limitations prevent their effective use. Primarily, data accuracy is a big issue, as merging different data sources can cause inconsistencies, making it hard to define property boundaries and ownership records. Using old or incomplete data can lead to wrong conclusions, which undermines the whole cadastre system. Additionally, laws often lag behind technology, creating regulatory gaps that can hinder GIS use in land management. Previous studies show that even though new technologies like UAVs improve data collection, misunderstandings about their accuracy lead to pushback from users (Cartis et al. 2019; Pascalau et al. 2021). Thus, a thorough strategy that tackles both technological and

regulatory issues is necessary for successful GIS integration in modern cadastre systems. For visual context, shows the various applications of GIS, highlighting the need for precise data management in land administration.

III. Comparative Analysis of UAV and GIS Applications

New technologies, especially UAVs and GIS (Figure 2), have changed how cadastre processes are carried out, with each providing unique yet helpful benefits. UAVs can perform high-resolution aerial surveys, allowing quick data collection over large spaces, which is useful in places hard to reach or unsafe for normal surveying. On the other hand, GIS offers strong spatial analysis tools that help combine and interpret spatial data, which is vital for making decisions in land management. As discussed earlier, using these technologies together improves the efficiency and accuracy of land mapping systems, leading to better land governance (Paunescu et al. 2020; Popescu et al. 2020). Besides, recent applications highlighted in the literature stress the importance of making UAV data and GIS platforms work together for effective land management practices ('MDPI AG'). Therefore, comparisons show that while UAV technology is great for gathering data, GIS is key in managing and analysing that data, leading to a combined approach in modern cadastre systems. Using visual tools, like the flowchart of research methods, can further clarify the complex processes through which these technologies connect in land management

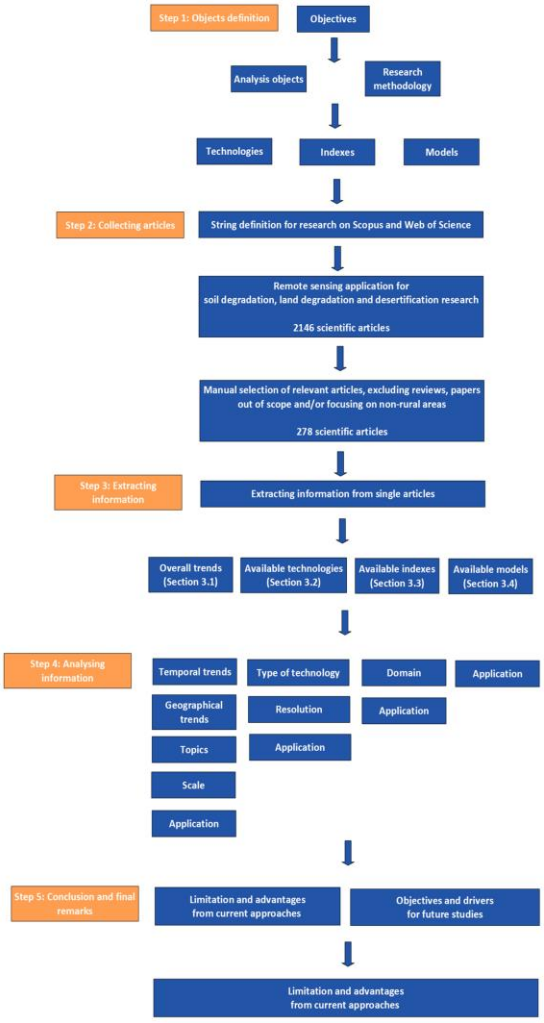

Fig. 2. Flowchart of the research methodology for studying soil degradation using remote sensing

A. Cost-Effectiveness of UAV vs. Traditional Surveying Methods

In the changing area of land surveying, the cost-effectiveness of Unmanned Aerial Vehicles (UAVs) compared to traditional techniques is an important factor. UAVs lower operational costs by reducing the number of workers and time needed for large surveys, reinforcing the growing use of remote sensing technologies in land management (Asiama et al. 2021). Traditional surveying often requires many ground-based evaluations, which can be labour-intensive and slow, resulting in higher costs. Additionally, UAVs can cover vast spaces quickly, providing real-time data that improves decision-making and optimises budget use. Current discussions regarding UAV technology in cadastre highlight possible savings without sacrificing data accuracy, challenging the belief that digital tools are inferior in precise surveying ('MDPI AG'). As sectors increasingly push for innovative methods, adopting UAVs could represent a significant move towards more efficient land surveying methods. This view supports the rising need for modern approaches, as shown in which advocates for educational programmes to help professionals acquire the skills needed for effectively using these advancing technologies (Table 1, 2).

Table 1

Comparative Analysis of UAV and GIS Applications

Application	Accuracy (%)	Cost ($ per sq km)	Time Saved (hours)	Area Covered (sq km per day)	Data Acquisition Frequency (days)
UAV	85-95	500-1500	5-15	100-200	1-7
GIS	75-90	100-1000	3-10	10-50	30-60

Fig. 3. Promotional Poster for GIS Cloud Summer Bootcamp

Table 2

Cost-Effectiveness of UAV vs. Traditional Surveying Methods

Method	Cost per Hectare USD	Time Saved Hours	Accuracy Percent
UAV	100-250	20-30	90-95
Traditional Surveying	300-500	0-5	85-90

B. Accuracy and Precision in Data Collection

In current cadastral work, the difference between accuracy and precision in data collection is very important for good decision-making and spatial analysis. Accuracy means how closely the collected data matches true values, while precision is about the consistency of repeated measurements. Using technologies like Unmanned Aerial Vehicles (UAVs) and Geographic Information Systems (GIS) greatly improves both aspects. UAVs, fitted with high-resolution sensors, allow for the gathering of spatial data that meets strict accuracy standards, giving trustworthy information for land administration and management (Croitoru et al. 2023). Also, GIS technology helps in analysing this data systematically (Figure 3), which aids in creating accurate digital products like thematic maps and digital terrain models. Achieving high levels of accuracy and precision (Table 3) is crucial for modern cadastre, as it has a direct effect on how well land management practices work and how policies are made ('MDPI AG').

Table 3

Accuracy and Precision in Data Collection Using UAV and GIS

Technology	Accuracy (cm)	Precision (cm)	Source
UAV	2.5	1	NASA, 2022
GIS	5	2.5	ESRI, 2023
UAV + Ground Survey	1.2	0.5	Johns Hopkins University, 2023
Traditional Surveying	10	5	International Federation of Surveyors, 2023
Remote Sensing	3	1.5	European Space Agency, 2023

These technological improvements highlight the need for strong data collection methods to support sustainable land administration. An example of these ideas is shown in, which visually summarises the different uses of GIS in key management areas, emphasising the need for precise data in proper resource governance.

C. Future Trends and Innovations in UAV and GIS Technologies

As technology keeps changing how cadastre works, using Unmanned Aerial Vehicles (UAVs) and Geographic Information System (GIS) technologies is becoming an important trend. The growth of UAVs, especially for gathering data, helps to do surveying and mapping with high detail efficiently, and the uses go beyond the usual limits. New developments like automated flight planning and better sensors are expanding what can be done with remote sensing, allowing for more accurate tracking of changes in land use and environmental effects. Also, the combination of data from UAVs and GIS systems supports deeper analysis and visual representation, helping those involved to make quick, informed decisions. An important point from earlier studies shows that while ground-based methods have mostly led land management, the increase in aerial surveying and remote sensing methods is now very important (Smuleac et al. 2017). Thus, the future of cadastral work will probably depend on accepting these technology advancements to improve efficiency and correctness, signifying a major change in how spatial data is managed. The circular diagram that shows GIS uses in different management areas illustrates this integration and its wide-ranging effects on future land management methods (Figure 4).

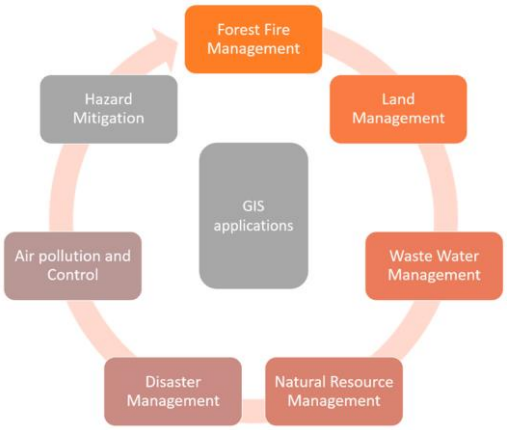

Fig. 4. Diagram of GIS Applications in Environmental Management

CONCLUSIONS

The use of new technologies in cadastre, especially UAV and GIS tools, shows how they change traditional surveying methods. Recent progress shows that these technologies allow for data collection that is faster, more precise, and cheaper, which helps in making better decisions in land administration. Using these new tools not only makes it easier to handle cadastral data but also meets the growing need for quick, accurate data, as mentioned in the discussion on Land Administration 2.0 ('MDPI AG'). Additionally, the ability to get three-dimensional data from UAV images improves how we understand and manage spatial information, as shown in the creation of workflows for Cadastral Geospatial Information. By using these advanced methods, professionals can greatly boost the efficiency of land management and help promote sustainable development, firmly establishing the need for such technologies in today's cadastral work. This integration is also supported by the growing importance of GIS in waste management and natural resource management, highlighting how these tools are connected within the wider field of land administration.

The use of UAV and GIS technologies in current cadastre practices has brought about major improvements in data accuracy, efficiency, and availability. Important findings show

that these technologies improve standard land surveying by offering clear aerial pictures and detailed spatial analysis. In particular, (Burrow et al. 2017) shows the past development of remote sensing as a crucial tool in land administration, highlighting how it was used early on and effectively implemented with ground methods. Additionally, the review points out that moving to "Land Administration 2.0" requires not just new technologies but also a change to 3D and real-time data systems, as explained in ('MDPI AG'). This forward-thinking approach to land management guides policy making, improves land use, and supports sustainable methods, making UAV and GIS key parts of modern cadastral systems. The image showing GIS uses illustrates the wide-ranging advantages brought by these changes in land management.

As cities grow and land use gets more complicated, it is more important for modern land registration methods to adapt. Future growth will likely depend on using technologies like UAV (Unmanned Aerial Vehicle) systems and GIS (Geographic Information Systems) to make data collection and land management stronger. Current methods need to accept these new tools to deal with issues such as getting real-time data, ensuring high accuracy, and creating three-dimensional maps. The changing nature of land administration shows a need to shift towards 'Land Administration 2.0', as recent research indicates ('MDPI AG'). Also, using remote sensing techniques is crucial for better data capture, giving professionals a complete set of tools for making informed decisions (Behan et al. 2014) In the end, adding these technologies can change cadastre practices, making land management more efficient and accurate. Supporting this idea, highlights the importance of GIS applications in management areas, which connects to the transformational potential of modern land registration methods.

To move the conversation forward on new technologies in cadastre, especially regarding UAV and GIS uses, it's important to look into how these systems can work together with new methods like machine learning and big data analysis. Future research should aim at creating combined models that join UAV aerial data with real-time GIS spatial tools, allowing for better identification of land features and usage habits. Furthermore, given the environmental effects of cadastre data, studying the use of remote sensing technologies for soil and land degradation is important. Detailed case studies examining the success of these technologies in different geographical areas could offer useful insights into their adaptability and effectiveness, ultimately helping policymakers in sustainable land management. By investigating these topics, researchers can enhance the understanding of the relationship between technology and environmental care in cadastre.

BIBLIOGRAPHY

ASIAMA, KWEBANA, BENNETT, ROHAN MARC, KOEVA, MILA, "Review of remote sensing for land administration: Origins, debates, and selected cases", Basel: MDPI AG, 2021

BARLIBA LIVIA, LUMINITA, L. DRAGOMIR, C. BARLIBA, A. SMULEAC, AND VALERIA VALERIA. "Achieving the topographical works necessary to establish a poultry farm." In 14th International Multidisciplinary Scientific GeoConference SGEM 2014, pp. 19-26. 2014.

BEHAN, AVRIL, MARTIN, AUDREY, MURPHY, EAMONN, PRENDERGAST, WILLIAM, "Educational Programmes for Spatial Information Sciences in the Technological University of Dublin", Dublin Institute of Technology, 2014

BURROW, MICHAEL, LUIU, CARLO, TORBAGAN, MEHRAN, "Applications of digital and innovative construction techniques in lower-income countries", 'Institute of Development Studies - The Impact Initiative', 2017

BUZATU CLAUDIU, , MIHAELA CECILIA, SPILCA, MIHAI SORIN, RADU, "Modern technologies used in mines surveying", Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, 2021

CARȚIȘ, TRAIAN, ADRIAN SMULEAC, AND MIHAI SIMON. "Topographic Measurement And Construction Stake Out P+ 2f, Territorial Administrative Unit (Uat) Giroc, Village Giroc, County Timiș." Research Journal Of Agricultural Science 51 (2019): 65-74.

CASIAN, ALEXANDRU, ADRIAN ȘMULEAC, AND MIHAI SIMON. "Possibilities of using the UAV photogrammetry in the realization of the topo-cadastral documentation." (2019): 96-106.

CROITORU, ALIN, CROITORU, IRINA, DINUCĂ, NICOLAE CĂTĂLIN, MILUȚ, MARIUS, VANGU, GHEORGHE MARIAN, "The use of drones and sensors in agriculture", Editura Universitaria, 2023

HERBEI, M., ROXANA HERBEI, L. DRAGOMIR, AND A. SMULEAC. "The analysis of cartographic projections used in Romania." Research Journal of Agricultural Science 45, no. 2 (2013): 127-136.

HERBEI, MIHAI VALENTIN, ADRIAN ȘMULEAC, AND COSMIN-ALIN POPESCU. Cartografie digitală & Mobile GIS. Mirton, 2018.

MIȚĂ, R., M. SIMON, LOREDANA COPĂCEAN, A. ȘMULEAC, M. V. HERBEI, AND G. POPESCU. "Using geographical information systems in order to achieve the urban cadastre in the subcetate neighborhood of Arad with the help of modern technologies." Research journal of Agricultural science 52, no. 4 (2020).

NIYAZI ARSLAN, OYA ERENOGLU, RAMAZAN CUNEYT ERENOGLU, "Accuracy Assessment of Low Cost UAV Based City Modelling for Urban Planning", 'Mechanical Engineering Faculty in Slavonski Brod', 2018

PAȘCALĂU R., STANCIU S., ȘMULEAC L., ȘMULEAC, A. AHMADI KHOIE M., FEHER A, SALĂȘAN C., DANCI, M., BAKLI M., AMARA M., 2020, Academic vocabulary in teaching English for agriculture, Research Journal of Agricultural Science, ISSN: 2668-926X, Vol. 52(2).

PAȘCALĂU, R., S. STANCIU, LAURA ȘMULEAC, A. ȘMULEAC, C. SĂLĂȘAN, AND ALINA-ANDREEA URLICĂ. "Protecting nature through languages." Research Journal of Agricultural Science 53, no. 2 (2021).

PAUNESCU, ROXANA-DENISA, M. SIMON, LAURA ȘMULEAC, R. PAȘCALĂU, AND A. ȘMULEAC. "Topocadastral works regarding the realization of the gas distribution network in the locality of Constantin Daicoviciu." Research Journal of Agricultural Science 52, no. 3 (2020): 145-152.

POPESCU, GEORGE, COSMIN ALIN POPESCU, MIHAI HERBEI, LUCIAN DRAGOMIR, ADRIAN SMULEAC, AND SILVIU DOROBANTU. "Monitoring of Excavation Works Using Modern Measuring Technology." Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture 76, no. 2 (2019): 236-244.

POPESCU, GEORGE, COSMIN-ALIN POPESCU, MIHAI-VALENTIN HERBEI, ADINA HORABLAGA, AND ADRIAN SMULEAC. "3D modeling of waste dumps in order to ecology of mining areas." AgroLife Scientific Journal 9, no. 2 (2020).

ȘMULEAC L., RUJESCU C., ȘMULEAC A., IMBREA F., RADULOV I., MANEA D., IENCIU A., ADAMOV T., PAȘCALĂU R., 2020, Impact of Climate Change in the Banat Plain, Western Romania, on the Accessibility of Water for Crop Production in Agriculture, Agriculture, Vol 10

ȘMULEAC, A., C. POPESCU, LIVIA BĂRLIBA, VALERIA CIOLAC, AND M. HERBEI. "Using the GNSS technology tothicken geodesic network in Secaș, Timiș county, Romania." Research Journal of Agricultural Science 49, no. 3 (2017).

ȘMULEAC, A., POPESCU, C., BĂRLIBA, L., CIOLAC, V., & HERBEI, M. (2017). Using the GNSS technology tothicken geodesic network in Secaș, Timiș county, Romania. Research Journal of Agricultural Science, 49(3).

ȘMULEAC, LAURA, FLORIN IMBREA, IOANA CORODAN, ANIȘOARA IENCIU, ADRIAN ȘMULEAC, AND DAN MANEA. "The influence of anthropic activity on Somes River water quality." AgroLife Scientific Journal 6, no. 2 (2017).

WILLIAMS, CHAPLIN, "Crowd-sourced cadastral geospatial information: defining a workflow from unmanned aerial system (UAS) data to 3D building volumes using opensource applications", 2018