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TECHNICAL METHODOLOGIES FOR CADASTRAL PLAN DEVELOPMENT USING GNSS AND UAV TECHNOLOGIES: A CASE STUDY IN PIETROASA, ROMANIA

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Abstract

The realization of the cadastral plan for administrative territorial units, involves as field activities, the identification of owners and neighbors, the identification and spatial positioning of plots, and the verification of the category of use. The case study was carried out within the administrative territorial unit Pietroasa, Bihor County, and aims to analyze the technical aspects related to the realization of the cadastral plan of cadastral sector 31. For the identification of the cadastral sector and the plots, a drone flight was carried out, thus obtaining an orthophotogram of the respective location. The spatial positioning of the detailed topographic points related to the plots was carried out with GNSS technology, GPS system, using the RTK method, based on the GNSS station Beiuș. The reporting of the coordinates of the characteristic points of detail, and the preparation of the cadastral plan in digital format was done with the program MapSys 9.0. In the end, a total of 652 plots were reported in cadastral sector 31. By using the above-mentioned logistics and working methods, a high degree of automation and superior positioning accuracy was achieved.

Key words: *cadastral plan, cadastral sector, GNSS technology, GPS system,* plots*, land use categories.*

INTRODUCTION

In Romania, the general cadastre is established by Law No. 7/1996 on Real Estate Cadastre and Advertising. It represents a unified, mandatory system for the systematic registration and inventory of real estate assets nationwide, addressing their legal, quantitative, and qualitative aspects (Mihăilă et al., 1995).

The International Federation of Geodesy (FIG) defines cadastre as "an updated land information system based on cadastral parcels and records of land interests" (Ercan, 2023). Cadastre can also be defined as a creation of man, namely "the effect of his relationship with the land" (Comparetti & Raimondi, 2019).

The cadastre plays a fundamental role in identifying, documenting, and graphically representing properties in official registers and cadastral maps, serving as legal proof of ownership (Boș & Iacobescu, 2009; Nistor et al., 2012).

In the European Union (EU), there are currently two original models of cadastral system, related to land registration systems. As a result, there is the central model, in which the cadastre appears as a graphic basis (map) of land registration (land registry), so that physical changes must be reflected in the cadastre, and legal changes in the land registry, by maintaining a perfect parallelism, and respectively a Latin model, in which it appears only as a taxation instrument, useful for collecting land taxes. Knowledge of the cadastral models related to the EU Member States is a fundamental condition for the harmonisation of the land cadastre at EU level, as an inventory for environmental, social, economic, legal and fiscal purposes (Comparetti & Raimondi, 2019).

The National Agency for Cadastre and Real Estate Advertising (A.N.C.P.I.) is responsible for updating the national land fund records. This includes registering real estate transactions, creating new properties, modifying existing ones, and updating cadastral data in collaboration with local authorities, licensed service providers, public notaries, and survey professionals (https://lege5.ro/Gratuit/g44dcmjsge/...).

Accurate records support territorial planning, urban and r ural development, environmental protection, and sustainable natural resource management, while also enhancing land tenure security and investment stability (Boș & Iacobescu, 2009).

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Systematic registration of property rights and cadastre in Romania is free of charge for property owners. The financing is full and comes from three different sources: from ANCPI's own revenues worth approximately 900 million euros, non-reimbursable funds from the European Union, worth approximately 312 million euros, and respectively from allocations from the budget of the administrative-territorial units, through co-financing (Bancioiu & Kovacs, 2022).

Systematic registration relies on field measurements using established surveying methods to generate parcel and cadastral plans. These activities are carried out ex officio, free of charge, and apply to both public and private property, irrespective of legal ownership status, as per Article 918 of the Civil Code. All measurements conform to applicable technical norms and legal requirements (https://lege5.ro/Gratuit/g44dcmjsge/...).

As of January 31, 2025, systematic registration had been completed in 298 administrative-territorial units (U.A.T.s), while in 1,773 U.A.T.s - approximately 64% of the national total-work was still underway (https://www.ancpi.ro/pnccf/documente/H3.).

Key elements of the cadastre include (Badea, 2005; Grecea, 2007, Novac, 2006):

- Cadastral sector: a subdivision of a commune or city, encompassing multiple plots, typically 50-200 ha in plains and 20-100 ha in hilly areas;
- Building: one or more adjacent parcels, with or without constructions, under single ownership;
- Parcel: A land area with a single use category;
- Land register: the official document recording ownership, use rights, area, encumbrances, and other legal attributes;
- Agricultural register: contains data on the ownership and use of agricultural lands, supporting land-use planning and agricultural policy;
- Basic cadastral plan: derived from the topographic plan and enhanced with cadastral attributes, showing location, surface, and boundaries of properties;
- Parcel plan: graphical representation of properties within a cadastral sector, verified by the County Cadastre Office and integrated into the cadastral plan (https://topogalati.ro/ce-este-planul-parcelar/).
- Land use category: a coded cadastral attribute used to determine property taxation.

The systematic registration of properties in Romania, within the framework of the National Cadastre and Real Estate Advertising Program, successfully requires the unitary integration of legal, institutional and geospatial components, for the optimal achievement of transparent and responsible land governance, efficient management of all resources and sustainable rural development (Gherheș et al., 2025).

Although a legal and technical framework exists, the lack of standardized software and methods for creating digital cadastral plans has caused inconsistencies in data handling across counties. National norms offer guidance, but their varied implementation reveals a need for unified standards. At present, research on standardizing digital cadastral plans and systematic registration at the ATU level is scarce, highlighting the need for further studies to improve and align cadastral processes nationally.

Registration in the Land Book through the Systematic Cadastre of real estate, although some difficulties have been reported in some areas, represents an efficient solution and an alternative to the Sporadic Cadastre, which was carried out in the past at the national level. Consequently, field work and working time will be optimized, and the determination of the areas of plots in the cadastral sectors will be achieved with high accuracy (Pop et al., 2021).

MATERIALS AND METHODS

Study location

The case study was carried out within the Pietroasa territorial administrative unit (UAT), Bihor County (Figure 1).

The town of Pietroasa is situated in the meadow zone at the point where the Crișul Pietros River emerges between the surrounding hills, partially extending to the base of the slope along the Bălătrucului Valley.

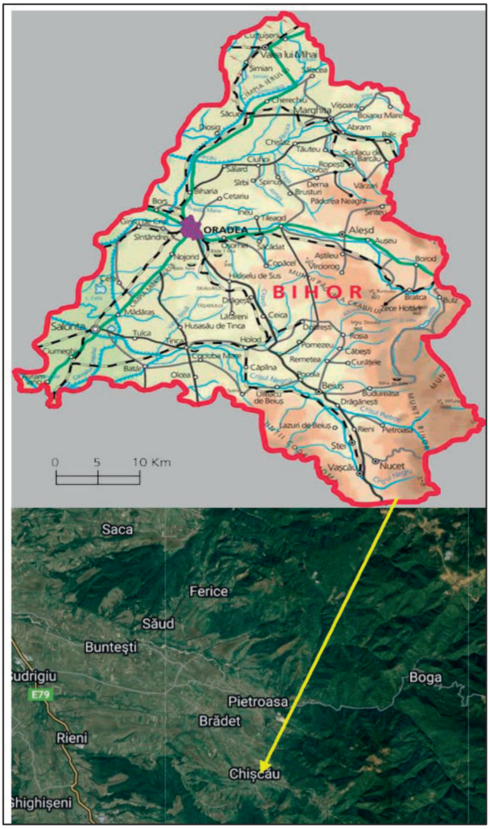

Figure 1. Location of research (https://provinciacrisana.wordpress.com/2017/10/06/scurta-descriere-a-judetului-bihor-provincia-crisana/; http://www.searchromania.net/harta_harti/bihor/pietr./)

The Crișul Pietros flows through the town from east to west, receiving three left-side tributaries - Lazului Valley, Bălătrucului Valley, and Mare Valley. On the right side, within the built-up area, it is joined by the Bălăcel Valley and a smaller, unnamed tributary (General Urban Plan, 2008).

The primary objectives of this case study are to investigate and analyze the specific characteristics and procedural aspects of creating the parcel plan and, subsequently, the cadastral plan for cadastral sector 31 in UAT Pietroasa, Bihor County. This is examined within the broader framework of systematic property registration in the integrated cadastre and land registry system, particularly within the built-up area and non-collectivized zones.

According to data as of January 31, 2025, the process of systematic registration in Bihor County had been completed in six administrative-territorial units (UATs), was ongoing in 49, and had not yet commenced in 46 (Figure 2) (https://www.ancpi.ro/pnccf/documente/H3_Lucrari). This distribution underscores the relevance of the current research in capturing the unique dynamics, implementation challenges, and progression of cadastral registration in the selected study area.

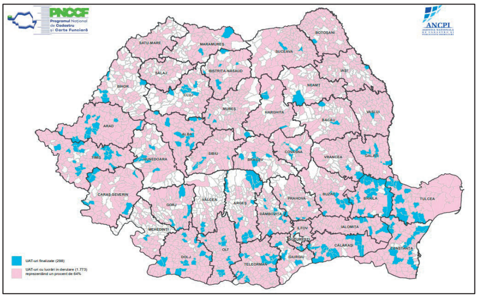

Figure 2. Status of systematic registration works of real estate at the ATU level as of 31 01 2025 (https://www.ancpi.ro/pnccf/documente/H3_Lucrari...)

The research employed a combination of methods, including bibliographic documentation, route and stationary observation, experimentation, simulation, comparison, and analytical techniques.

The bibliographic documentation involved a thorough review of specialized sources such as university courses, technical standards, scientific publications, technical projects in land surveying and cadastre, the General Urban Plan (PUG), and the agricultural register relevant to the case study area.

Field data recording

The experiment consisted of generating GNSS recordings for the spatial positioning of characteristic detail points that define the boundaries of plots and buildings (Crainic, 2024; Pica et al., 2021). This process included data processing, calculation of final coordinates within the national reference system, and the subsequent creation of both the parcel plan and the cadastral plan for cadastral sector 31, located within the Pietroasa administrative-territorial unit (A.T.U.).

To accurately identify the cadastral sector, buildings, and plots included in the plans, reference was made to the General Urban Plan

(PUG) and the coordinate inventory for the boundary points of cadastral sector 31, as provided by the Bihor County Office for Cadastre and Real Estate Advertising (OCPI).

Figure 3. Rebel FAE1718FW drone used for the work (https://fae-drones.com/2023/08/18/drona-fae-1718-fixed-wing-rebel/)

Currently, for the implementation of the National Cadastre and Land Registry Program, for the systematic registration of real estate properties, the recording and processing of the necessary data can be achieved under optimal conditions, through the successful integration of intelligent technologies, namely the Global Navigation Satellite System (GNSS) and Unmanned Aerial Vehicles (UAV) or drones (Ghergar et al., 2023).
To effectively capture, record, and analyze the attributes, features, and specific characteristics of land across different use categories, advanced techniques from geomatics - such as digital photogrammetry and satellite remote sensing - can be employed with high efficiency (Popescu et al., 2024, Tereșneu, & Tereșneu, 2023). Accordingly, an aerial survey was conducted using the Rebel FAE1718FW drone model (Figure 3), resulting in the production of an up-to-date orthophoto map of the targeted area (Figure 4).

The spatial positioning of the characteristic detail points related to the plots was carried out with GNSS technology, the GPS system, with the RTK method, using the Beiuş GNSS station as a base, and the ROMPOS system, respectively. As a result, used as rover GNSS receiver STONEX S900A IMU.

Figure 4. Orthophoto of the work area

Processing of recorded data. Programs used
Real-time data processing was carried out using the STONEX CUBE application, and the transformation of ellipsoidal coordinates into the national reference system STEREO-1970 was carried out using the TransDatRO4.01 application (Bodog et al., 2024; Crainic, 2024).
For reporting the coordinates of the detailed characteristic points, and for drawing up the parcel plan and subsequently the cadastral plan in digital format, the MapSys 10.0 program was used (Marton, 2007).
The simulation was used to obtain the final graphic products in digital format, for all the properties that were positioned and described.
The comparison was carried out at the stage of establishing the attributes of the positioned plots, having the results of the experiment and the records from the property deeds related to them.
The analysis was carried out upon completion of the experiment and the preparation of the plot plan, depending on the specifics and particularities of its elements and those from the property deeds, presented in accordance with the

legislation in force (Law on Cadastre and Real Estate Advertising no. 7/1996 updated in 2025). The case study was carried out according to the steps presented in Figure 5.

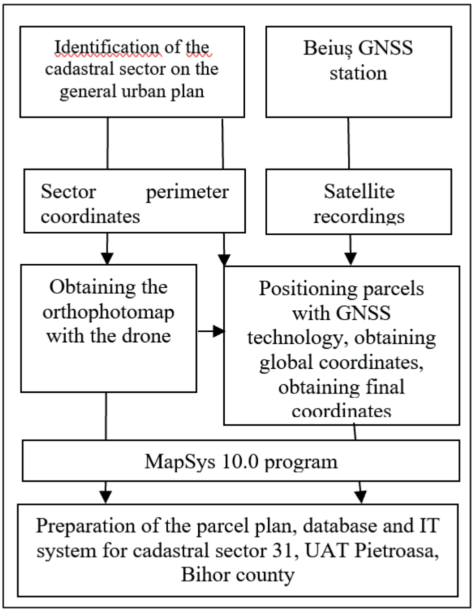

Figure 5. Sequence of stages for carrying out the case study

RESULTS AND DISCUSSIONS

In order to create the parcel plan and implicitly for the systematic registration of real estate at the level of cadastral sector 31, UAT Pietroasa, a number of 658 parcels were identified and verified on the current orthophoto map.
As a result, the use of UAV (Unmanned Aerial Vehicle) technology, by performing multiple flights, optimizes the process of preparing a topographic plan, reducing the time for recording field data and providing various details necessary for architectural planning, both in the studied area and in neighboring areas, compared to other methods, which require more time and provide fewer details, with similar precision (Naș et al., 2023).
As a result, the coordinates for a total of 5404 characteristic topographic points, necessary for the delimitation and positioning of the identified plots, were positioned with GNSS technology and determined in the national reference system STEREO-1970 (in 2D space).
The coordinates of the points are characterized by high precision, since the transformation into the national reference system was performed with the updated transformation parameters for the work area.
The inventory of the coordinates of the detailed characteristic topographic points is presented in a file with the extension txt., configured with four columns, namely the point number, the X coordinate, the Y coordinate and the layer into which it will be imported into the MapSys 10.0 program (Table 1). To obtain the parcel plan and subsequently the cadastral plan, the coordinates of the topographic points were graphically reported with the MapSys 10.0 program.
The way to work with this program is presented suggestively in Figure 6.

Table 1. Extract from the inventory of the coordinates of the detailed topographic points, in the national reference system

No. crt.	X(m)	Y(m)	Layer
1	568496.138	310959.577	1
2	568502.816	310944.096	1
3	568505.244	310939.163	1
4	568521.033	310927.350	1
5	568514.632	310890.788	1
6	568532.234	310862.699	1
7	568542.175	310857.842	1
8	568569.975	310853.287	1
9	568594.639	310864.433	1
10	568643.367	310879.990	1
11	568666.170	310838.515	1
12	568667.722	310824.888	1
13	568674.932	310821.094	1
14	568692.386	310829.368	1
15	568696.655	310827.755	1
16	568699.975	310818.269	1

Analysis of the data presented in Figure 6 reveals that the workflow for generating the cadastral plan using the MapSys 10.0 software follows a logical and well-structured sequence, dictated by the program's internal algorithms and marked by a high degree of automation.
At the initiation of a new project (work-job), the working parameters and necessary metadata were defined to support the specific requirements of the cadastral task. Consequently, the datum elements corresponding to the national land fund were integrated into the system (Figure 7).

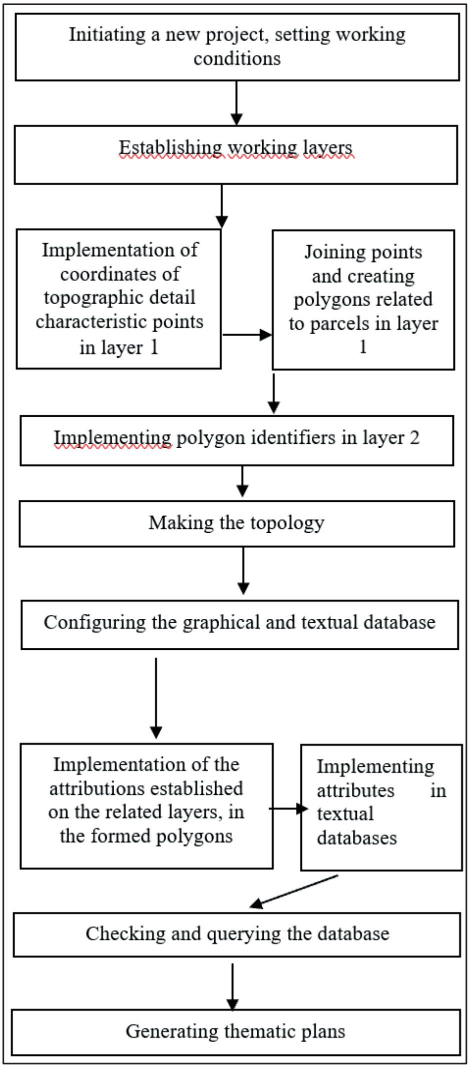

Figure 6. Working steps with the MapSys 10.0 program, to obtain the cadastral plan

The creation and organization of working layers were structured hierarchically, aligned with the operational algorithms of the MapSys software and the logical sequence of inputting collected spatial and attribute data. This hierarchical arrangement ensured consistency in data processing and efficient integration of graphical and textual components.

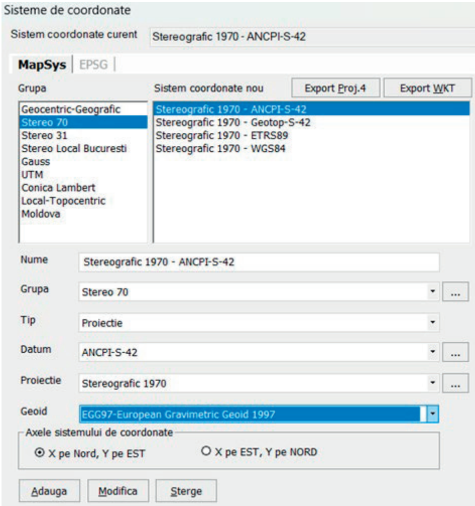

Figure 7. Implementation of the elements of the datum related to the national land fund

The layers were organized as follows:
- Layer 1 - coordinates of detailed topographic points and subsequent creation of plot (real estate) polygons.
- Layer 2 - cadastral identifiers, linking graphical data with the textual database, supporting topology generation and configuration of the primary textual dataset.
- Layer 3 - characteristic points marking the boundaries of cadastral sector 31.
- Layer 4 - text annotation indicating the cadastral sector number under investigation.
- Layer 5 - planimetric coordinates of electric poles located within the plots.
- Layer 6 - textual attributes referencing property deeds and existing topographic numbers associated with positioned plots.
- Layer 7 - records of possession minutes and corresponding property titles.
- Layer 8 - documents confirming possession and actual land use by property holders.
- Layer 9 - land registry extract data available at the time of the study.
- Layer 10 - existing data on newly assigned cadastral numbers as of the study date.
- Layer 11 - data regarding cadastral numbers established by final court decisions.

- Layer 12 - surface discrepancies, where applicable.
- Layer 13 - information on plots with unidentified owners.
- Layer 14 - data concerning areas designated as land reserves.
- Layer 15 - land use categories attributed to the studied plots.
- Layer 16 - coordinates of localities adjacent to cadastral sector 31 in U.A.T. Pietroasa, Bihor County.

The initial stage of the workflow involved importing the planimetric coordinates of the detailed characteristic points corresponding to the parcels within cadastral sector 31 into Layer 1 (Figure 8). Subsequently, within the same layer, a total of 5,404 characteristic topographic points were connected, resulting in the generation of 658 parcel polygons representing the spatial configuration of the positioned plots (Figure 9).

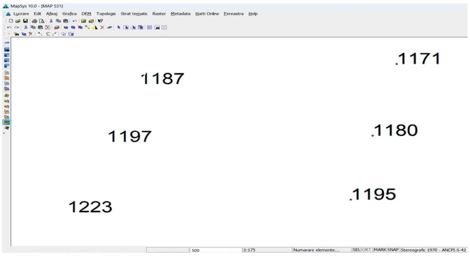

Figure 8. Implementation of feature points

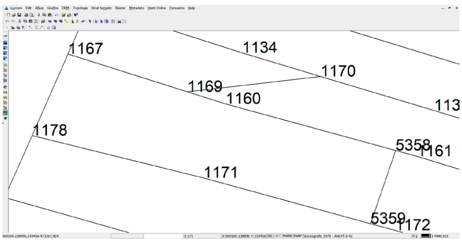

Figure 9. Obtaining polygons

The overlay of the generated parcel polygons onto the newly created orthophotomap enabled optimal verification of the accuracy and precision of the digital graphic representations (Figure 10).

A critical stage in the development of both the parcel plan and the subsequent cadastral plan involved the implementation of cadastral identifiers and the marking of individual parcels. This process commenced in the northwestern part of the locality and progressed toward the southwest, following a systematic spatial logic.

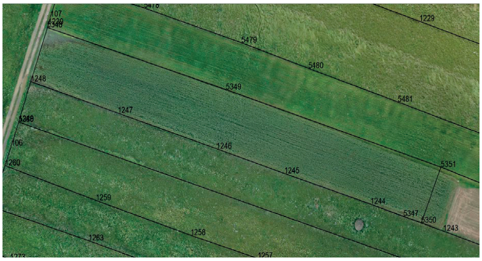
Figure 10. Overlaying polygons on the orthophoto plane

This step was carried out using the cadastral number creation/digitization function, which involved assigning a unique identifier to each polygon (Figure 11). These identifiers establish a direct and exclusive link between each polygon in the graphical database and its corresponding entry in the textual database, ensuring data consistency and integration (Marton, 2007).

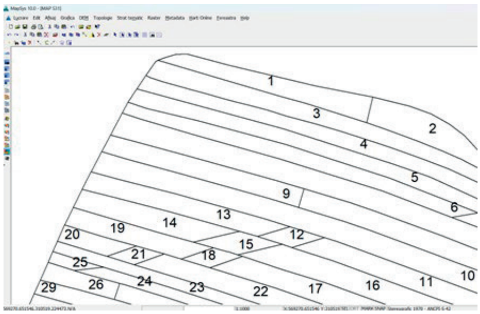

Figure 11. Implementation of cadastral identifiers for each polygon obtained

Verification of non-closure errors in the polygons representing the positioned parcels, the generation of the primary Geographic Information System (GIS) database, and the execution of operations on spatially referenced objects were performed using the Topology menu within the software.

Analysis of the data presented in Figure 12 confirms the absence of non-closure errors in the polygons generated. Additionally, it verifies that the total number of areas computed using the analytical method matches the total number of polygons. The cumulative area of cadastral

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sector 31 was determined to be 984,546.153 m², equivalent to 98.45 hectares.

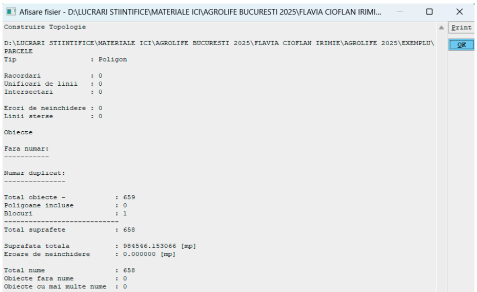
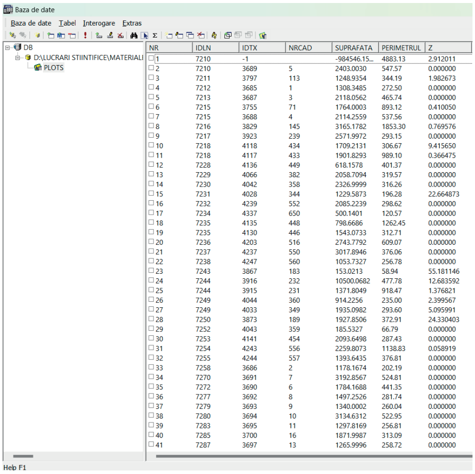


Figure 12. Topology creation

Upon completion of the topology creation process, the primary database (databank) was automatically generated for the polygons (plots) that had been graphically represented in Layer 1 (Figure 13).



NR	IDLN	IDTX	NRCAD	SUPRAFATA	PERIMETRUL	Z
1	7210	-1		-984546.15...	4883.13	2.912011
2	7210	3689	5	2403.0030	547.57	0.000000
3	7211	3797	113	1248.9354	344.19	1.982673
4	7212	3685	1	1308.3485	272.50	0.000000
5	7213	3687	3	2118.0562	465.74	0.000000
6	7215	3755	71	1764.0003	893.12	0.410050
7	7215	3688	4	2114.2559	537.56	0.000000
8	7216	3829	145	3165.1782	1853.30	0.769576
9	7217	3923	239	2571.9972	293.15	0.000000
10	7218	4118	434	1709.2131	306.67	9.415650
11	7218	4117	433	1901.8293	989.10	0.366475
12	7228	4136	449	618.1578	401.37	0.000000
13	7229	4066	382	2058.7094	319.57	0.000000
14	7230	4042	358	2326.9999	316.26	0.000000
15	7231	4028	344	1229.5873	196.28	22.664873
16	7232	4239	552	2085.2239	298.62	0.000000
17	7234	4337	650	500.1401	120.57	0.000000
18	7235	4135	448	798.6686	1262.45	0.000000
19	7235	4130	446	1543.0733	312.71	0.000000
20	7236	4203	516	2743.7792	609.07	0.000000
21	7237	4237	550	3017.8946	376.06	0.000000
22	7238	4247	560	1053.7327	256.78	0.000000
23	7243	3867	183	153.0213	58.94	55.181146
24	7244	3916	232	10500.0682	477.78	12.683592
25	7244	3915	231	1371.8049	918.47	1.376821
26	7249	4044	360	914.2256	235.00	2.399567
27	7249	4033	349	1935.0982	293.60	5.095991
28	7250	3873	189	1927.8506	372.91	24.330403
29	7252	4043	359	185.5327	66.79	0.000000
30	7253	4141	454	2093.6498	287.43	0.000000
31	7254	4243	556	2259.8073	1138.83	0.058919
32	7255	4244	557	1393.6435	376.81	0.000000
33	7258	3686	2	1178.1674	202.19	0.000000
34	7270	3691	7	3192.8567	524.81	0.000000
35	7272	3690	6	1784.1688	441.35	0.000000
36	7277	3692	8	1497.2526	281.74	0.000000
37	7279	3693	9	1340.0002	260.04	0.000000
38	7280	3694	10	3134.6312	522.95	0.000000
39	7283	3695	11	1297.8169	256.81	0.000000
40	7285	3700	16	1871.9987	313.09	0.000000
41	7287	3697	13	1265.9996	258.72	0.000000

Figure 13. Generation of the primary database related to the polygons (parcels) that were graphically reported in layer 1

To gather all attributes required for the development of the parcel plan and, subsequently, the cadastral plan, the database was modified and configured accordingly (Figure 14). The necessary columns were implemented in alignment with the layer structure defined during the initial project configuration.

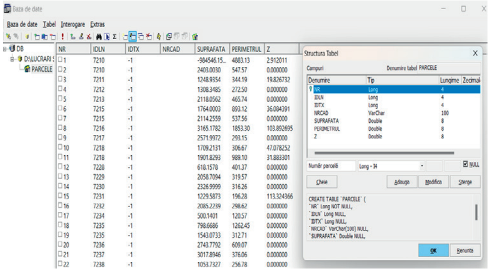


Figure 14. Primary database configuration, depending on the way the layers are organized and the implementation of the established attributes related to the starts

The implemented attributes were assigned to specific layers as follows:
- Layer 3: boundary of the cadastral sector;
- Layer 4: cadastral sector number;
- Layer 5: locations of concrete electric poles;
- Layer 6: property deeds with associated topographic numbers;
- Layer 7: minutes of taking possession, with ownership titles pending issuance as of the study date;
- Layer 8: certificates of actual land use, issued by Pietroasa City Hall based on entries in the agricultural register;
- Layer 9: land register extracts available at the time of the study, confirming property rights based on deeds or converted old registry sheets;
- Layer 10: newly assigned cadastral numbers;
- Layer 11: cadastral numbers granted through final court decisions.

The various documents used to establish ownership or possession rights, which formed the basis for the creation of the parcel plan, are summarized in Figure 15 as percentage distributions. These documents include:
- 254 certificates of actual land use;
- 237 property deeds with topographic numbers;
- 119 land register extracts;
- 30 minutes of taking possession;
- 11 new cadastral numbers.

As illustrated in Figure 15, the largest proportion of documentation consists of certificates of actual use (39%), followed by property deeds with topographic numbers (36%), existing land register extracts (18%), minutes of possession (5%), and new cadastral numbers (2%).

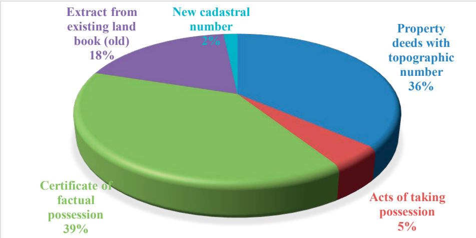


Figure 15. Percentage of documents attesting to the ownership right over the positioned and studied plots

Another important stage was represented by the verification of the areas of the polygons related to the plots, with those in the documents certifying ownership, or with the areas in the official records, respectively with the uses.
Currently, there is a possibility that the changes that are necessary to correct errors in parcels (real estate) can be made efficiently by preparing digital vector parcel plans, only for the respective area, based on accurate measurements, with modern geospatial technologies. As a result, in such situations, it will not be necessary to redo the entire parcel plan and subsequently the cadastral plan, for the entire respective sector (Kyseľ & Hudecová, 2022).
As a result, in layer 12, a number of 13 corrections were implemented for the area of 13 plots, for which it was necessary to reposition the boundaries, due to the differences between the area of the identified and positioned plots and the area in the property documents, respectively.
Also, in layer 13, a number of 6 observations were implemented for 6 plots, with a total area of 6851 m^2, for which the owners were not identified. Finally, in layer 14, a number of 3 plots were implemented, with a total area of 1007 m^2, which were considered as a reserve.
Resolving inconsistencies between the cadastral map in analog format and the cadastral register can be solved by obtaining new parcel plans and cadastral plans, respectively, through vectorization. Consequently, computer processing does not guarantee quality if it is not carried out professionally and conscientiously, and the inadequate maintenance of cadastral maps has facilitated the constant presence of inconsistencies between the two entities mentioned (Roić et al., 2021).
After clarifying the situation of the plots' areas reported graphically, the land use category for the studied buildings was implemented in layer 15. According to the results presented in Figure 16, 651 plots have the arable land use category (A), and 4 plots have the exploitation road use category (Er).

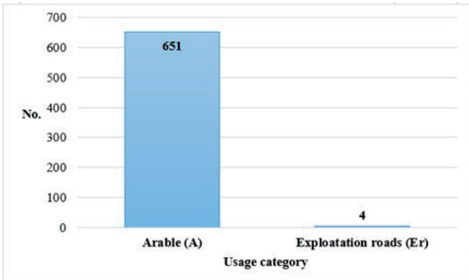


Figure 16. Representation of the number of land use categories for cadastral sector 31 Pietroasa

The land use categories were identified based on ownership documents and official records, with the following distribution:
- 651 parcels classified as arable land (A);
- 4 parcels identified as exploitation roads (Er).
Attributes corresponding to Layers 3 through 16 were incorporated into the database using the Attribute Collection menu. Through this process, the values extracted from text elements located within the topological objects of the active layer were systematically loaded into the respective database fields of the current topological layer.
The updated database containing all necessary attributes for the creation of the parcel plan and, subsequently, the cadastral plan, can be efficiently accessed and managed as needed. A representative extract from the parcel plan and the associated database is presented in Figure 17.

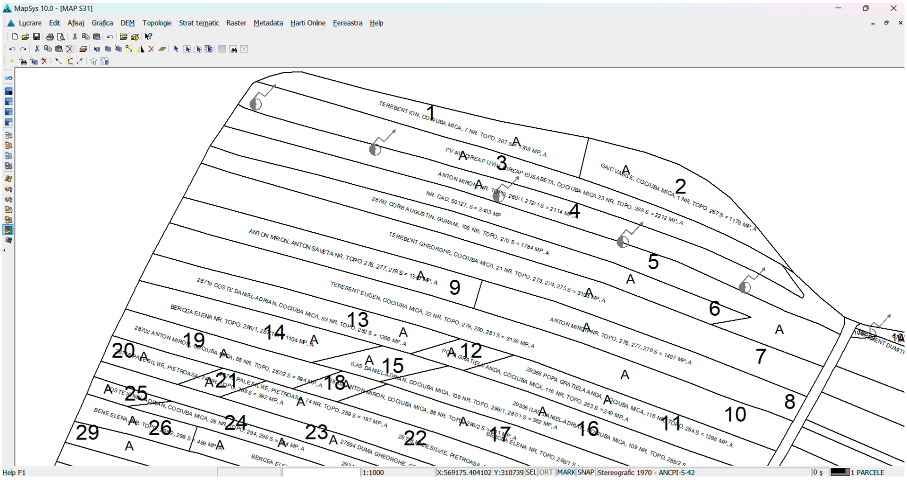


Figure 17. Extract from the parcel plan for cadastral sector 31, UAT Pietroasa, Bihor County with all attributes activated

The MapSys 10.0 software enabled efficient graphical input of contour point coordinates and supported the creation of both the parcel plan and its associated database. The platform allows for direct adjustments based on verified ownership documents. In cases where discrepancies existed between calculated parcel areas and legal records, boundaries were corrected within the software. Revised coordinates were exported as .txt files and transferred to a dual-frequency GNSS receiver for precise field repositioning.

The finalized parcel plan and database were submitted in digital format to the Bihor County Office for Cadastre and Real Estate Advertising (OCPI) for cadastral number assignment and integration into the national land registry system.

The work of registering real estate in the Systematic Cadastre in Romania, performed by the private sector, is perceived as qualitative or predominantly qualitative, based on the verifications carried out by the county Cadastre and Real Estate Advertising Offices (OCPI). Consequently, three elements of the quality of the work carried out by the private sector were highlighted, which need to be optimized, namely credibility, reliability of the service and the level of competence of the human resource (Păunescu et al., 2023).

Field positioning of parcel boundaries is a crucial step requiring the involvement of landowners to ensure spatial and legal accuracy. Recent studies have shown that the success factors in establishing the cadastral boundaries of parcels are the surveyor and the land owner, while paradoxically, land data (cadastral data) is the least important factor (Golob & Lisec, 2022). Consequently, the experienced and well-intentioned surveyor can effectively manage the issues related to cadastral boundaries, especially for lands with unidentified boundaries, which are frequently the subject of possible litigation, which can have a negative impact on cadastral recording activities.

Surveying activities included GNSS-based positioning of characteristic points, enhanced through RTK (Real-Time Kinematic) positioning with data from the Beiuș GNSS permanent station via the ROMPOS service, ensuring high precision.

Final coordinates referenced to the national geodetic system enhanced the accuracy of the digital parcel plan. Legal documents were used to resolve discrepancies between measured and recorded areas.

The cadastral database for Sector 31 was configured under optimal conditions, adapted to the specific requirements of systematic registration. Overall, the use of MapSys 10.0 proved effective in producing high-quality digital outputs - parcel plans, cadastral plans, integrated databases, and thematic maps - critical tools for modern cadastral operations.

From the synthetic analysis of the implementation of the National Systematic Land

Cadastre Program in Romania, by some specialists, it was concluded that it was not designed as an approach fit for purpose. Consequently, there are a number of suggestions that the transition to such a system would optimize the systematic registration process. Also, high standards of precision without flexibility, the use of large-scale field measurements or the lack of provisions for improving and updating the system, are considered factors that significantly delay this process (Păunescu et al., 2022).

Currently, cadastral systems that manage the people-land relationship have evolved into a multifunctional form, supporting various land activities. As a result, it has become necessary to modernize traditional land administration systems and cadastral systems in order to effectively manage the people-land relationship. Consequently, the interest in promoting 3D cadastre is increased, while the cadastre of public right restrictions and the disaster-responsive cadastre are the least promoted (Uşak et al., 2024).

Current research on the possibilities of implementing 3D cadastre shows that the registration of objects for its implementation involves the use of data from various sources, namely laser scanning measurements and technical documentation (Grzelka et al., 2024), as well as other additional data, as appropriate.

CONCLUSIONS

This study highlights the effectiveness of integrating GNSS and UAV technologies with specialized GIS software (MapSys 10.0) in the systematic development of cadastral plans, using Cadastral Sector 31 in Pietroasa, Romania, as a case study. The approach demonstrated high precision in spatial data acquisition and efficient data processing, providing a model for similar cadastral operations in non-collectivized, rural settings.

Key insights include the operational benefits of combining RTK positioning with orthophotomap overlays for boundary verification, and the flexibility of digital workflows in updating parcel attributes based on legal documents. The involvement of landowners verifying plot boundaries was identified as a critical factor for accurate cadastral representation.

Limitations of the study include the reliance on the completeness and accuracy of historical land documents, and challenges in identifying owners for certain plots. Additionally, software-specific constraints in data structuring may affect standardization across regions if not uniformly implemented.

Practical applications of this workflow extend to national cadastral programs, especially in areas undergoing systematic registration. The integration of UAV, GNSS, and GIS technologies offers a scalable, cost-effective solution that can accelerate cadastral mapping efforts and enhance land administration services.

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REFERENCES

Badea, G. (2005). *General Cadastre*. Conspress Publishing House Bucharest, Romania.

Bancioiu, R., & Kovacs, L. (2022). The Systematic Registration of Property Law and Cadastre on the Territory in Romania: Discussing a Case Study. *Nova Geod. 2*(2), 28. https://doi.org/10.55779/ng2228.

Bodog, M. F., Șchiopu, E. C., Crainic, G. C., & Lazăr, A. N. (2024). Assessment of contamination degree of oil residues on a former agricultural site. *Journal of Agricultural Science and Technology A, 14*, 67–82. https://doi.org/10.17265/2161-6256/2024.02.003.

Boș, N., & Iacobescu, O. (2009). *Cadastre and land registry*. C.H. Beck Publishing House.

Comparetti, A., & Raimondi, S. (2019). Cadastral models in EU member states. *EQA - International Journal of Environmental Qualit,y 33*, 55-78. https://doi.org/10.6092/issn.2281-4485/8558.

Crainic, G. C., (2024). Issues related to the implementation of geomatic applications in the national forestry fund. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 13*, 794-804.

Ercan, O. (2023). Evolution of the cadastre renewal understanding in Türkiye: A fit-for-purpose renewal model proposal. *Land Use Policy, 131*. https://doi.org/10.1016/j.landusepol.2023.106755.

Ghergar, A., Madăra, R., Popescu, G., & Dragomir, L. (2023). Aplication of Modern Measurement Technologies in the Process of Sistematic Registration of Real Estate. *Res. J. Agric. Sci.*, *55*(3). ISSN: 2668-926X.

Gherheș, V., Grecea C Vilceanu., C.-B., Herban S., & Coman, C. (2025). Challenges in Systematic Property Registration in Romania: An Analytical Overview. *Land*, *14*(5), 1118. https://doi.org/10.3390/land14051118.

Golob, P., & Lisec, A. (2022). Success factors in cadastral boundary settlements based on land surveyor's opinions. *Land Use Policy, 114*, 105990. https://doi.org/10.1016/j.landusepol.2022.105990.

Grzelka, K., Pargieła, K., Jasińska, A., Warchoł, A., & Bydłosz, J. (2024). Registration of Objects for 3D Cadastre: An Integrated Approach. *Land*, *13*(12), 2070. https://doi.org/10.3390/land13122070.

Grecea, C. (2007). Cadastral system: New trends and experiences. *Journal of Geodesy and Cadastre, 7*.

Kysel, P., & Hudecová, L. (2022). Testing of a new way of cadastral maps renewal in Slovakia. *Geodetski Vestnik, 66*(4), 521-535. DOI: https://doi.org/10.15292/geodetski-vestnik.2022.04.521-535.

Marton, H. (2007). *MapSys, TopoSys - User manual*. Odorheiu Secuiesc, Romania.

Mihăilă, M., Corcodel, Gh., & Chirilov, I. (1995). *General Cadastre and Real Estate Advertising – The Basics and Component Works*. Ceres Publishing House, Bucharest, Romania.

Naș, S.M., Bondrea, M.V., Rădulescu, V.M., Gâlgău, R., Vereș, I.S., Bondrea, R., & Rădulescu, A.T. (2023). The Use of UAVs for Land Use Planning of Brownfield Regeneration Projects-Case Study: Former Brick Factory, Cluj Napoca, Romania. *Land*, *12*(2), 315. https://doi.org/10.3390/land12020315.

Nistor, Gh., Georgescu, D., & Nica, D. C. (2012). Aspects concerning the achievement of the digital cadastral plan of a road. *Buletinul Institutului Politehnic din Iași, LVIII (LXII)*(1-2), *Hidrotehnică*.

Novac, Gh. (2006). *Specialized cadastres*. Solness Publishing House, Timişoara, Romania.

Păunescu, V., Iliescu, A. I., Călin, M. C., Sălăgean, T., Kohli, D., Nap, M. E., & Șuba, E. E. (2023). A Quality Assessment of the Romanian National Program of Systematic Land Registration the Point of View of Local Cadastral Offices Directors. *Survey Review*, *56*(396), 284–299. https://doi.org/10.1080/00396265.2023.2233825.

Păunescu, V., Kohli, D., Iliescu, A. I, Nap, M. E., Șuba, E. E., & Sălăgean, T. (2022). An Evaluation of the National Program of Systematic Land Registration in Romania Using the Fit for Purpose Spatial Framework Principles. *Land*, *11*(9), 1502. https://doi.org/10.3390/land11091502.

Pop, S.B., Pop N., Miluț M., & Bădescu G. (2021). Research on how to Implement the Systematic Cadastre within Medias Municipality, Sibiu County. *Bulletin Of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture*, *78*(2*)*. DOI:15835/buasvmcn-hort:2021.0008.

Popescu, G., Popescu, C. A., Dragomir, L. O., Herbei, M. V., Horablaga, A., Țenche Constantinescu, A. M., Sălăgean, T., Bruma, S., Dinu-Roman Szabo, M., Colișar, A., Ceuca, V., Kader, S., & Sestraș, P. (2024). Utilizing UAV technology and GIS analysis for ecological restoration: A case study on *Robinia pseudoacacia* L. in a mine waste dump landscape rehabilitation. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* *52*(4), Article 13937. https://doi.org/10.15835/nbha52413937.

Roić, M., Križanović, J., & Pivac, D. (2021). An Approach to Resolve Inconsistencies of Data in the Cadastre. *Land*, *10*(1), 70. https://doi.org/10.3390/land10010070.

Tămăioagă, G., & Tămăioagă, D. (2007). *Automation of cadastre works*. Matrix Rom Publishing House.

Tereșneu, C. C., & Tereșneu, C. S. (2023). GIS facilities for the automation of cadastral documentations. *Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering, 12*, 371-376.

***Agenția Națională de Cadastru și Publicitate Imobiliară (ANCPI). (n.d.). *Lucrări de înregistrare sistematică a imobilelor la nivel de UAT*. https://www.ancpi.ro/pnccf/documente/H3_Lucrari%20de%20inregistrare%20sistematica%20a%20imobilelor%20la%20nivel%20de%20UAT.pdf.

****Cadastral plan for cadastral sector 31, U.A.T. Pietroasa, Bihor County*.

***FAE Drones. (2023, August 18). *Drona FAE 1718 fixed wing Rebel*. https://fae-drones.com/2023/08/18/drona-fae-1718-fixed-wing-rebel/.

***Law on Cadastre and Real Estate Advertising No. 7/1996, updated 2025.

***Lege5. (n.d.). *Organizarea lucrărilor sistematice de cadastru în vederea înscrierii în cartea funciară – Legea 7/1996*. https://lege5.ro/Gratuit/g44dcmjsge/organizarea-lucrarilor-sistematice-de-cadastru-in-vederea-inscrierii-in-cartea-funciara-lege-7-1996?dp=hazdsmjygu2dc.

***Provincia Crișana. (2017, October 6). *Scurtă descriere a județului Bihor – Provincia Crișana*. https://provinciacrisana.wordpress.com/2017/10/06/scurta-descriere-a-judetului-bihor-provincia-crisana/.

***Search Romania. (n.d.). *Harta Pietroasa, județul Bihor*. http://www.searchromania.net/harta_harti/bihor/pietroasa/.