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ASSESSMENT OF LAND USE CHANGES IN NON-COLLECTIVIZED AREAS USING GEOMATIC APPLICATIONS: A CASE STUDY IN VÎRFURILE, ROMANIA

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Abstract

After 1990, land use categories in non-collectivized hilly and mountainous areas experienced distinct changes, influenced by various socio-economic and environmental factors. This study focuses on cadastral sector 15 within the administrative territorial unit of Vîrfurile, Arad County - an area that was not subjected to collectivization. The objective is to analyze the current state of land use categories using geomatic applications. Plot localization was achieved using orthophotoplans, while spatial positioning was conducted via GNSS technology employing the Real-Time Kinematic (RTK) method, with data transmission between receivers facilitated by internal radio. Base point coordinates were determined using data from the GNSS station in Gurahonț. The coordinates of the characteristic detail points were processed with the MapSys10 software and overlaid onto the orthophotoplan. Analysis of the results reveals that several plots formerly designated for agricultural use are now partially covered by arboreal forest vegetation, indicating a significant process of natural succession and land use transformation.

Key words: *geomatic applications, land use categories, non-collectivized areas, spatial positioning, GNSS technology.*

INTRODUCTION

Land can be classified based on its use and economic designation - criteria that are essential to both general and specialized cadastre activities (Novac, 2007). The land use category serves as the primary basis for this classification and constitutes one of the cadastral attributes of a land parcel. It is codified in accordance with applicable legislation and technical regulations. This classification may reflect natural conditions or result from human intervention (anthropogenic activity). It is documented in the technical component of the general cadastre, primarily to establish tax liabilities associated with real estate (Novac, 2007).

The land use category is a subset of a broader group of uses and can be further divided into subcategories. However, in general cadastre practices, these subcategories are not individually recorded; they are only identified and registered within specialized cadastres (Novac, 2007). Land use monitoring and analysis are effective tools for identifying the most important developments with positive and negative effects on their use categories. Consequently, the need for the immediate implementation of the national general cadastre system, appropriate policies and legislative provisions, with direct implications for optimal management practices of the national land fund, is highlighted (Călina et al., 2025).

The built-up area refers to the densely constructed portion of the territory - essentially the settlement itself. These areas include buildings, yards, roads, socio-cultural facilities, parks, forests, water bodies, and other land uses within the established boundaries of urban or rural localities. They are regulated by specific legal provisions related to construction permits and urban planning (Novac, 2007; Table 1).

Table 1. Land fund of Romania on 1.01.2004 (statistical data, Novac, 2007)

Land use category	**Area (ha)**	**%**
Arable	9,414,341	38.35
Grassland	3,354,970	14.07
Rough	1,490,384	6.25
Vineyards	230,527	0.97
Orchards	227,204	0.95
Agricultural total	**14,717,426**	**61.74**
Private property	14,155,954	59.38
Forestry	6,751,645	28.32
Water	843,710	3.54
Other lands	1,526,290	6.40
Total non-agricultural	**9,121,645**	**38.26**
Total land fund	**23,839,071**	**100.00**

The extra-urban area refers to the territory located between a locality's administrative boundary and the outer limit of its built-up zone. This area encompasses land designated for various uses, including agriculture, forestry, transportation infrastructure (roads and railways), water bodies, yard-buildings, and non-productive functions. In accordance with current legislation, these lands are systematically subdivided into cadastral sectors, fields, plots, and subplots, following specific cadastral rules. The agricultural use group comprises lands utilized for agricultural purposes and includes the following use categories: arable land, pastures, hayfields, vineyards, and orchards (Figure 1).

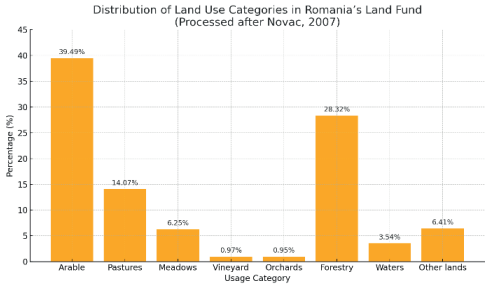

Figure 1. The share of use categories in the agricultural and non-agricultural use group in Romania's land fund (processing after Novac, 2007)

The non-agricultural use group comprises lands not designated for farming, including forests and areas with forest vegetation, water bodies and wetlands (including reed-covered areas), transport infrastructure (roads and railways), lands used for courtyards and other specific purposes, as well as unproductive lands (Novac, 2007; Tămăioagă & Tămăioagă D., 2005).

The credibility of cadastral data on land use and the methodology for their verification and updating. Information on the category of land use is of particular importance in all countries, constituting the basis for taxation and urban planning, directly influencing real estate values and land management procedures. Modern geospatial technologies can facilitate the regular verification of data and information on land use, ensuring future economic benefits for territorial administrative units. As a result, the results of research conducted using unmanned aerial vehicles (UAVs) resulted in obtaining high-resolution orthophotomaps (with a GSD of 3 cm), which provide precise data on the specificity and dynamics of land use at the time of photogrammetric registration (Cienciała et al., 2021).

In conclusion, land use categories are fundamental attributes within the cadastre and real estate registration systems. They play a key role in property classification, taxation, and land management processes.

Land use change has been a major concern for many countries around the world over the years. The main reasons for this situation are: rapid population growth, population migration, the transformation of rural areas into urban areas, changing political systems, and the effect of climate change (Nedd et al., 2021).

Since 1989, uncultivated, hilly, and mountainous regions in Romania have experienced notable shifts in land use categories due to socio-political changes. The declining interest in traditional agricultural activities has led to the abandonment of several arable land subcategories, rendering some parcels unsuitable for conventional crop production.

Currently, obtaining high-precision land use classification can be achieved from high-resolution remote sensing images, using models that can be used as automatic tools for precise land classification and mapping (Kang et al., 2022).

A Western method for recording land use categories, used in Switzerland, is based on two inputs, namely information provided by base topographic maps at a scale of 1:25,000 and national land use statistics, which were obtained from high-precision aerial photointerpretation, performed on a rectangular grid with a side of 100 m. Consequently, the method combines a simple spatial weighting of the inverse distance of information about 36 nearest neighbors and an expert system of correspondence between land use categories on base maps, as input data, and possible land use types obtained by photointerpretation, as output data. This method can be used with high efficiency to transform and use different types of geographic information at scale (Giuliani, 2022).

Additionally, many administrative territorial units (ATUs) in these regions have not updated their agricultural registers, often due to a lack of initiative from landowners. Consequently, the

real land use categories recorded during the systematic property registration and cadastral plan development were based on outdated documents and registry information, rather than on-site verification.

To address these discrepancies, it is essential to conduct field identification, observation, and analysis of plots to accurately determine the productive capacities of the land. In many cases, prolonged abandonment has allowed for the growth of subshrub, shrub, and woody vegetation, obstructing access and complicating evaluation.

Modern geomatic technologies offer effective solutions for analyzing and updating land use categories. These include spatial positioning of cadastral features, data processing, and generation of accurate coordinates through integrated methods. For defining the boundaries of cadastral sectors and individual parcels, tools such as the Global Navigation Satellite System (GNSS), total stations, and other integrated surveying technologies are commonly employed.

Collectively referred to as geomatics, these advanced geospatial technologies ensure accurate acquisition, verification, and processing of spatial data, all referenced to the national coordinate system (Crainic, 2024; Boș, 2003). Their application greatly enhances the efficiency and precision of cadastre-related activities, supporting identification, positioning, area measurement, and classification of land uses across Romania's national land fund.

Geomatics applications are particularly effective for analyzing agricultural land use. They enable the creation of thematic maps that classify agricultural areas by category and subcategory, offering valuable insights into land suitability for various crop types. Furthermore, geomatics tools facilitate spatial analysis and classification of lands for fruit tree cultivation, enhancing land management strategies in agriculture (Roşca et al., 2015).

As a result, space technologies and related applications in the land survey sector support the integrity and record of land, with direct implications for climate change monitoring, disaster risk reduction, land tenure security, land governance, geospatial information management, sustainable land administration and management, spatial planning and land valuation (Upadhyaya, 2024).

MATERIALS AND METHODS

This study was conducted in cadastral sector 15 within the administrative territorial unit (ATU) Vârfurile, located in Arad County, Romania. The region is a rural, non-collectivized area situated at the intersection of Arad, Bihor, and Alba counties, at the foot of the Bihor and Codru-Moma Mountains, within the northwestern part of the Hălmagiu Depression along the Crișul Alb River.

The dominant landforms in the study area are represented by hills, with good accessibility, which in the past were cultivated with potatoes, wheat, oats and corn. There were also lands on which fruit tree orchards were installed, of the apple, plum, pear and cherry species. After 1989, the activities related to the agricultural sector in this location reduced their intensity, because currently they are found only sporadically, due to the lack of adequate equipment and the recent climate changes.

The objectives of the research refer to the study and analysis of the current situation of the categories and subcategories of land use, in cadastral sector 15, which belongs to the territorial administrative unit (UAT) Vârfurile, using geomatic applications. These are necessary due to the current situation of the lands in the mentioned location, in order to establish the necessary strategies for their inclusion in a productive circuit, in correlation with their real use and agricultural production capacity.

This study is conducted as part of a doctoral research program and benefits from the completion of systematic registration works for buildings located outside the built-up area within the targeted cadastral sector. As a result, a parcel plan has been developed and is available in both digital and analog formats (Figure 2).

The primary objective of this research was to analyze the current state of land use categories using geomatic applications. The study benefits from the recent completion of systematic land registration in this area, which resulted in the creation of both digital and analog parcel plans. The research is part of ongoing doctoral studies

and employed a combination of the following methodologies:
- bibliographic analysis of cadastre-related literature, technical norms, cadastral records, agricultural registers, and monographs;
- field observations, both in motion and stationery, for identifying and mapping topographic features;
- experimental measurements using GNSS-based techniques;
- comparative analysis of historical and current land use data;
- simulation and interpretation of land use category transformations.

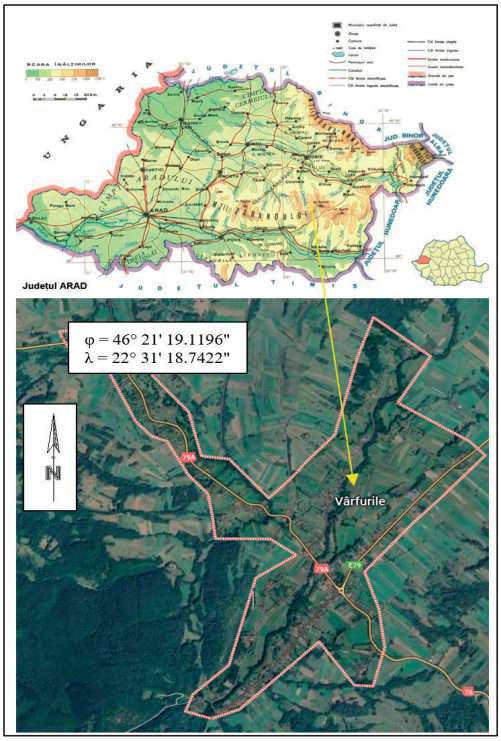

Figure 2. Location of the case study (https://pe harta.ro/judete/Arad.jpg;ttps://www.google.com/maps/place/317390+V%C3%A2rfurile)

To identify and map the characteristic topographic points defining parcel boundaries and land use separations, GNSS positioning was performed. These characteristic detail points delineate the contours of the land plots and subcategories of use.

During the field campaign, GNSS data were collected using the Trimble R8 receiver (with 4W external radio) as the base and the Trimble R10 (with 2W internal radio) as the rover. Positioning was executed using the RTK (Real-Time Kinematic) method. Additionally, remote RTK corrections from the ROMPOS system, using satellite recordings from the Deva GNSS permanent station in Hunedoara County, were integrated to enhance positional accuracy. Five base points were positioned and used as GPS references. The Trimble Access software was employed for field data acquisition and processing, while coordinate transformations into the national reference system were performed using TransDatRO 4.01. Eighteen plots with known use classifications from 1990 were initially surveyed. Subsequently, field validation and digital analysis were expanded to 50 plots, leveraging access to current data from the agricultural register of Vârfurile City Hall and the newly established parcel plan (Figure 3). The recorded coordinates of characteristic point were graphically reported using MapSys 10 software (Marton, 2007).
Digital transformation is vital for modernizing Land Administration Systems (LAS), ensuring efficient, transparent and secure land services. This suggests the implementation of digital workflows, automation services and collaboration with the land survey sector (Chehrehbargh et al., 2024).
Identified subcategories of land use were then compared with historical data from the agricultural register to detect changes and transformations over time.
To further support the interpretation, representative images of selected plots were analyzed, focusing on notable land cover transitions relevant to the case study objectives. These visual and spatial data formed the basis for simulating the evolution of land use subcategories in the studied area.
Also, satellite recordings from the permanent GNSS station Deva, Hunedoara County, were used, with the remote RTK method, using the ROMPOS system. As a result, 18 plots were positioned, where access was allowed and information was held about the categories of use in 1990. After carrying out the systematic registration works of the buildings outside the built-up area and drawing up the plot plan in

digital format, the use categories were analyzed on this plan, superimposed on the orthophoto plan, in parallel with field observations, for a number of 50 plots, where access to the field and to the necessary information was also facilitated.

Figure 3. Location of Cadastral Sector 15, Vârfurile ATU, Arad County

To collect satellite data, the TRIMBLE R8 GNSS receiver with an external 4w radio was used for the base and the TRIMBLE R10 receiver, with an internal 2w radio, as the rover. The Trimble Access program was used to record and process the satellite data. Consequently, rigorously compensated ellipsoidal coordinates were obtained, which were transformed into final coordinates in the national reference system. The coordinates were transformed with the TransDatRO4.01 program, using the updated transformation parameters for Arad County.

This program can be found on the website of the National Agency for Cadastre and Real Estate Advertising (ANCPI) and is used free of charge. As a result, the precision of the coordinates thus obtained is high.

For the graphic reporting of the final coordinates obtained and obtaining the contour of the positioned buildings, the MapSys 10 program was used.

The use subcategories that were identified based on the observations made and the results obtained, for the studied plots, were analyzed and compared with those recorded in the

agricultural register in digital format, related to UAT Vârfurile, Arad County.
Based on the analysis and comparison of the results obtained, a simulation of the current use categories and subcategories was carried out, with the related particularities and occupied areas.

RESULTS AND DISCUSSIONS

The final coordinates of the 307 characteristic points defining the plot boundaries were determined using GNSS technology and are presented in Tables 2 and 3. These coordinates were referenced to the national coordinate system and represent the spatial framework for analyzing current land use categories.
Figure 4 specifically highlights arable land that has undergone natural succession, now being partially or fully covered by forest vegetation, particularly native oak species such as *Quercus cerris* and *Quercus robur*. This transition is indicative of land abandonment and the ongoing ecological succession in previously cultivated areas.
Analysis of field data and imagery (Figures 4 and 5) reveals that portions of the arable plots have undergone natural succession, leading to the establishment of forest vegetation. This transition is characterized by the emergence of biogroups composed of native oak species (*Quercus cerris* and *Quercus robur*) as shown in Figure 4 and pioneer species such *Betula pendula* and *Populus tremula* in Figure 5. These species exhibit clear tendencies toward biological independence and are progressing toward the massif stage of forest development.
A comparative assessment of 50 plots included in the digital parcel plan was conducted, contrasting current land use subcategories (as of 2024) with those recorded in 1989. The synthesized data, grouped by area and category, are presented in Table 2.
Figures 6 and 7 illustrate the spatial positioning of these plots on the orthophoto map of the study area. The positioning method, utilizing base and rover units, allowed for high-precision delineation of parcel boundaries. These boundaries align closely with the current land use categories, as visualized on the orthophoto map.
Proper management of images obtained through remote sensing technologies can facilitate the interpretation and efficient use of spatiotemporal information, which can be used for land use classification. As a result, mapping land use categories, and their changes using, for example, Landsat 5, 7 and 8 images, ensures an optimal investigation of their impact on the environment and implicitly on society (Amini, 2022).
Findings reveal that in 1989, land ownership in the Vârfurile ATU was fragmented, with each plot typically assigned a single use category due to the lack of collectivization.
Today, many plots contain multiple land use subcategories, reflecting shifts in land use driven by reduced agricultural activity - especially potato farming - and widespread abandonment, which has enabled natural ecological succession.
Agricultural land is a basic resource, representative of territorial resilience. In many situations, fertile and relatively accessible soils are subject to pressure caused by urbanization processes, abandonment, the establishment of non-agricultural uses, and due to an agriculture, that is not well adapted to territorial resources. Consequently, the analysis of agricultural land use categories, for the planning of their use, can be carried out according to the properties of the soil and the requirements of society, respectively demographic pressure. Recent studies in the Madrid metropolitan area identified three land use strategies based on suitability: introducing crops in priority zones, designating agricultural protection areas, and promoting ecological regeneration (Morán-Alonso et al., 2025). Declining agricultural activity has led to ecological succession, with spontaneous tree and shrub growth now covering large areas. In addition, climate change - particularly in western Romania - has further contributed to the expansion of areas dominated by native oak species, including holm oak (*Quercus cerris*) and pedunculate oak (*Quercus robur*). These species have regenerated naturally from seed, colonizing many of the abandoned plots
This trend is consistent with findings reported in recent ecological studies. Figure 8 provides a visual summary of the current distribution of land use subcategories across the analyzed plots.

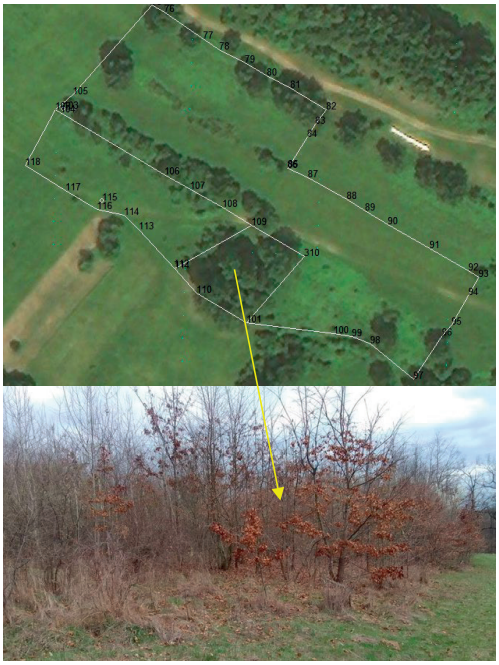

Figure 4. Land areas in the arable use category, on which forest vegetation has been established, native oak species, *Quercus cerris* and *Quercus robur*

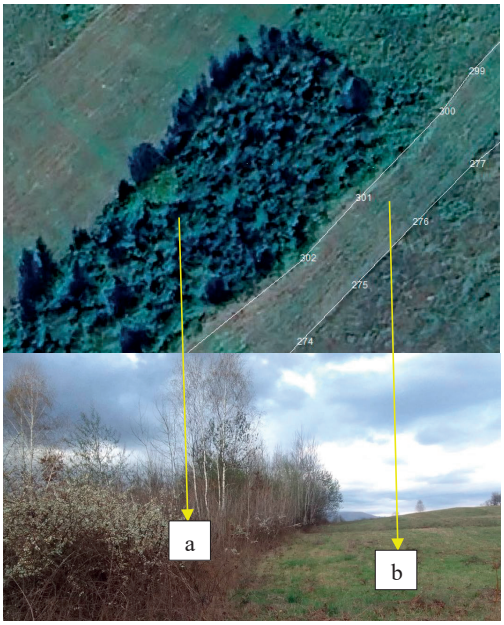

Figure 5. Land areas in the arable use category, on which pioneer forest vegetation has been established (a) and which have been transformed into hayfields (b), due to their improper management

Table 2. Inventory of coordinates of characteristic points related to the analyzed plots

Nr. pct.	X (m)	Y (m)	Z (m)	Nr. pct.	X (m)	Y (m)	Z (m)	Nr. pct.	X (m)	Y (m)	Z (m)
1	538272.727	307751.215	282.088	80	538146.476	307925.075	273.802	151	538202.427	307432.717	262.429
10	538286.930	307741.747	282.681	81	538141.430	307934.378	273.873	152	538208.704	307449.117	263.032
11	538290.370	307743.809	282.791	82	538132.684	307948.609	273.649	153	538.221.184	307.492.569	261.896
12	538295.585	307746.958	283.099	83	538126.966	307944.397	271.103	154	538.223.805	307.514.293	261.243
13	538289.447	307762.806	282.782	84	538121.494	307941.259	268.559	155	538.172.211	307.549.862	252.118
14	538278.606	307789.459	281.686	85	538109.257	307933.463	265.301	156	538.169.227	307.534.707	252.886
15	538262.44	307825.819	280.047	86	538109.024	307933.262	265.247	157	538.167.522	307.512.184	253.036
16	538253.762	307846.404	279.119	87	538105.082	307941.427	264.559	158	538.165.067	307.489.725	254.429
17	538252.177	307849.609	279.062	88	538096.261	307956.850	264.456	159	538.162.914	307.475.563	255.484
18	538249.235	307856.066	278.543	89	538091.576	307964.340	264.354	160	538.158.534	307.459.492	256.278
19	538246.669	307860.822	278.174	90	538086.191	307973.324	264.395	161	538154.020	307442.110	253.989
20	538240.796	307871.47	277.092	91	538076.335	307990.113	264.041	162	538141.460	307.446.524	251.880
21	538235.491	307880.654	275.910	92	538067.429	308005.434	263.276	163	538.130.131	307454.460	249.819
22	538231.013	307887.994	274.731	93	538064.819	308009.759	263.087	164	538.145.202	307.465.217	252.868
23	538230.981	307887.64	274.866	94	538057.384	308005.602	262.920	165	538.146.333	307.476.944	252.138
24	538227.262	307893.682	273.886	95	538045.350	307998.874	260.720	166	538.151.295	307.499.437	251.448
25	538221.752	307901.004	273.124	96	538041.118	307994.864	260.425	167	538.153.354	307.517.298	251.385
26	538218.181	307906.459	272.608	97	538023.408	307983.464	252.790	168	538.158.479	307.550.503	250.382
27	538213.835	307913.17	271.909	98	538037.758	307966.398	254.138	169	538.157.929	307550.600	250.321
28	538211.699	307916.817	271.720	99	538040.699	307959.118	254.320	170	538.147.715	307.553.624	248.744
29	538207.720	307922.572	271.128	100	538041.885	307951.543	254.516	171	538.143.013	307.554.639	248.153
30	538201.165	307932.811	270.225	101	538046.188	307916.929	256.506	172	538.136.482	307.506.472	249.292
31	538191.867	307948.452	269.508	102	538132.625	307840.314	261.802	173	538.132.699	307.478.238	249.303
32	538208.154	307889.491	276.291	103	538132.972	307843.554	262.243	174	538.115.599	307.507.471	249.094
33	538196.548	307902.105	274.628	104	538131.565	307842.386	261.597	175	538.095.516	307.508.148	251.534
34	538194.510	307904.627	274.525	105	538138.85	307847.484	264.045	176	538.082.406	307.509.327	253.732
35	538186.192	307915.564	274.129	106	538106.467	307884.141	260.233	177	538.076.599	307.509.527	253.487
36	538174.391	307938.664	274.279	107	538100.446	307894.260	259.673	178	538.065.195	307.509.139	251.073
37	538195.754	307942.409	269.772	108	538093.071	307907.091	259.852	179	538.067.057	307.517.567	251.425
38	538177.334	307933.692	274.123	109	538085.834	307918.789	259.931	180	538.063.561	307.519.389	250.649
39	538208.899	307888.804	276.391	110	538058.183	307896.984	257.061	181	538.063.763	307.534.223	250.352
40	538207.173	307889.811	276.318	111	538068.420	307888.225	257.892	182	538.072.335	307535.46	251.641
41	538222.564	307868.182	278.176	112	538068.723	307887.796	257.936	183	538.072.384	307.535.504	251.626

Table 3. Inventory of coordinates of characteristic points related to the analyzed plots (continued)

Nr. pct.	X (m)	Y (m)	Z (m)	Nr. pct.	X (m)	Y (m)	Z (m)	Nr. pct.	X (m)	Y (m)	Z (m)
42	538232.754	307851.770	278.815	113	538084.166	307873.654	258.654	184	538.082.948	307.536.021	252.535
43	538244.107	307833.343	279.560	114	538089.803	307867.975	259.098	185	538.084.535	307.518.025	253.239
44	538248.198	307826.812	279.678	115	538095.841	307859.221	259.669	186	538.091.938	307.518.041	251.35
45	538256.029	307813.526	280.247	116	538092.296	307857.057	259.411	187	538.115.476	307.517.373	248.644
46	538263.246	307798.137	280.962	117	538099.997	307844.339	259.536	188	538.113.148	307.537.303	248.498
47	538271.651	307778.792	281.837	118	538110.181	307828.326	259.835	189	538116.550	307.537.222	248.173
48	538275.570	307768.692	282.212	119	538181.871	307685.093	259.191	190	538.081.021	307.492.428	254.566
49	538282.424	307751.181	282.563	120	538168.264	307680.153	257.678	191	538.071.805	307469.500	255.273
50	538286.438	307741.204	282.619	121	538181.362	307648.443	258.315	192	538.051.081	307.472.286	251.776
51	538278.100	307736.984	282.191	122	538188.584	307628.054	259.576	193	538.071.926	307.469.403	255.282
52	538280.504	307733.920	282.036	123	538208.062	307577.166	259.927	194	538.075.256	307.468.738	255.572
53	538283.200	307730.032	281.948	124	538221.345	307542.646	259.223	195	538090.390	307.465.935	255.758
54	538288.233	307721.691	281.598	125	538.215.049	307611.001	261.595	196	538101.920	307.462.039	254.516
55	538293.236	307713.595	281.116	126	538225.948	307585.440	262.102	197	538.114.594	307.458.148	252.758
56	538297.695	307706.286	280.584	127	538237.582	307555.174	261.310	198	538.114.709	307.482.532	250.979
57	538302.909	307698.123	279.925	128	538259.510	307563.160	265.894	199	538.304.637	307.372.146	279.234
58	538308.956	307687.577	278.839	129	538266.992	307536.188	267.254	200	538.300.835	307.377.686	278.591
59	538314.649	307676.597	277.968	130	538271.500	307520.973	268.165	201	538.296.131	307.389.494	278.168
60	538321.253	307664.438	276.840	131	538272.949	307504.617	268.593	202	538.287.173	307.401.685	277.099
61	538326.561	307654.417	276.104	132	538273.389	307493.285	269.016	203	538280.240	307410.740	277.653
62	538332.024	307643.175	275.276	133	538265.299	307491.561	268.100	204	538275.480	307.416.257	275.484
63	538334.851	307636.555	274.915	134	538270.751	307465.212	273.130	205	538269.090	307.420.633	274.688
64	538339.551	307626.223	274.718	135	538268.507	307452.288	275.341	206	538.287.713	307445.140	274.083
65	538344.969	307611.087	275.116	136	538267.840	307431.847	273.914	207	538.335.681	307.389.272	281.115
66	538331.603	307604.636	274.123	137	538260.058	307418.405	274.041	208	538.028.705	307.022.064	271.954
67	538325.331	307618.941	273.798	138	538253.267	307410.437	273.242	209	538.006.721	307.024.786	279.351
68	538317.828	307635.255	274.088	139	538247.899	307415.961	271.887	210	538.006.717	307.024.804	279.330
69	538308.222	307652.854	273.914	140	538247.799	307415.980	271.852	211	537.998.757	307.026.456	280.152
70	538297.241	307671.895	274.881	141	538253.547	307425.640	272.595	212	537.956.196	307.006.218	285.672
71	538287.493	307687.328	276.289	142	538263.810	307443.859	272.336	213	537.947.622	307.005.818	286.005
72	538279.410	307701.427	278.124	143	538265.642	307459.992	283.517	214	537.949.397	307.011.019	285.474
73	538269.165	307717.593	278.741	144	538241.138	307481.678	263.170	215	537972.130	307.004.151	285.595
74	538261.384	307728.645	278.638	145	538234.324	307457.776	264.550	216	538.030.671	307.003.574	278.328
75	538175.28	307878.903	275.567	146	538219.091	307401.040	263.605	217	538.029.956	306.996.126	278.686
76	538172.141	307884.013	275.733	147	538219.120	307400.161	263.665	218	538.028.829	306.981.575	279.048
77	538161.261	307899.513	275.400	148	538227.599	307406.750	265.697	219	538.029.043	306.983.245	279.026
78	538156.949	307905.969	275.121	149	538206.649	307406.614	261.193	220	537.873.384	308.282.923	244.207
79	538151.615	307916.146	274.637	150	538195.544	307413.333	260.118	221	537.867.488	308.279.819	244.011
222	537857.992	308275.388	243909	251	537836.019	308297.410	241313	280	536295.006	310484.474	293.031
223	537845.326	308269.244	243.943	252	537840.860	308282.503	242.797	281	536305.88	310495.575	293.530
224	537845.103	308269.198	243.885	253	537844.259	308272.064	243.604	282	536322.203	310511.979	293.364
225	537878.112	308285.077	244.317	254	537845.030	308269.931	243.787	283	536335.433	310525.694	293.173
226	537886.276	308289.609	244.461	255	537845.016	308269.882	243.753	284	536347.667	310536.968	293.100
227	537875.081	308303.462	243.365	256	537841.589	308280.047	242.998	285	536363.612	310551.485	294.198
228	537864.885	308317.928	242.095	257	537974.347	308479.104	241.681	286	536373.264	310560.801	294.864
229	537857.749	308327.891	241.357	258	537.987.495	308483.803	241.444	287	536385.474	310571.807	295.905
230	537846.870	308340.283	240.342	259	538001.230	308488.406	241.142	288	536393.851	310579.457	296.363
231	537845.410	308341.705	240.158	260	538012.186	308492.841	240.981	289	536402.552	310570.480	295.057
232	537837.906	308350.649	239.438	261	538026.288	308498.893	240.479	290	536394.076	310562.631	293.880
233	537829.796	308360.410	238.724	262	538021.762	308504.451	239.659	291	536364.445	310531.671	291.213
234	537817.345	308374.553	237.269	263	538015.373	308511.827	238.162	292	536354.906	310522.169	291.244
235	537810.661	308383.896	236.335	264	538013.931	308513.332	237.854	293	536348.434	310516.285	291.304
236	537801.655	308397.707	234.918	265	538004.518	308511.686	237.780	294	536343.170	310511.006	291.328
237	537789.269	308417.307	233.137	266	537991.022	308509.854	238.395	295	536333.504	310502.239	291.496
238	537781.481	308430.283	231.919	267	537978.974	308508.347	238.668	296	536318.573	310485.745	291.995
239	537779.678	308433.795	231.664	268	537957.830	308505.213	239.413	297	536302.277	310468.734	291.028
240	537774.403	308441.842	230.783	269	536180.558	310377.956	284.636	298	536283.879	310452.580	290.083
241	537773.803	308431.955	231.029	270	536176.002	310376.201	283.538	299	536275.307	310444.628	289.744
242	537774.311	308418.835	234.531	271	536189.914	310384.330	285.304	300	536266.828	310438.508	289.371
243	537781.605	308401.295	232.593	272	536200.724	310393.823	286.516	301	536248.527	310421.006	288.857
244	537792.237	308385.777	234.130	273	536207.859	310399.783	286.424	302	536235.853	310409.266	287.939
245	537801.809	308370.031	235.187	274	536218.175	310408.687	288.304	303	536214.554	310383.360	285.784
246	537809.841	308355.666	236.980	275	536230.041	310420.072	289.653	304	536185.722	310355.955	281.686
247	537819.967	308339.963	238.210	276	536243.435	310432.846	290.607	305	536185.713	310355.895	281.679
248	537823.787	308330.278	238.767	277	536255.749	310444.891	290.682	306	536183.512	310359.650	282.004
249	537830.186	308313.456	239.696	278	536264.295	310454.975	291.267	307	536180.337	310364.972	282.456
250	537836.003	308297.397	241.307	279	536278.544	310468.304	291.764	-	-	-	-

Figure 6. Positioning of plots occupied by forest vegetation using the RTK method, with radio modules

Figure 7. Positioning of characteristic points of parcels by RTK method with internal radio - external radio modules

Analysis of the diagram in Figure 9 shows that 75% of the analyzed plots are currently classified as meadows, while the remaining 25% are categorized as forested meadows.

The tree species identified on the studied plots include a diverse range of native and naturalized species (Stănescu, Șofletea, & Popescu, 1997). These are: *Quercus cerris* L., *Quercus robur* L. (Figure 10), *Carpinus betulus* L., *Tilia tomentosa* Moench., *Robinia pseudoacacia* L., *Populus tremula* L. (Figure 11), *Betula pendula* Roth (Figure 11)., *Fagus sylvatica* L., *Quercus petraea* Matt., *Prunus avium* L., *Salix caprea* L., *Ulmus minor* Mill., *Ulmus laevis*, *Pinus sylvestris* L., *Alnus glutinosa* L., and *Fraxinus excelsior* L.

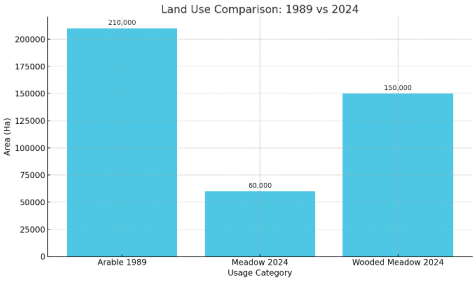

Figure 8. Comparative presentation of use categories for the years 1989 and 2024

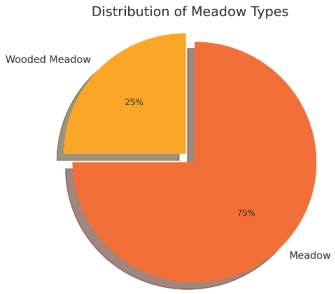

Figure 9. Percentage of subcategories of use, 75% meadow, 25% wooded meadow

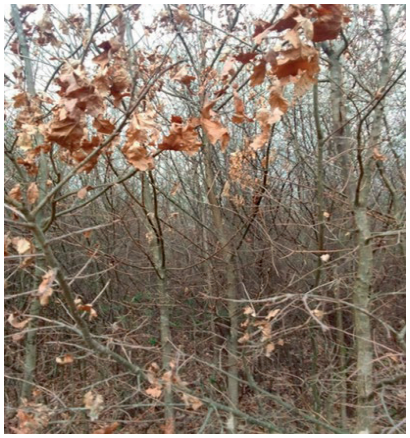

Figure 10. Naturally regenerated forest vegetation of *Quercus robur* (pedunculate oak) established on formerly arable land in Cadastral Sector 15, Vârfurile ATU

Shrub and bush species observed include *Prunus spinosa* L., *Malus sylvestris* Mill., *Pyrus pyraster* L., and *Prunus cerasifera* Ehrh. (Stănescu, Şofletea, & Popescu, 1997).

It is important to note that the maintenance of some plots in good agricultural condition has been supported by financial incentives provided through the Payments and Interventions Agency for Agriculture (PIAA), which encourage landowners to manage and preserve their land use categories effectively.

The changes in land use reported in recent decades are determined by various economic activities carried out in agricultural ecosystems, which have profound implications for society, while also having a major impact on agriculture, the environment, and in the assessment of the sustainability of food and organic products (Barbara et al., 2023).

Figure 11. Biogroups of *Betula Pendula* and *Populus tremula* established through natural succession on former arable land in Cadastral Sector 15, Vârfurile ATU, illustrating the early stages of forest regeneration following land abandonment

CONCLUSIONS

The application of geomatics technologies provides a modern and effective approach for analyzing land use categories and subcategories, particularly in non-collectivized, hilly regions. The integration of GNSS positioning, specifically using RTK methods with dual-frequency receivers and internal/external radio modules, enabled the collection of high-precision spatial data while significantly optimizing fieldwork efforts.

The completion of systematic cadastral registration in Cadastral Sector 15 and the development of parcel plans in both digital and analog formats facilitated a detailed analysis of land use through the MapSys 10 digital cartography program. The overlay of parcel plans onto orthophoto imagery, combined with field observations, allowed for the accurate identification of current land use categories and their spatial distribution.

A comparative analysis revealed that the current land use classifications differ significantly from those recorded in 1990. This shift reflects broader socio-economic changes, particularly the decline in interest in traditional crop cultivation (e.g., potatoes) and the drastic reduction in livestock farming, which has led to widespread abandonment of hayfields and pastures. Consequently, natural ecological succession has occurred, resulting in the

expansion of arboreal and shrub vegetation on previously arable lands. Native deciduous species, especially pedunculate oak (*Quercus robur*) and Turkey oak (*Quercus cerris*), have naturally regenerated and established themselves in biogroups and strips across these abandoned areas. These changes have been further accelerated by evolving climatic conditions in the region.

The land classified under forested and shrub-dominated categories has increased considerably since 1990, often at the expense of arable land and hayfields. Conversely, orchard areas have expanded, supported by the establishment of new plantations financed through European structural funds or private investment.

The continued preservation and productive use of arable land, pastures, and hayfields are largely sustained by financial support provided through the Agricultural Payments and Interventions Agency (APIA). Access to non-reimbursable European development funds has also played a key role in maintaining the viability of traditional land use categories under optimal conditions.

This study highlights significant land use transformations in non-collectivized rural areas, driven by agricultural decline and supported by natural ecological processes. Using modern geomatic tools and precise spatial data, it was found that arable land has increasingly transitioned into meadows and forested areas, reflecting both human inactivity and climate-driven regeneration. Targeted funding - particularly through APIA and European programs - has played a vital role in maintaining productive land use where possible. These insights can inform future land management strategies, support sustainable rural development, and guide the efficient allocation of financial resources.

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