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ASSESSMENT OF LAND USE DYNAMICS AND PREDICTION OF CHANGES THROUGH GIS TECHNIQUES. CASE STUDY

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Abstract. *The paper evaluates land use dynamics and spatial development trends in Tauț commune (Arad County) by applying modern geomatic methods and geospatial databases. The research is based on a comparative analysis of Corine Land Cover (CLC) data for the period 1990–2018 and on predictive modeling of possible changes up to the year 2035, using the Land Change Modeler (LCM) module within the TerrSet environment. Morphometric (altitude, slope) and accessibility factors (distance to roads and settlements) were integrated in order to capture the influence of physical-geographical conditions on land use conversions. The results indicate a general trend of expansion of arable land (+158%) and grasslands (+23%), alongside a reduction of agricultural land with natural vegetation (−56%), shrub vegetation (−61%), and wetlands (−53%). The forested area remained stable, with a slight increase (+4%), while projections for 2035 suggest spatial stability of the landscape, with moderate expansion of productive land. Overall, the study highlights a process of controlled anthropization, in which agricultural land use expands without disrupting the general ecological balance, demonstrating the importance of GIS applications and spatial modeling for analyzing and predicting territorial dynamics. These findings provide a valuable scientific basis for local and regional land management policies aimed at ensuring sustainable rural development and environmental protection.*

Keywords*: land use; GIS; Corine Land Cover; spatial modeling; prediction.*

INTRODUCTION

Technical and technological progress over the past decades, particularly the development of remote sensing methods and Geographic Information Systems (GIS), has enabled the analysis of land use and vegetation ecosystems in a multidisciplinary context, with an increasingly high degree of complexity and precision. The use of satellite imagery offers the possibility to remotely analyze a wide range of phenomena and processes, such as the spatial distribution of species (ZIMMERMANN, KIENAST, 1999; BORDEAN ET AL., 2013; CALUSERU ET AL., 2013; HARSHIT, JEGANATHAN, 2019), the delineation and characterization of vegetation and landscape types (HERBEI ET AL., 2012; DIXON ET AL., 2014), monitoring of invasive species (HELLESEN, MATIKAINEN, 2013), as well as the mapping and analysis of land use changes (BĂLTEANU, POPOVICI, 2010; IFTIKHAR ET AL., 2016; TARANTINO ET AL., 2016; KIZEKOVÁ ET AL., 2018).

In this context, geospatial datasets represent an essential resource for spatial inventory, spatial analysis, and the representation of land use patterns (CEGIELSKA ET AL., 2018; SIMON ET AL., 2021). Among the globally available databases are Global Land Cover 2000 (BARTOLOME, BELWARD, 2005) and ESA GlobCover 2005 (DEFOURNY ET AL., 2006). Among these, the Corine Land Cover (CLC) database, developed under the coordination of the European Environment Agency, is one of the most widely used in territorial research due to its spatial resolution of 25 m, which allows detailed analysis at national and regional levels (HANGANU, CONSTANTINESCU, 2015; COPĂCEAN ET AL., 2019; RUSU ET AL., 2020; URSU ET AL., 2020; KHOSHNOOD MOTLAGH ET AL., 2021; LIU ET AL., 2023; COJOCARIU ET AL., 2024).

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Analyzing land use changes based on geomatic techniques (GIS and remote sensing) has major importance both for assessing natural environment components and from a socioeconomic perspective (CHI ET AL., 2019; MEHRABI ET AL., 2019; MSOFE ET AL., 2020). It allows the identification of spatial and temporal landscape transformation trends, providing essential information for resource management, territorial planning, and ecosystem conservation (TARANTINO ET AL., 2016). In this regard, the Corine Land Cover database constitutes a fundamental tool, providing harmonized data on land cover and its dynamics at the European level, making it extremely useful in studies on surface evolution and land use changes.

In this context, analyzing land use evolution at a local scale becomes essential for understanding landscape transformation processes and their environmental impacts. The application of GIS techniques and harmonized spatial databases, such as Corine Land Cover, allows not only the identification of changes that have occurred in recent decades, but also the modeling of future trends. From this perspective, the present study aims to investigate land use dynamics in Tauț commune (Arad County) and to develop a projection of possible changes up to the year 2035, providing an integrated view of the interaction between natural and anthropogenic factors.

MATERIALS AND METHODS

Study zone

The Tauț commune, considered as the case study in this research, is located in the central–south-eastern part of Arad County, at the contact zone between the Arad Plain and the Zărand Mountains, in a transitional area characterized by pronounced morphological and ecological diversity (Figure 1). It is situated between parallels 46°09’N - 46°18’N and meridians 21°48’E - 22°04’E.

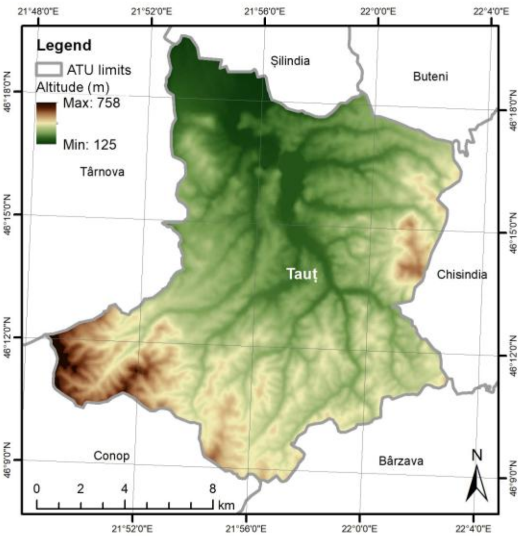

Figure 1. Location of the study area and Digital Elevation Model (DEM) of Tauț administrative unit (processed after GEOSPATIAL, 2022; EEA, 2022)

At the level of the Tauț administrative unit, a variety of physical–geographical conditions can be identified, favorable for agricultural and forestry activities, as well as for the

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development of biodiversity specific to contact areas. The Digital Elevation Model of the territory (Figure 1) highlights the altitudinal differences and contributes to understanding the spatial distribution of the main landforms and land use types.

Research methodology

The research was based on geospatial analysis of cartographic and satellite data, aiming to assess the evolution of land use between 1990 and 2018 and to project future trends up to the year 2035. The methodological process included four main stages: data processing, dynamics analysis, predictive modeling, and presentation of results.

1. Data processing

The following sources and tools were used:

- Digital Elevation Model (DEM) with a spatial resolution of 25 m (EEA, 2022), for morphometric analysis and delimitation of physical–geographical units;
- Corine Land Cover (CLC) data for the years 1990, 2000, 2006, 2012 and 2018, provided by the Copernicus Land Monitoring Service, for identifying and comparing land use classes;
- Auxiliary geospatial data, such as administrative boundaries, hydrographic network, settlements (GEOSPATIAL, 2022), used for georeferencing and spatial orientation.

The data were processed in ArcGIS 10.8 and TerrSet environments, where operations such as reprojection, legend harmonization, and thematic map generation were performed.

2. Analysis of land use dynamics

Comparing the CLC datasets for the period 1990 - 2018 allowed the identification of spatial changes and their quantification through area calculations and transition matrices. The results were represented cartographically and statistically in order to highlight the major trends in landscape transformation.

3. Evolution scenario modeling (for the year 2035)

The projection was carried out in the TerrSet environment, using the Land Change Modeler (LCM) module. The years 1990 and 2018 served as temporal reference points for training the model. Determining factors of territorial change (altitude, slope, distance to roads and settlements) were selected, and the simulation was performed using the Multilayer Perceptron (MLP) neural network algorithm. The results were validated using statistical indicators such as the Kappa coefficient and the confusion matrix.

4. Presentation of results

Thematic maps were generated for each analyzed year and for the projected year 2035, along with comparative surface tables and a qualitative and quantitative interpretation of the identified changes, with the aim of evaluating the implications for the rural landscape structure.

RESULTS AND DISCUSSION

The spatial–temporal analysis of land use in the Tauț administrative unit highlights complex transformations in land use patterns, driven by natural processes and human intervention. The resulting changes and their implications are presented and discussed below.

General evolution of land use between 1990 and 2018

To capture the general dynamics of land use in the Tauț administrative unit, Arad County, the analysis covered the period 1990 - 2018, using cartographic and statistical data summarized in Table 1 and illustrated cartographically in Figures 2 and 3. The evolution of land use classes reflects complex transformations within the rural landscape, generated both by

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natural processes of vegetation regeneration and by human activities related to agricultural and forestry land use.

Table 1

Land use evolution in the Tauț administrative unit (1990–2018)

Land use classes	Area (ha)	
	1990	2018
Culturi complexe	370	97
Forests	12019	12550
Grasslands	2874	3527
Vineyards	30	0
Urban area	456	290
Agricultural land with natural vegetation	2939	1290
Arable land	898	2314
Shrub vegetation	392	153
Wetlands and water bodies	458	214
Total	20435	20435

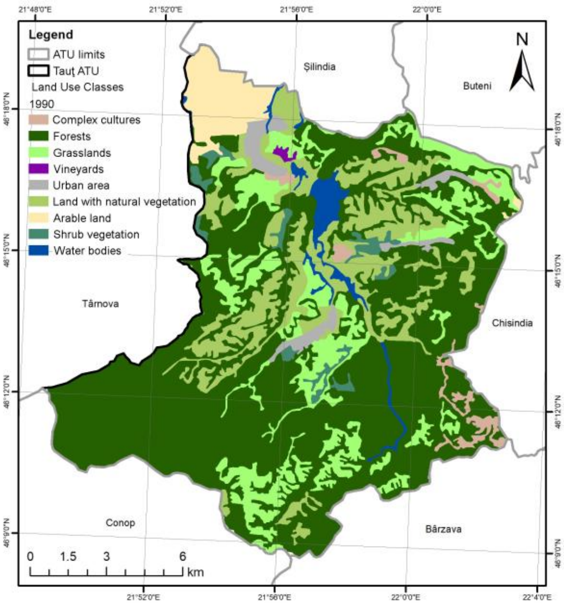

Figure 2 Spatial distribution of land use classes in the Tauț administrative unit in 1990 (processed after GEOSPATIAL, 2022; COPERNICUS LAND MONITORING SERVICE, 2022)

The data in Table 1 indicate that, during the analyzed period, forested areas experienced a slight increase, from 12,019 ha in 1990 to 12,550 ha in 2018, which suggests natural reforestation processes and a relative stability of the forest fund. Grasslands also increased, from 2,874 ha to 3,527 ha, reflecting an expansion of herbaceous vegetation, possibly due to the abandonment of some agricultural lands. In contrast, agricultural land with natural vegetation saw a significant decrease (from 2,939 ha to 1,290 ha), a phenomenon that can be explained by its conversion into arable land or by the establishment of forest vegetation. Arable land almost tripled, from 898 ha to 2,314 ha, confirming the trend of intensifying agricultural use in accessible and fertile areas.

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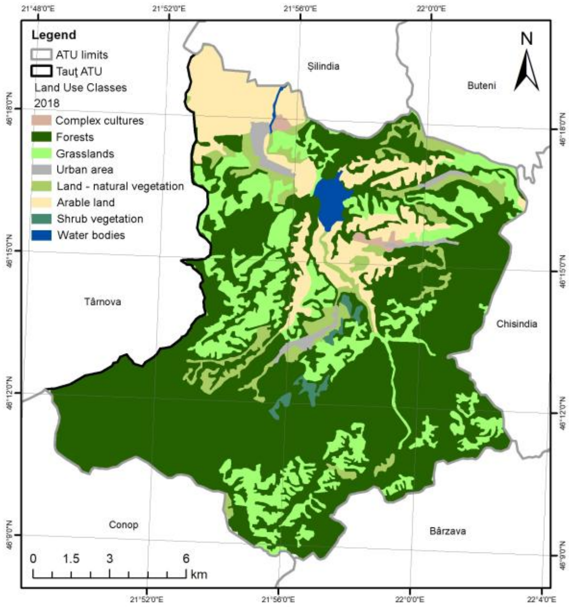

Figure 3. Spatial distribution of land use classes in the Tauț administrative unit in 2018 (processed after GEOSPATIAL, 2022; COPERNICUS LAND MONITORING SERVICE, 2022)

On the other hand, certain categories recorded pronounced declines. Shrub vegetation decreased from 392 ha to 153 ha, and wetlands from 458 ha to 214 ha, indicating a reduction of natural habitats and possible drainage of marshy areas. Vineyard areas disappeared completely from the landscape, and urban space decreased slightly, from 456 ha to 290 ha, possibly as a result of reclassification of buildable land or administrative changes.

The spatial distribution of land use classes, illustrated in the maps corresponding to the years 1990 and 2018 (Figure 2, Figure 3), confirms these general trends. Forests dominate the southern and western parts of the administrative unit, extending slightly into hilly areas and onto slopes with steeper gradients. In the central and northern areas, an expansion of arable land is noticeable, along with a reduction in natural agricultural land. Wetlands have shrunk, especially near Tauț Lake, where agricultural activities and local hydrological modifications have influenced spatial configuration.

Overall, the period 1990–2018 highlights a trend of increasing agricultural and forested areas, to the detriment of land with natural vegetation and wetlands, reflecting a progressive anthropization of the landscape and a consolidation of productive land uses at the expense of natural ones.

Spatial analysis of changes (1990–2018)

To highlight the spatial distribution and magnitude of land use changes, data corresponding to the years 1990 and 2018 were compared (Table 2). This table summarizes the absolute and relative differences for the main territorial transformations.

The most significant increases were recorded for arable land (+1,416 ha, +158%) and grasslands (+653 ha, +23%), expanding mainly in lowland areas and along the boundary between arable land and forests. These changes are associated with the intensification of agricultural activities and, locally, with natural regeneration processes on abandoned land.

In contrast, agricultural land with natural vegetation (−1,649 ha, −56%) and shrub vegetation (−239 ha, −61%) experienced the greatest losses, reflecting their conversion to productive land uses. Forests recorded a slight increase (+532 ha, +4%), remaining stable in hilly and mountainous areas, while wetlands decreased by more than half (−244 ha, −53%), especially around Tauț Lake.

Table 2

Land use dynamics in the Tauț administrative unit (1990–2018)

Land use classes	Area in 1990 (ha)	Area in 2018 (ha)	difference 1990 - 2018 (ha)	Relative increase/decrease (%)
Complex crops	370	97	-273	-74
Forests	12019	12550	532	4
Grasslands	2874	3527	653	23
Vineyards	30	0	-30	-100
Urban area	456	290	-166	-36
Agricultural land with natural vegetation	2939	1290	-1649	-56
Arable land	898	2314	1416	158
Shrub vegetation	392	153	-239	-61
Wetlands and water bodies	458	214	-244	-53
Total	20435	20435	0	0

The spatial distribution of these changes highlights a polarization of the landscape: the southern and western parts of the administrative unit are dominated by forests, while the northern and central areas are dominated by agricultural land, confirming a trend toward anthropization and expansion of productive surfaces at the expense of natural ones.

Analysis of transitions and quantitative changes in land use (1990–2018)

To understand the direction and magnitude of land use changes, a transition matrix was developed (Table 3), which highlights the conversion flows between land use classes during the period 1990–2018.

The results show high stability of the forest fund, with 11,883 ha maintaining their forest use, along with additional gains through conversions from other classes (e.g., 110 ha originating from agricultural land with natural vegetation). Forests absorbed areas mainly from shrub vegetation and marginal agricultural lands, confirming natural regeneration processes and the general trend toward afforestation in areas with low accessibility.

In the case of arable land, the total increase of 1,416 ha resulted primarily from the conversion of agricultural land with natural vegetation (888 ha) and, to a lesser extent, shrub vegetation (100 ha). This dynamic reflects the intensification of agricultural use on accessible land and the productive valorization of previously underutilized areas.

Table 3

Land use dynamics in UAT Tauț (1990–2018)

2018 / 1990	1	2	3	4	5	6	7	8	9	Total (ha)
1		4.96	0.00		43.96	1.47		46.46	0.00	96.85
2	81.50	11883.06	296.70		6.52	109.97	1.24	119.97	51.14	12550.10
3	145.40	61.11	2232.77	1.10	1.32	915.61	7.50	116.82	45.43	3527.06
5	3.49	0.63	0.43		284.23	1.65	0.00	0.00	0.00	290.43
6	92.56	32.78	243.76	27.39	110.21	605.15	0.74	96.40	80.59	1289.58
7	47.00	2.86	0.00	1.17	8.29	1287.52	888.77	12.06	66.49	2314.16
8		33.13	100.74		1.51	17.32		0.00		152.70

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9		0.00	0.00		0.00	0.00	0.00		214.00	214.00
Total (ha)	369.95	12018.53	2874.40	29.66	456.04	2938.69	898.25	391.71	457.65	20434.88

Legend: 1 – Complex crops; 2 – Forests; 3 – Grasslands; 4 – Vineyards; 5 – Urban area; 6 – Agricultural land with natural vegetation; 7 – Arable land; 8 – Shrub vegetation; 9 – Wetlands and water bodies

Grasslands also showed a positive dynamic, recording conversions from agricultural land and natural vegetation (over 2,200 ha), suggesting an expansion of herbaceous vegetation areas as a result of agricultural abandonment and plant succession.

On the other hand, agricultural land with natural vegetation lost more than half of its surface (Table 3), being converted into arable land (888 ha), forests (605 ha), or grasslands (244 ha). Shrub vegetation decreased similarly, being replaced by forests and arable land, while wetlands and water bodies were reduced to 214 ha, remaining only in the Tauț Lake area.

Overall, the structure of transitions highlights two dominant trends:
(1) the expansion of productive uses (arable land and grasslands) at the expense of natural and shrub-covered land;
(2) the stability of forests, which continue to occupy the largest share of the landscape. These transformations reflect a process of controlled anthropization, characterized by the agricultural utilization of accessible areas and the regeneration of forest vegetation in peripheral and hilly zones.

Evolution scenario for the year 2035

Based on the trends recorded between 1990 and 2018, a projection scenario for the year 2035 was developed, summarized in Table 4 and illustrated cartographically in Figure 4. The model highlights the probable directions of transformation for the main land use classes in the Tauț administrative unit, based on the continuity of natural and socio-economic processes observed during the analyzed period.

Table 4

Projection of land use class areas in the Tauț administrative unit for the year 2035

Land use classes	Area in 2018 (ha)	Area in 2035 (ha)	Difference 2018–2035 (ha)	Relative increase/decrease (%)
Forests	12550	12555	5	0
Grasslands	3527	3620	92	3
Urban area	290	289	-1	0
Agricultural land with natural vegetation	1290	3	-1286	-100
Arable land	2314	3601	1286	56
Shrub vegetation	153	153	0	0
Wetlands and water bodies	214	214	0	0
Total	20435	20435	0	0

The results indicate an overall stability of the landscape, with moderate changes in surface areas. Forests maintain almost their entire extent, recording a slight increase of 5 ha, which confirms the continuity of regeneration processes and the protection of the forest fund. Grasslands continue to expand (+92 ha, +3%), particularly in contact zones between forests and agricultural land, reflecting the ongoing trend of converting abandoned land into natural vegetation.

Arable land follows an upward trajectory (+1,286 ha, +56%), expanding mainly in the northern and eastern parts of the administrative unit, at the expense of agricultural land with natural vegetation, which is almost entirely reduced (−1,286 ha, −100%). This conversion

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confirms the intensification of agricultural use and the transformation of non-productive areas into cultivated land.

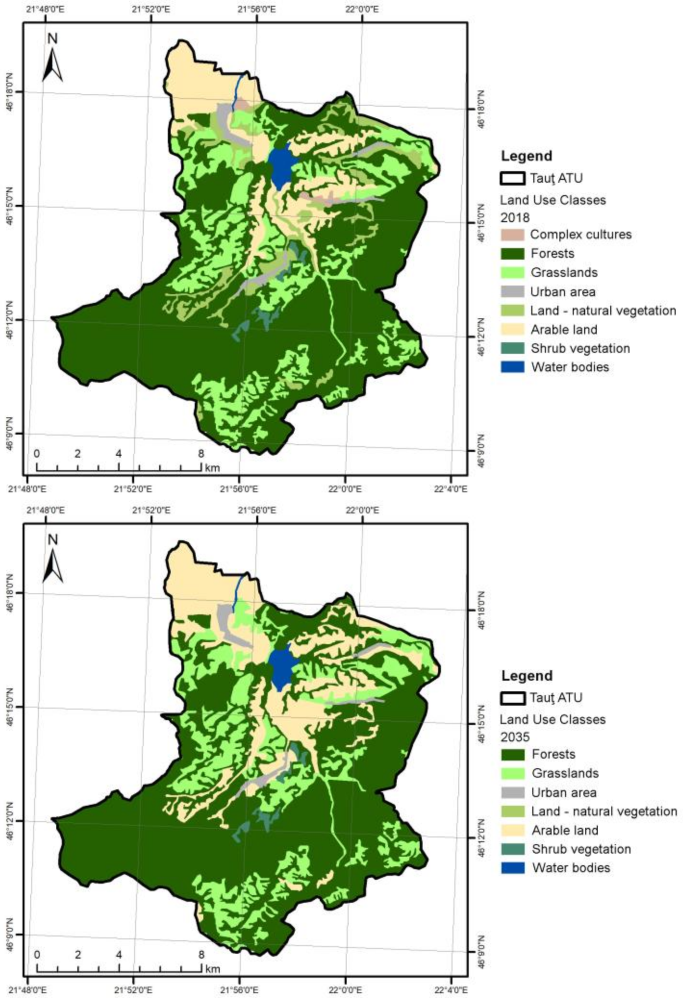

Figure 4. Spatial distribution of land use classes in the Tauț administrative unit in 2018 and 2035 (processed after GEOSPATIAL, 2022; COPERNICUS LAND MONITORING SERVICE, 2022)

The other land use classes — urban area, shrub vegetation, and wetlands — maintain their 2018 extents, without significant variations, suggesting a balance between land occupation processes and natural regeneration.

Comparing the maps corresponding to 2018 and 2035 (Figure 4) highlights a relative spatial stability of land use, with a slight expansion of arable land in the north and grasslands in hilly areas. Overall, the 2035 scenario depicts a landscape dominated by forests and agricultural land, characterized by moderate anthropization and the preservation of the general ecological balance within the Tauț administrative unit.

CONCLUSIONS

The analysis of land use dynamics in the Tauț administrative unit, Arad County, for the period 1990–2018, complemented by the projection for 2035, reveals a balanced evolution between natural processes and human intervention. Arable land and grasslands experienced the most significant expansions, while agricultural land with natural vegetation, shrub vegetation, and wetlands decreased substantially, being converted into productive land uses. The forest area remained stable, with a slight tendency toward growth, confirming its role as a key element of ecological balance.

Transitions between land use classes showed a polarization of the landscape - forests dominate the southern and western areas, while agricultural land is concentrated in the northern and central parts - reflecting the orientation of human activities toward the exploitation of fertile land. The scenario for 2035 indicates a general landscape stability, with a moderate expansion of arable land and a maintained balance between natural areas and agricultural land.

Overall, the evolution of land use in the Tauț administrative unit suggests a controlled anthropization process, in which agricultural activities develop without compromising the overall ecological structure of the territory.

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