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ASPECT PARAMETER FOR CHARACTERIZING A MOUNTAIN AREA BASED ON REMOTE SENSING

Anda VUȘCAN[1], M. AVĂDANEI[1], I. VETO[1], Florina ȚÂRLE BURESCU[1], F. SALA[2,3], M.V. HERBEI[1,2]

[1] University of Petrosani , 332006, University Street, nr. 20, Petroșani, Romania

[2]University of Life Sciences "King Mihai I" from Timisoara, 300645, 119, Calea Aradului, Timisoara, Romania

[3]Agricultural Research and Development Station Lovrin, 307250, Lovrin, Romania

Corresponding author: florin_sala@usvt.ro

Abstract. *The study aimed to analyze and characterize the ATU Lupsa area, Alba County, Romania, based on the ASPECT parameter, through remote sensing technique. In the study area, land surfaces with different types of soil texture were identified, Clayey loam texture (CLt), Clay texture (Ct), Sandy clay texture (SCt), Sandy loam - clayey texture (SLCt), and other types of texture - Varied texture (Vt). Based on the ASPECT parameter, ten classes (AC1 to AC10) were generated, which included variable land areas, in relation to soil texture. The size of the ASPECT classes varied between 217.39 ha (AC1) and 1840.39 ha (AC4). ANOVA Test confirmed significant differences between mean values and Kruskal-Wallis test confirmed significant differences between median values of ASPECT classes. Mann-Whitney (post hoc) highlighted differences between land surfaces with different types of soil texture, on ASPECT classes. Multivariate analysis assessed the correlation between ASPECT classes and soil categories (texture aspect), and the principal components confirmed 82.174% of the total variance. Cluster analysis grouped ASPECT classes and soil texture types based on similarity, in relation to the related surface values (Coph. corr. = 0.846). The highest level of similarity was recorded at the level of classes AC2 and AC10, with SDI = 22.77. A ranking of the ASPECT classes was generated based on the land area values, with the first position occupied by class AC4.*

Keywords*: ASPECT, clustering, mountain area, PCA, remote sensing, soil texture*

INTRODUCTION

The properties of the land surface can be described by remote sensing based on parameters that express altitude, slope, terrain exposure, degree of vegetation cover, structure and condition of vegetation, soil parameters, biochemical parameters, etc. (WANG ET AL., 2019; HUANG ET AL., 2020; RAHAMAN ET AL., 2020; MAXWELL AND SHOBE, 2022). Remote sensing parameters and AI (artificial intelligence) have been used in land use and landscape change studies (ANAND ET AL., 2025).

In studies of the Earth's crust and terrestrial areas, ASPECT is an important parameter that, along with other specific parameters (e.g. topographic position, surface curvature, slope, topographic roughness, etc.), is useful in describing and characterizing habitats (LEE ET AL., 2020; MAXWELL AND SHOBE, 2022).

The ASPECT parameter, along with other parameters derived from the DEM model, has been used for classification in certain thematic studies and for the assessment of land surface change (ALBA-FERNÁNDEZ ET AL., 2021; WANG ET AL., 2024).

For the study of mountain areas, remote sensing, through specific parameters and associated applications, is a very useful technique, which provides information with multiple practical uses (HERBEI AND SALA, 2014; JOMBO ET AL., 2023; FAROOQ ET AL., 2024; BIAN ET AL., 2025).

To characterize mountainous areas with rugged terrain, remote sensing studies have used specific parameters to analyze reflectance and its distribution in relation to the slope and

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exposure of the terrain (WEN ET AL., 2018).

ASPECT and SLOPE are important parameters for the placement of crops or plantations (vines, fruit trees, forests) with plant species with high requirements for light, humidity, and nutrients (ZHANG ET AL., 2025). The vine has specific requirements for soil, water and nutrients, which make the most of sloping land with southern exposure (SE – SW), and the local grapevine germplasm is adapted to local conditions (SALA AND BLIDARIU, 2012; DOBREI ET AL., 2015).

Terrain parameters (e.g. SLOPE, ASPECT, etc.) are important in the context of sustainable development, for the design of ecological settlements, for an energetically sustainable production and living system, especially in mountainous areas (LENG ET AL., 2024; LUO ET AL., 2024; YI ET AL., 2024).

This study aimed to analyze and characterize a mountainous area, ATU Lupsa, Alba County, Romania, through remote sensing techniques, classified the study area based on the ASPECT parameter in relation to soil texture, and comparatively analyzed the ASPECT classes through appropriate mathematical and statistical methods and tests.

MATERIAL AND METHODS

The study analyzed and characterized the ATU Lupsa, Alba County, Romania, based on the ASPECT parameter. Remote sensing facilitated the acquisition of images for the area of interest. The locality of Lupșa is located on the Northern slopes of the 'Muntele Mare' and on the Southern slopes of the 'Muntii Metaliferi', Figure 1, created based on ArcGIS (ESRI, 2011). The area of interest is characterized by a predominantly mountainous relief, formed on crystalline schists and metalliferous rocks. The altitude ranges from 550 m in the 'Aries' River meadow, which crosses the commune for a distance of 19 km, to 1,350 m, in the 'Geamana' area.

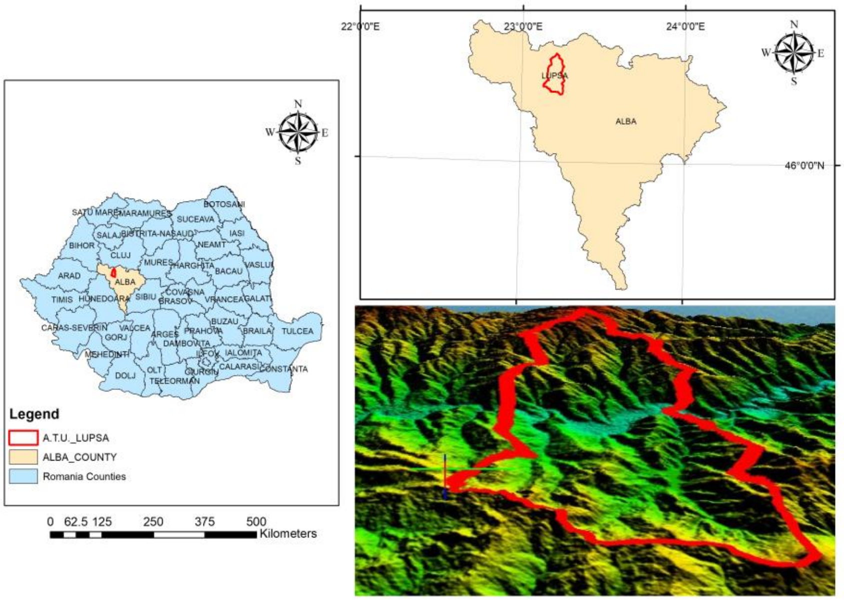

Figure 1. Study location, ATU Lupsa, Alba County, Romania

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For the characterization of the area, the ASPECT parameter was considered, an important parameter for evaluating the potential of the area under consideration. Ten ASPECT classes (AC1 to AC10) were generated for the characterization of the area under consideration.

The area considered was evaluated in relation to soil types by texture classes: Clayey loam texture (CLt), Clay texture (Ct), Sandy clay texture (SCt), Sandy loam - clayey texture (SLCt), Varied texture (Vt). Soil texture information was considered according to ICPA (https://icpa.ro/harti-sol/).

Data recorded for ASPECT classes and soil texture, in the form of land areas (ha) were analyzed mathematically and statistically appropriately. Comparative data series were analyzed to evaluate the mean and median values (ANOVA Test, Kruskal-Wallis test). Multivariate analysis (PCA) was applied to evaluate the correlation of ASPECT classes (AC) with soil texture, based on the recorded land areas. Cluster analysis was used to find out the level of similarity between ASPECT classes. A ranking hierarchy of ASPECT classes was made based on the related area values.

PAST software (HAMMER ET AL., 2001) was used for the purpose of analyzing experimental data and generating figures and graphs.

RESULTS AND DISCUSSIONS

The area considered in the study, ATU Lupșa, is located on the northern slopes of 'Muntele Mare' and on the southern slopes of 'Muntii Metaliferi', with a specific mountainous relief (https://ghidulprimariilor.ro). The analyzed area is characterized by The altitude ranges from 550 m (Arieș river meadow) to 1,350 m (in the 'Geamăna' area), with the longitudinal profile presented in Figure 2.

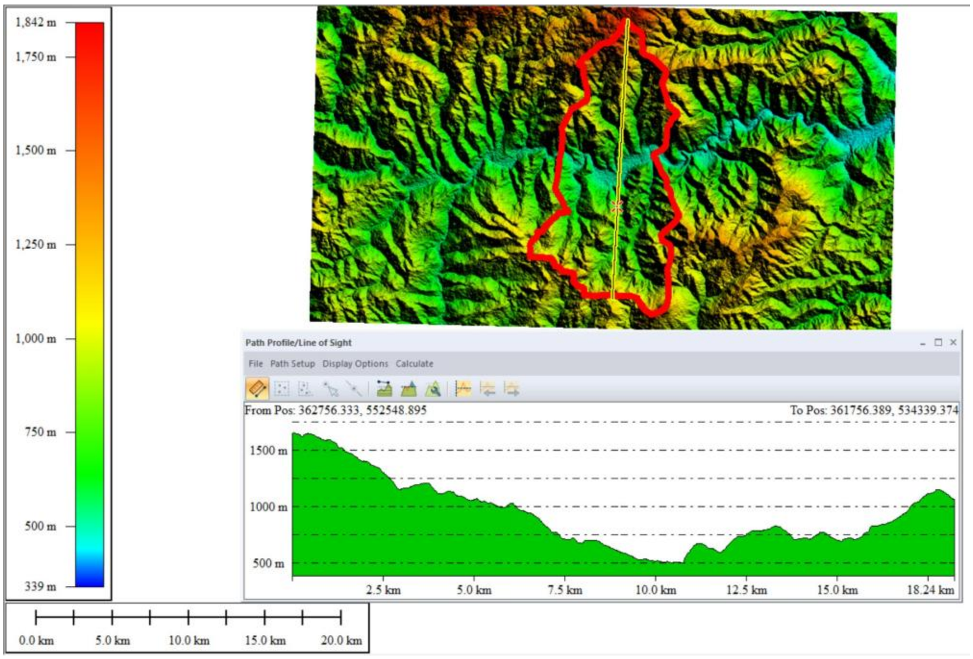

Figure 2. Longitudinal profile of the study area, ATU Lupsa

The studied area has a mono-industrial economic profile, and the characterization based on the ASPECT parameter is important for future potential investments, such as, for example, for renewable energy parks, but also other economic objectives.

The ASPECT (AC) classes recorded variable land areas, in relation to the soil texture in the study area, ranging between AC = 217.39 ha and AC = 1840.92 ha, Figure 3. The longitudinal profile of the study area is presented in figure 3. The ANOVA test indicated significant differences between the mean values, Table 1.

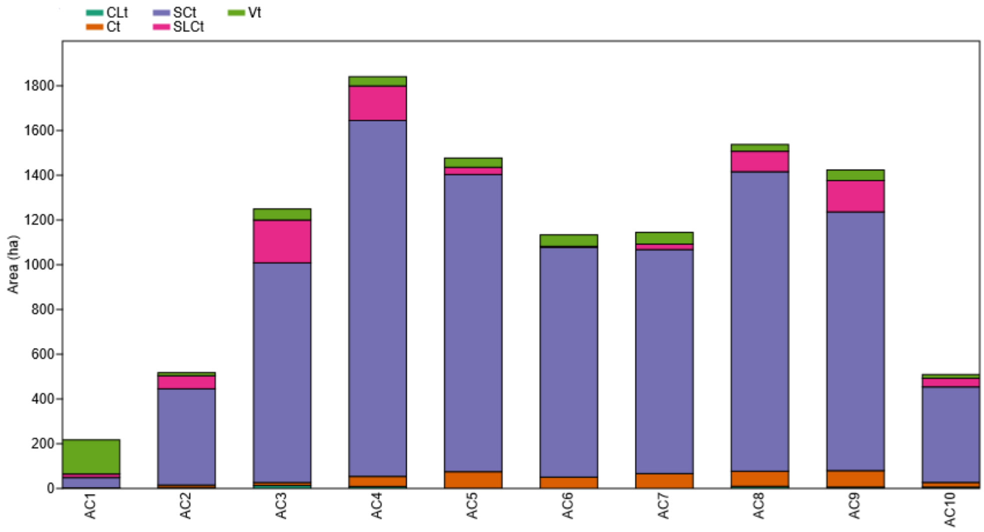

Figure 3. Graphical representation of ASPECT classes

Table 1

Results of ANOVA Test

Statistical parameters	Sum of sqrs	df	Mean square	F	p (same)
Between groups:	6.36E+06	4	1.59E+06	32.88	7.82E-13
Within groups:	2.18E+06	45	48349.6		
Total:	8.54E+06	49	1.00E-05		
Components of variance (only for random effects):					
Var(group):	154160	Var(error):	48349.6	ICC:	0.761247
omega2:	0.7184				
Levene´s test for homogeneity of variance, from means	p (same):	2.55E-08			
Levene´s test, from medians	p (same):	4.27E-06			
Welch F test in the case of unequal variances:	F=17.56, df=18.39, p=4.353E-06				
Bayes factor:	1.405E10 (decisive evidence for unequal means)				

Significant differences were recorded between the median values, according to the Kruskal-Wallis test, with H (chi^2) = 32.98, H_c (tie corrected) = 32.98, p<0.001.

Following the differences statistically confirmed by the ANOVA test and the Kruskal-Wallis test, the Mann-Whitney test (post hoc) was applied, with the results in Table 2.

Table 2

Mann-Whitney test results

	CLt	Ct	SCt	SLCt	Vt
CLt		0.00130	0.00018	0.00076	0.00018
Ct	0.00130		0.00077	0.38470	0.96980
SCt	0.00018	0.00077		0.00077	0.00077
SLCt	0.00076	0.38470	0.00077		0.67760
Vt	0.00018	0.96980	0.00077	0.67760	

Significant differences were confirmed between different soil types in terms of texture, based on the areas occupied in the study area. Based on the recorded area values, there were no significant differences for soils with Ct texture in relation to SLCt and in relation to Vt, as well as between SLCt and Vt soil types.

Multivariate analysis evaluated the correlation between ASPECT classes and soil categories, based on texture type, in the study area. In the case of the ASPECT parameter, PC1 explained 50.057% of variance, and PC2 explained 32.117% of variance, Figure 4. The Eigenvalue (%) – Components relationship is presented in Figure 5.

The score of the ASPECT classes in relation to the Principal Components is presented in Table 3, and the factor loading values (texture types) in the Principal Components are presented in Table 4, under the conditions of the ASPECT classes.

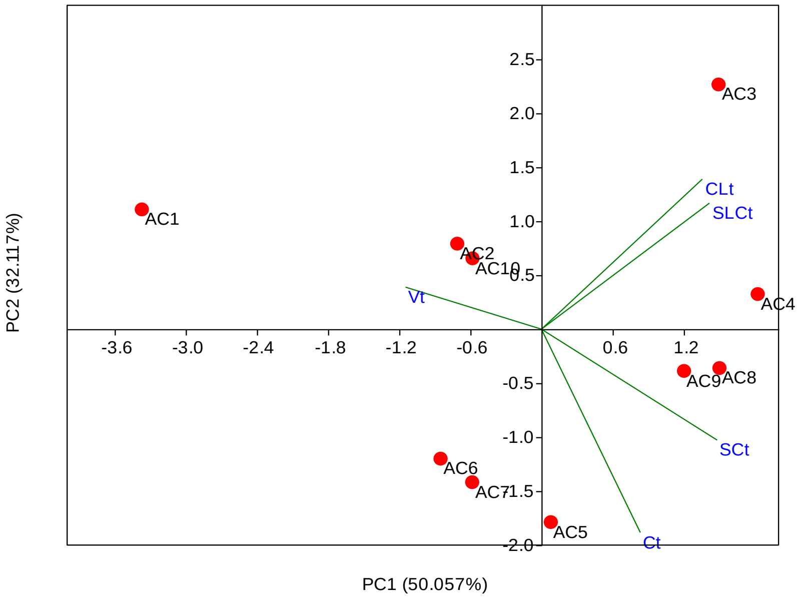

Figure 4. PCA diagram in relation to the ASPECT parameter and soil texture

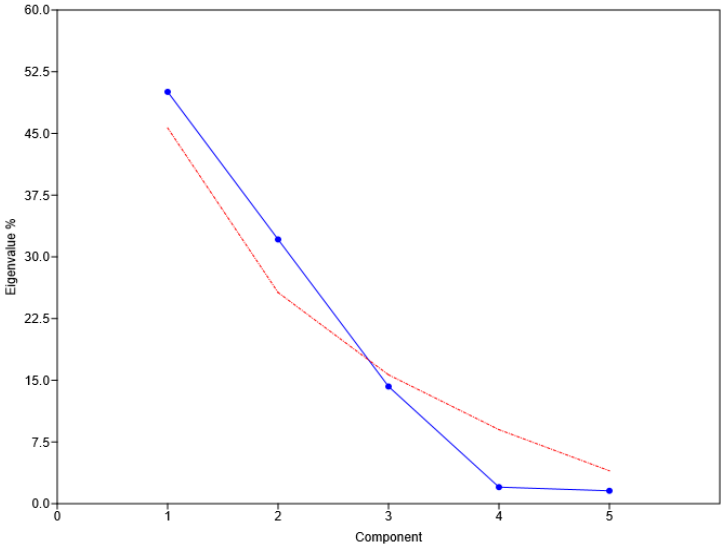

Figure 5. Graphical representation of the Eigenvalue - Component relationship

Table 3

ASPECT class score in relation to Principal Components

	PC 1	PC 2	PC 3	PC 4	PC 5
AC1	-3.3702	1.1092	1.2692	0.0460	0.0944
AC2	-0.7105	0.7921	-1.4275	-0.0842	-0.3288
AC3	1.4932	2.2670	0.3250	-0.0762	-0.0104
AC4	1.8240	0.3255	0.5741	-0.5299	-0.0973
AC5	0.0789	-1.7869	0.0857	-0.1561	-0.0522
AC6	-0.8512	-1.1995	-0.1748	-0.3438	0.0793
AC7	-0.5845	-1.4172	0.0677	0.1041	-0.0950
AC8	1.5007	-0.3598	0.0515	0.2358	0.5971
AC9	1.2015	-0.3866	0.6106	0.6002	-0.3988
AC10	-0.5819	0.6563	-1.3814	0.2042	0.2117

Table 4

Factor loading in the principal components, in relation to ASPECT classes

	PC 1	PC 2	PC 3	PC 4	PC 5
CLt	0.4780	0.4899	-0.0039	0.2256	0.6933
Ct	0.2938	-0.6639	0.2162	0.6504	0.0561
SCt	0.5222	-0.3621	0.2778	-0.7089	0.1281
SLCt	0.4994	0.4115	0.3025	0.1527	-0.6830
Vt	-0.4039	0.1373	0.8858	0.0124	0.1824

Cluster analysis grouped the ASPECT (AC) classes based on similarity (Coph.corr. = 0.846), Figure 6. Sandy clay texture (SCt) soils were predominant in the area.

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The AC classes were grouped into two distinct clusters. One cluster contained three classes (AC1, AC2 and AC10) with land area values. In the central area of the dendrogram, the AC4 class with the highest area values was positioned, in a subcluster with the AC5 and AC8 classes. In the left area of the dendrogram, the other ASPECT classes were positioned, with intermediate values.

The highest level of similarity was recorded at the level of classes AC2 and AC10, with SDI = 22.77. The complete set of SDI values for the ASPECT classes in the study area is presented in Table 5.

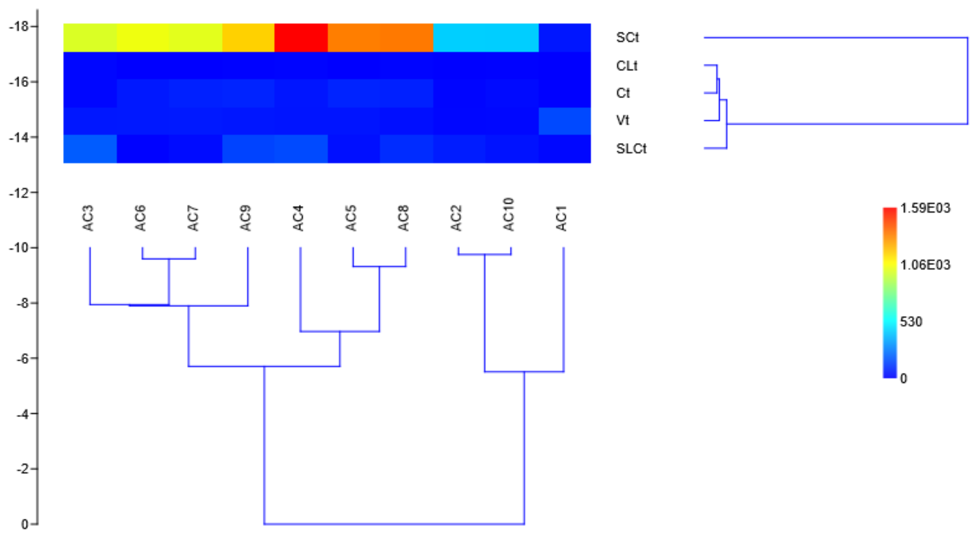

Figure 6. Cluster dendrogram for the ASPECT parameter

Table 5

SDI values for ASPECT classes

	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9	AC10
AC1		411.14	958.56	1556.00	1289.70	988.26	962.72	1302.80	1124.50	406.20
AC2	411.14		569.09	1165.60	901.47	602.37	576.09	911.31	734.01	22.77
AC3	958.56	569.09		610.81	386.65	197.10	177.41	375.08	191.43	576.75
AC4	1556.00	1165.60	610.81		291.20	583.28	604.56	260.98	436.07	1170.00
AC5	1289.70	901.47	386.65	291.20		303.34	327.79	62.38	203.87	903.28
AC6	988.26	602.37	197.10	583.28	303.34		36.72	324.59	188.80	603.07
AC7	962.72	576.09	177.41	604.56	327.79	36.72		345.27	193.94	577.09
AC8	1302.80	911.31	375.08	260.98	62.38	324.59	345.27		190.19	914.53
AC9	1124.50	734.01	191.43	436.07	203.87	188.80	193.94	190.19		738.46
AC10	406.20	22.77	576.75	1170.00	903.28	603.07	577.09	914.53	738.46	

A ranking of ASPECT classes was generated based on the land surface values, in relation to soil texture, Figure 7. In first position was identified class AC4, followed by AC9 and AC8, for the first three positions.

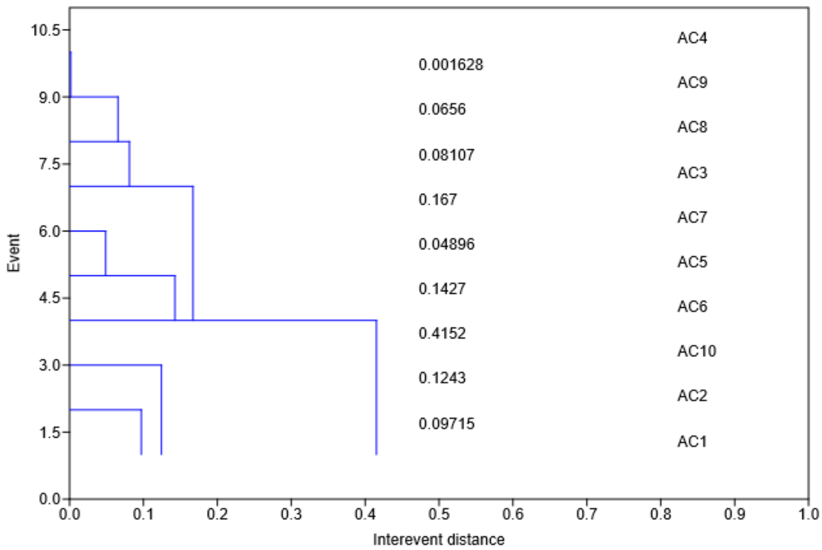

Figure 7. Hierarchy of ASPECT classes in the study area

Remote sensing has provided reliable information for describing land areas in relation to geographical aspects, terrain morphology, and suitability for different crops (LEE ET AL., 2020; MAXWELL AND SHOBE, 2022; ZHANG ET AL., 2025). ASPECT and SLOPE were presented as important parameters in relation to the degree of favorability and the realization of tree species plantations (ZHANG ET AL., 2025). Also, the ASPECT and SLOPE parameters were considered in the design and sustainable management of mountain areas, for the exploitation of energy sources in an ecological context and the sustainable development of human settlements (LENG ET AL., 2024; YI ET AL., 2024).

The present study classified the area considered in the study, ATU Lupsa, Alba County, Romania, based on the ASPECT parameter into ten classes (AC1 to AC10) with variable surfaces. It also identified land surfaces with different types of soil texture, according to ICPA.

A generated longitudinal profile presented the variability of the studied area in terms of altitude, with values ranging between 550 m (Aries River meadow) and 1350 m (Geamana area).

Multivariate analysis (PCA) comparatively analyzed the two elements (ASPECT classes, soil texture) and quantified the correlation between ASPECT classes with soil texture based on the related surfaces. The two main components (PC1, PC2) explained a high share of the total variance (82.174%).

The ASPECT classes have been grouped based on similarity in terms of surface values, and can be approached similarly for economic development objectives in the area. The hierarchy of classes can be useful in relation to certain priorities of approach.

CONCLUSIONS

Remote sensing facilitated the analysis of the mountainous area, ATU Lupsa, Alba

County, Romania, based on the ASPECT parameter, correlated with soil texture on different surfaces in the study area.

The ASPECT-based classification led to ten classes (AC1 to AC10), with variable surface sizes, AC1 = 217.39 ha (minimum value) and AC4 = 1840.92 ha (maximum value). The level of correlation between ASPECT classes and soil texture types was identified by PCA analysis, and the two main components (PC1, PC2) explained 82.174% of the total variance.

Comparative analysis between ASPECT classes showed significant differences between mean and median values, and the Mann-Whitney test (post hoc) confirmed the significance of the differences between most ASPECT classes.

Cluster analysis grouped ASPECT classes based on similarity, so that classes with similar values can be evaluated in relation to economic objectives of interest for the area considered.

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