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QUALITATIVE EVALUATION OF AGRICULTURAL LAND BY METHODS BASED ON GIS TECHNIQUES. LENAUHEIM CASE STUDY, TIMIS COUNTY, ROMANIA

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Abstract

This study assessed the quality of agricultural land in the area of Lenauheim, Timis County, Romania. Analog maps (1:10,000 scale) processed by GIS techniques (vectorization, digitization) were used. In relation to the 6 indicators taken into account, the studied area was characterized: Indicator 4C - Classes of average annual precipitation corrected in relation to the slope and permeability, 2 classes were found (0575 and 0650); Indicator 14 - Degrees of soil gleic status, 5 classes were found with high value for class 2 - low soil gleic level, 37.52%; Indicator 23A - Soil textural classes, 5 textural classes were found, between sand - clay and clay, with a high share of the medium clay class (42 - clay sand-clay, 92.01%); Indicator 39 - Depth classes of the groundwater level, 5 classes of groundwater were found (class 2 - shallow depth 2.01-3.00 m, 49.54%;); Indicator 44 - Classes of the degree of soil compaction, 4 classes of compaction level were found (class +5 - low compacted (1-10%), 75.51%); Indicator 144 - humus reserve class (in layer 0-50 cm), 6 classes were found (class 225 - very high humus reserve 201-250 t/ha, 81.60%).

Key words*: GIS techniques, quality classes, soil diversity, soil quality indices, spatial variability.*

INTRODUCTION

Agricultural lands show different levels of favorability for agricultural crops depending on the climatic zone (Borrelli et al., 2016; Raza et al., 2019), the physical, chemical, biological properties of the soil (Panday et al., 2019; Tesfahunegn and Gebru, 2020; Alawamy et al., 2021), the presence and degree of manifestation of some limiting factors (Everest et al., 2021).
In order to assess the favorability of agricultural land for different categories of agricultural use, and farm management, it is necessary to analyze and evaluate them based on specific quality indicators (Gelaw et al., 2015; Dai et al., 2018; Pouladi et al., 2020; Mulat et al., 2021).
Remote sensing has been used for a long time, successfully, in various studies and applications for land study, land quality assessment, land use classification, land records by use categories (Govedarica et al., 2015; Herbei and Sala, 2016; Kim, 2016; Popescu et al., 2020; Nedd et al., 2021; Winkler et al., 2021).
The characterization of agricultural land has been done in various studies related to land-use planning and management (Lee et al., 2020; Ippolito et al., 2021; (Ghadami et al., 2022), agricultural systems (Viana et al., 2022), basic soil parameters (Vilček et al., 2020), soil quality indices (Rahmanipour et al., 2014; Gelaw et al., 2015), agricultural technologies (Rocha et al., 2019), the impact of agricultural technologies and land management on the soil (Qi et al., 2011; Salvati, 2013), agricultural production and productivity (Blum, 2013), land use programs, policy and socioeconomic aspects (Rondhi et al., 2018; Spangler et al., 2020; Fei, 2022; Ghadami et al., 2022).
For the qualitative assessment of the land in relation to certain categories of use and agricultural crops, certain indicators of high importance for the soil are taken into account and certain calculation formulas were used, which quantify the participation of each factor in the assessment and classification of land in use categories (Florea et al., 1987a, b).
The present study used GIS techniques to evaluate agricultural land, in accordance with five soil quality indicators, in the area of Lenauheim locality, Timis County, Romania.

MATERIALS AND METHODS

Study area

The study considered for analysis and characterization a territory within the Lenauheim ATU (administrative-territorial unit), Timis County, Romania, Figure 1.

The land area taken in the study by satellite images and soil indices, the area of Lenauheim, was 9800.25 ha.

Soil indicators

For the characterization of the considered agricultural territory, six soil indicators were taken into account: indicator 4C (average annual precipitation classes); indicator 14 (soil gleic level); indicator 23A (soil textural classes); Indicator 39 (depth classes of the groundwater level); Indicator 44 (soil compaction level classes); Indicator 144 (humus reserve classes) (Florea et al., 1987a,b).

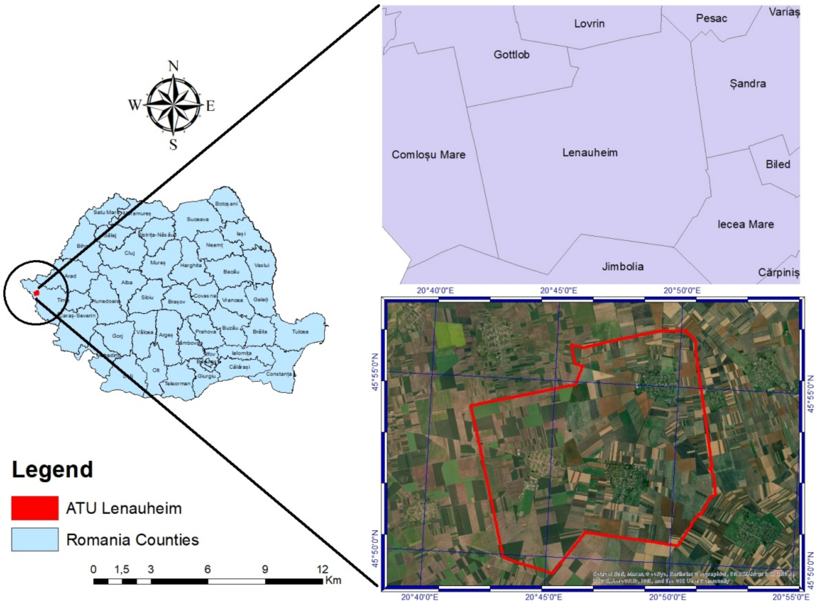

Figure 1. Study area, Lenauheim locality, Timis County, Romania

Indicator 4C expressed average annual rainfall (mm), corrected for terrain slope and soil permeability. Indicator 14 (14) expresses the gleic degree of soil.

Indicator 23A expressed groups of classes, classes and subclasses of soil textures. The granulometry classification was made according to the granulometric components of the soil, clay ($\Phi \leq 0.002$ mm), dust (Φ=0.002-0.02 mm), sand (Φ=2-0.02 mm), and Fs/Cs ratio (Fs – fine sand; Cs – coarse sand).

Indicator 39 (39) expresses depth classes of the groundwater level. Their classification is made according to the depth at which the groundwater is found in the boreholes.

Indicator 44 expresses classes of the degree of soil compaction. The degree of compaction was calculated by formulas, depending on the minimum required porosity (depending on the clay), and the total porosity (depending on the apparent and specific density).

Indicator 144 expresses humus reserve classes (in the 0-50 cm layer). The humus reserve was calculated according to the humus content (%), the thickness of the soil horizon (cm) and the apparent density (g/cm^3).

Use of geomatic technologies in land analysis

In the present study, analog maps (topographic and pedological, at a scale of 1: 10,000) were used, which were processed by GIS techniques (vectorization and digitization). The land area taken into account, Lenauheim ATU, was digitized and classified in relation to the Romanian Soil Taxonomy System and the indicators taken into account based on the land assessment methodology (Florea et al., 1987a, 1987b; Florea and Munteanu, 2012).

Data analysis

The data analysis was done in EXCEL (mathematical and statistical analysis module). PAST software was used for some calculations (Hammer et al., 2001). Within each indicator and classification classes, the corresponding area was calculated in absolute values (ha) and percentages values (%). The percentage share of land per class was calculated in relation to each index considered. The cluster analysis included all indices and classes (with the related surfaces), and the values considered were in the percentage form (%).

RESULTS AND DISCUSSIONS

The results obtained in the study of the agricultural land related to Lenauheim ATU, Timis County, were interpreted in relation to the classification classes of each indicator taken into account.

In relation to the 4C Indicator, within the Lenauheim ATU there are two classes of precipitation. In relation to the average annual precipitation (mm), corrected in relation to the slope of the land and the permeability of the soil, were found class 0575, flat land, and class 0650 land with micro unevenness.

The share of the two classes within the Lenauheim ATU was 73.59% for class 0575, respectively 26.41% for class 0650, Figure 2. The spatial distribution map of the territory of Lenauheim locality, based on the 4C indicator is shown in Figure 3.

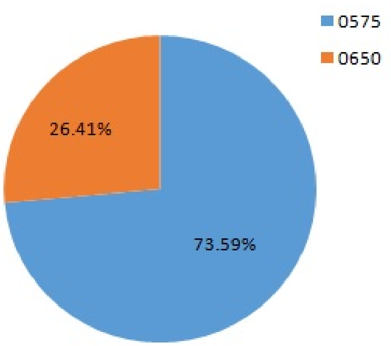

Figure 2. Share of the two classes (0575 and 0650) within the 4C indicator, Lenauheim ATU, Timis County, Romania

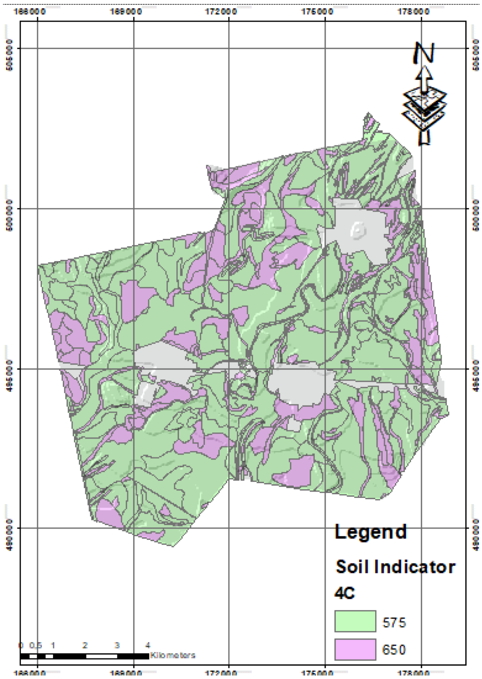

Figure 3. Map of 4C indicator for Lenauheim ATU, Timis County, Romania

In relation to Indicator 14, within the Lenauheim ATU, 5 classes of soil gleic status were identified: 1 - phreatic-wet (with deep gleic level), 33.18%; 2 - low gleic level, 37.52%; 3 - moderate gleic status, 19.14%; 4 - strong gleic level, 5.54%; 5 - very strong gleic level, 4.63%, Figure 4.

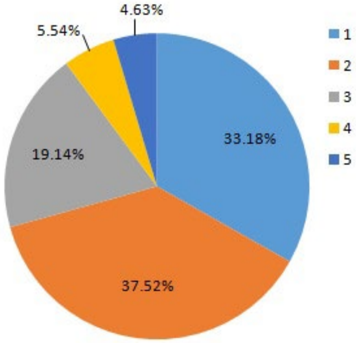

Figure 4. Share of agricultural land in relation to gleic classes, indicator 14, Lenauheim ATU, Timis County, Romania

Classification criteria are expressed in terms of the intensity of the gleic status and the depth on the soil profile at which the gleic phenomenon occurs. The spatial distribution map of the territory of Lenauheim, based on indicator 14 is shown in Figure 5.

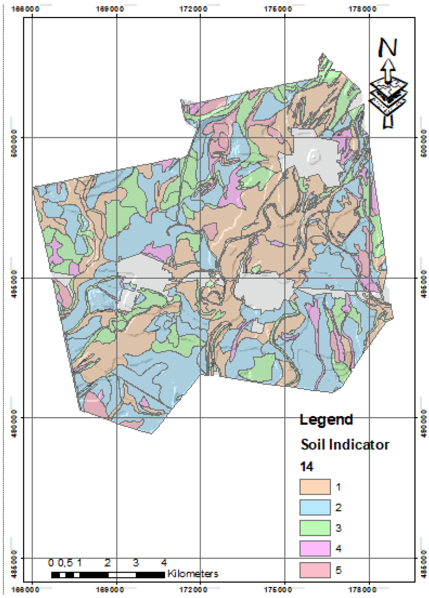

Figure 5. Map of 14 indicator for Lenauheim ATU, Timis County, Romania

In relation to indicator 23A, in the area of Lenauheim locality, 5 textural classes were identified (Figure 6), between sand - clay and clay, with a high weight of class 42, sand-clay; 32 - medium sandy-clay, 0.07%; 42- clay sand-clay, 92.01%; 52 – medium clay, 7.07%; 61 - medium clay-loamy, 0.17%; 62 - loamy-clay, 0.67%.

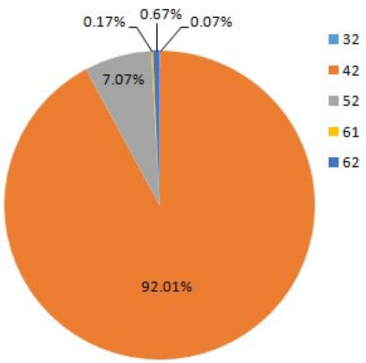

Figure 6. The share of agricultural land in relation to textural classes, indicator 23A, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 23A is shown in Figure 7.

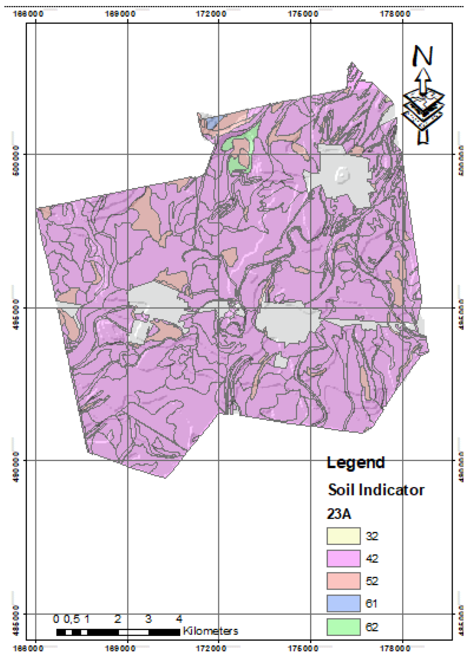

Figure 7. Map of 23A indicator (textural classes) for ATU Lenauheim, Timis County, Romania

In relation to indicator 39, within the Lenauheim ATU, 5 classes of groundwater depth were identified: 0.4 and 0.7 – extremely shallow depth (0.51-1.00 m) 0.12% and 1.12%; 1.4 – very small depth (1.01-2.00 m), 19.02%; 2 – shallow depth (2.01-3.00 m), 49.54%; 3.5 - medium depth (3.01-5.00 m), 30.19%, Figure 8.

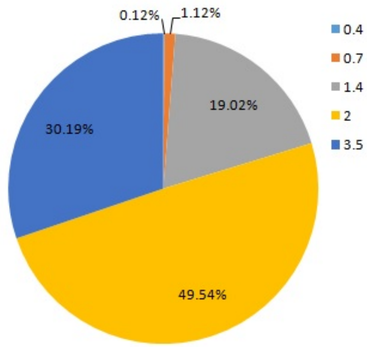

Figure 8. The share of agricultural land in relation to the groundwater depth, indicator 39, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 39 is shown in Figure 9.

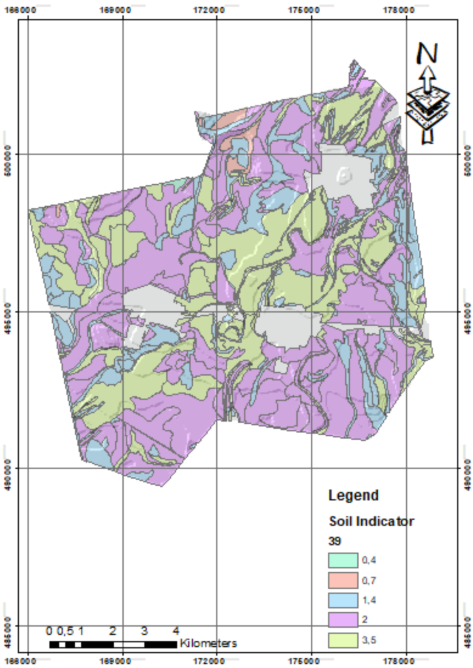

Figure 9. Map of 39 indicator (groundwater depth) for Lenauheim ATU, Timis County, Romania

In relation to indicator 44, 4 soil compaction classes were identified within the Lenauheim ATU: -5 – un-compacted soil (<1%), 11.80%; +5 – low compacted (1-10 %), 75.51%; +15 – moderately compacted (11-18 %), 12.59%; +25 – strongly compacted (≥ 18 %), 0.10%, Figure 10.

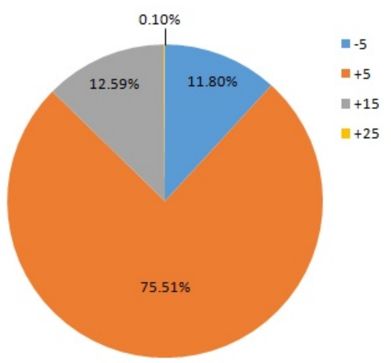

Figure 10. The share of agricultural land in relation to the degree of soil compaction, indicator 44, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 44 is shown in Figure 11.

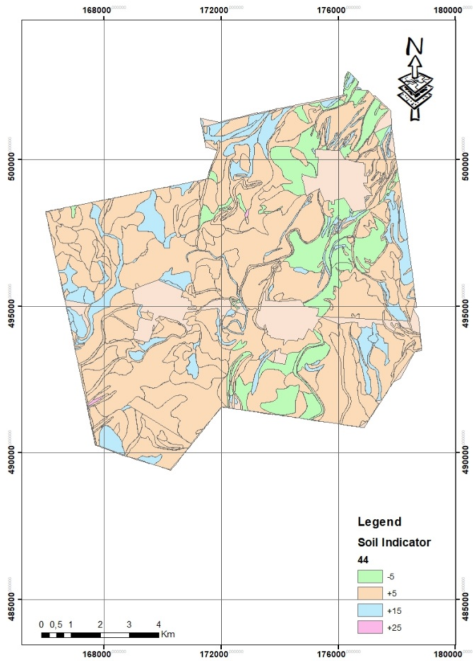

Figure 11. Map of 44 indicator (degree of soil compaction) for Lenauheim ATU, Timis County, Romania

In relation to indicator 144, the humus reserve in the 0-50 cm layer, within the Lenauheim ATU, 6 classes were identified, Figure 12: 090 - low humus reserve (61-120 t/ha), 0.30%; 140 - moderate humus reserve (121-160 t/ha), 0.05%;

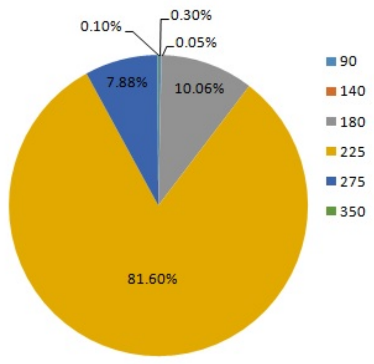

Figure 12. Share of agricultural land in relation to humus reserve (0 - 50 cm depth), indicator 144, Lenauheim ATU, Timis County, Romania

180 - high humus reserve (161-200 t/ha), 10.06%; 225 - very high humus reserve (201-250 t/ha), 81.60%; 275 - very high humus reserve (251-300 t/ha), 7.88%; 350 - extremely high humus reserve (301-400 t/ha), 0.10% (Figure 12).

The spatial distribution map of the territory of Lenauheim, based on indicator 144 is shown in Figure 13.

The overall analysis of the studied territory, in relation to the values on indicators and land classification classes (soil indicators considered) led to the representation in the form of a circular diagram, Figure 14.

The circular diagram in Figure 14 shows the indicators with maximum values (percentage expression of the associated land area) for the characterization of the agricultural territory studied.

Cluster analysis led to the grouping of soil indicators and classes in relation to the percentage value of the associated land area in the characterization of the studied territory, in conditions of statistical safety (Coph. corr. = 0.926).

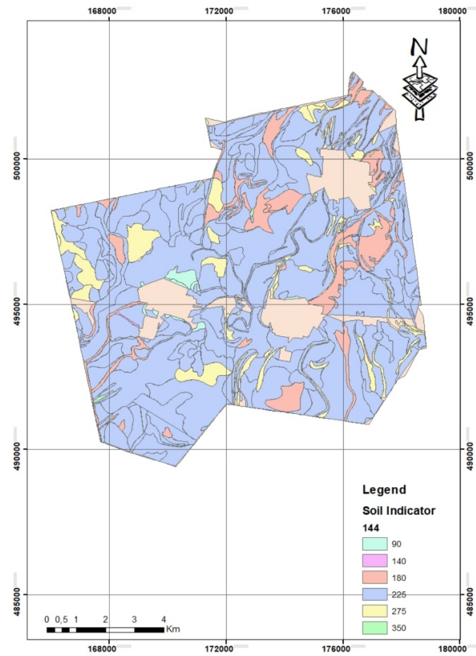

Figure 13. Map of 144 indicator (humus reserve, 0 - 50 cm depth) for Lenauheim ATU, Timis County, Romania

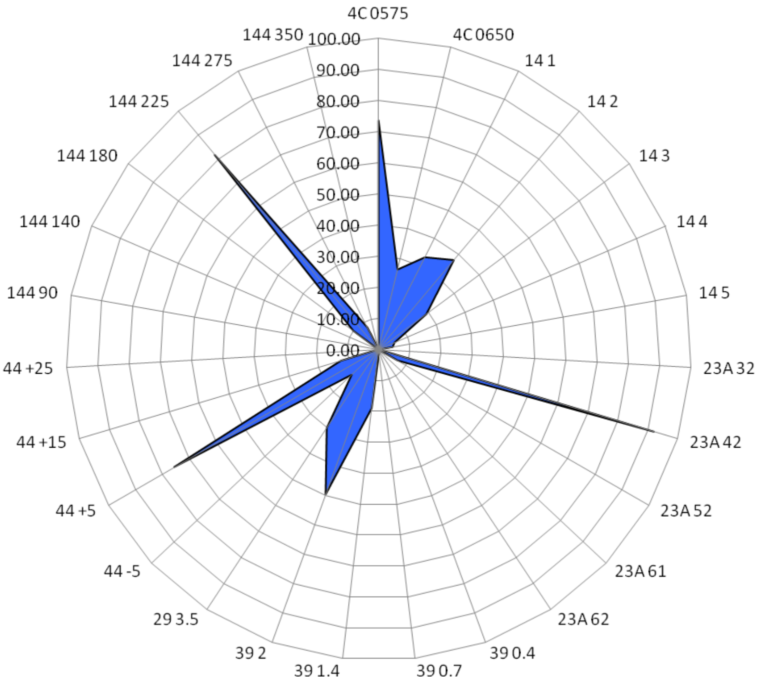

Figure 14. Circular diagram of land characterization indicators and classes, Lenauheim ATU, Timis County, Romania

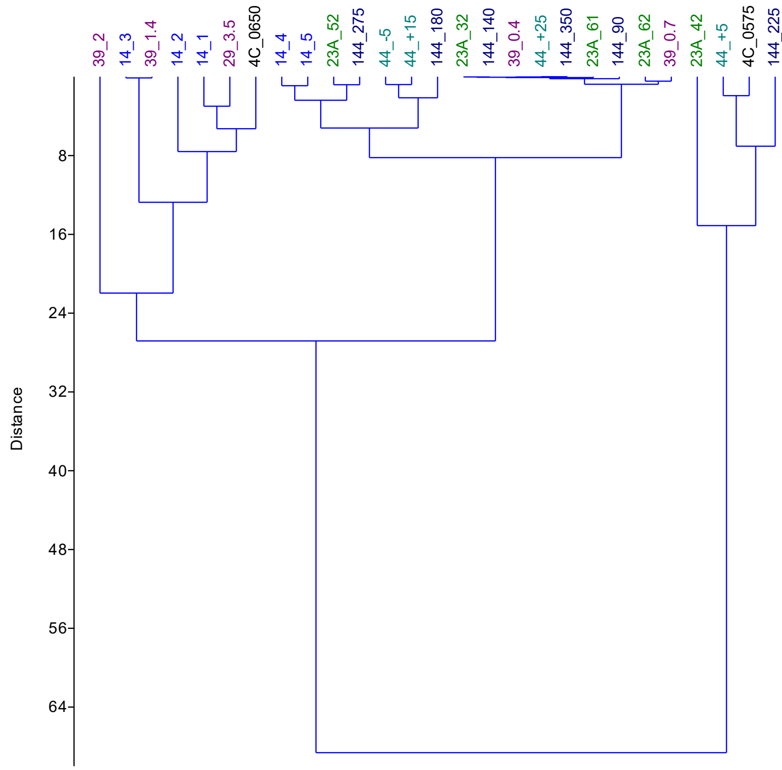

Figure 15. Dendrogram for grouping indices and land characterization classes, expressing the related areas (%), Lenauheim ATU, Timis County, Romania

The grouping of the indices (as a percentage expression of the studied land) was found in two distinct clusters (C1 and C2), with several sub-clusters each. Cluster C1 comprises surfaces associated with 4 indices and classes (maximum values), and cluster C2 comprises the other indices and classes considered, with the surfaces associated with them (Figure 15).

The evaluation of the categories of agricultural land use is important in order to efficiently classify the land in different socio-economic and ecological processes (Mendas and Delali, 2012; Geng et al., 2019; Viana et al., 2022).

Internal and external agricultural markets (Popescu, 2018; Popescu et al., 2018) are based on agricultural products of different categories, and the quantity and quality of agricultural production is consistent with the efficient use of land and agricultural technologies (Sala et al., 2015; King, 2017; Abate et al., 2018; Subramanian, 2021).

Various methods and techniques have been developed and used for the evaluation of agricultural land, due to the importance of framing as efficiently as possible in relation to the potential of each land area (Theobald, 2014; Burian et al., 2018; Herzberg et al., 2019; Mugiyo et al., 2021; Shang et al., 2021).

Agricultural land valuations are useful for decisions and planning support in crop management and resource allocation (Elsheikh et al., 2013; Herzberg et al., 2019; Li et al., 2020).

Techniques that used GIS and relied on multicriteria analysis in land assessment have been reported in some studies regarding the proper use of land in relation to different agricultural crops, and especially to crops of major importance (Ahmed et al., 2016; Yohannes and Soromessa, 2018), as well as for peri-urban agricultural land studied (Ustaoglu et al., 2021).

Given the appropriate classification of land by category of use, in agricultural areas, another stage in increasing productivity aims at issues of adequate biological material and improvement of agricultural technologies by optimizing inputs for quality production (Dobrei et al., 2009, 2016; Rawashdeh and Sala, 2014).

The results of the present study show that the technique based on remote sensing and GIS can be promoted for the study, classification and management of agricultural lands, the results communicated being in the trend registered from the reference studies in the field.

CONCLUSIONS

The soil quality indicators that were considered facilitated the classification of the land under consideration, ATU Lenauheim, in relation to the quality classes included in each indicator.

The technique based on remote sensing and GIS, which took into account the indicators and classes resulting from the classical method of analysis, facilitated their transposition into digitized format, the generation of maps for each indicator, and the safe classification of the studied territory.

The cluster analysis led to the grouping of the indicators, with the associated land surfaces on each class, in conditions of statistical security (Coph.corr = 0.926).

The GIS technique based on remote sensing used can be adapted and extended to other indicators, with applicability for different studies of agricultural land.

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