DESCRIPTION OF SOME SOIL AGROCHEMICAL CHARACTERISTICS THROUGH PCA ANALYSIS

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Abstract. The study evaluated how certain agrochemical indices, used in soil characterization, were classified. The study area, where the soil samples came from, was in the "Padurea Cenad" Protected Area, Timis County, Romania. The considered agrochemical indices resulted from soil analysis for agricultural land and forest land. The agrochemical indices were represented by soil reaction (pH), the content of some macroelements (Nt, P, K, Ca, Mg), microelements (Fe, Mn, Cu, Zn), and heavy metals (Cr, Ni, Pb). The soil reaction was considered with each group of elements in the analysis. According to the PCA analysis, in the case of macroelements, pH, Nt, K, Ca were grouped in PC1, and P and Mg were grouped in PC2. In the case of microelements, pH, Mn, Zn were grouped in PC1, and Cu and Fe were grouped in PC2. In the case of heavy metals, all elements were grouped in PC1. The soil reaction (pH) showed negative action in relation to macroelements (r = −0.999), and in relation to heavy metals (r = −0.972), and positive action in relation to microelements (r = 0.847). Negative action was also recorded in the case of Ca (r = −0.970). In the case of the macroelements, Mg showed a strong action (r = 0.770), and the other elements showed a very strong action (r > 0.900). In the case of microelements, pH and Fe showed a strong action (r = 0.847; r = 0.877), and the other elements showed a very strong action (r > 0.900). In the case of heavy metals, Cr showed a weak action (r = 0.576), and the other elements showed a very strong action (r > 0.900). In all three analyzed groups, the results showed statistical certainty (p < 0.001).

Keywords: factors, heavy metals, macroelements, PCA, soil indices, trace elements

INTRODUCTION

The physical, chemical and biological components and properties of the soils presented a differentiated contribution and high importance in the pedogenesis process, in the context and under the influence of abiotic factors, e.g. relief, land topography, climate (Simfukwe et al., 2021; Sainju and Liptzin, 2022; Sainju et al., 2022).

Recent studies approach soil quality indices from complex perspectives, such as soil ecosystem services, both in relation to natural ecosystems and within anthropogenic, agricultural, horticultural, agroforestry ecosystems (Toth, 2010; Drobnik et al., 2018; Hyun et al., 2022; Zhao et al., 2022).

Soil analysis was considered important in relation to soil functionality in ecosystem restoration, as well as in relation to agricultural yields (Muñoz-Rojas, 2018; Sainju et al., 2022).

The quality and functionality of the soil, in relation to the vegetal carpet, and especially in relation to agricultural crops, require periodic evaluations as a result of the transformations that take place in the soil under the influence of natural and anthropogenic factors (Maurya et al., 2020). The authors referred to the need to determine several parameters in each category of factors (physical, chemical, biological), in order to evaluate soil fertility in a balanced way, based on a minimum set of representative data.

The climatic factor has an increasingly significant contribution in the manifestation of soil parameters and functionality (Hamidov et al., 2018; Braidotti et al., 2021; Certini and Scalenghe, 2023). The authors considered important the need to identify the representative indicators in the evaluation of soil quality, and also the degree of soil vulnerability. Associated with climate changes, the productivity and sustainability of plant production ecosystems and anthropogenic ecosystems were analyzed (Dobrei et al., 2015; Herbei and Sala, 2020; Habib-Ur-Rahman et al., 2022; Semeraro et al., 2023).

In the context of the position that soil has for ecosystem production, some studies have reviewed the importance and functionality of soil quality indices (Sharma et al., 2023). In relation to the importance and manifestation of each factor in the soil, and the interactions between the factors, regarding the functionality of the soil for agricultural production, different soil conservation practices were deduced.

The soil quality indicators were analyzed in relation to crop productivity in different agroecological regions (Chandran et al., 2023).

Soil quality was analyzed in relation to different uses of agricultural land (Mulat et al., 2021; Kijowska-Strugała et al., 2022), agroecosystems and agricultural practices, focusing on peasant agricultural systems (de Melo et al., 2024). The authors of the study made a differentiation of soil quality indices in relation to the pedogenesis process and agricultural practices.

The study analyzed how certain agrochemical indices used in soil characterization were classified,
through PCA analysis, in the case of two land categories, agricultural land and forest land, in the area of "Padurea Cenad" Protected Area, Timis County, Romania.

MATERIAL AND METHODS
The study used values of some agrochemical indices obtained from the analysis of soil samples for two land categories, agricultural land and forest land.

The study area was represented by the "Padurea Cenad" Protected Area, Timis County, Romania, and included the soil samples of agricultural lands adjacent to the protected area, and forest land, figure 1, according to Rosu et al. (2021).

![Figure 1. Study area with agricultural land and forest land, Protected Area "Pădurea Cenad" (Timiș County, Romania) (ESRI, 2011; Rosu et al., 2021)](image)

Values of the soil reaction (pH) and values of the content of soil mineral elements, macroelements, microelements and heavy metals, were considered (Rosu and Sala, 2022a,b).

The soil samples were taken from agricultural land and forest land ("Cenad Forest"). Sampling was done from 25-30 points (as partial sub-samples) to constitute the average soil samples. The determinations were made within OSPA Timisoara.

In relation to the purpose of the study, the determined mineral elements were considered for analysis, in three groups: macroelements (N, P, K, Ca, Mg), microelements (Fe, Mn, Cu, Zn), and heavy metals (Cr, Ni, Pb). Soil reaction (pH) was considered in each of the three groups, in the analysis.

The PCA analysis quantified the grouping of elements by main component, and the mode of action of each element within the framing component.

In relation to the purpose of the study, appropriate mathematical and statistical analysis tools were used (Hammer et al., 2001; JASP, 2022).

RESULTS AND DISCUSSIONS
Starting from previous studies, regarding some soil agrochemical properties, in two land categories (agricultural land, forest land), properties represented by the soil reaction, the content of some main and secondary macroelements, the content of some microelements, and the content of some heavy metals (Rosu and Sala, 2022a,b), the present study analyzed the classification of the respective attributes through PCA analysis.

Soil reaction was considered in the analysis together with the other properties, in each group of elements (macroelements, microelements, heavy metals). The result of the Chi-square test, for the three skill groups considered, is presented in table 1.
The values of the p parameter (p<0.001) indicated the statistical reliability of the analysis.

### Table 1. Results of Chi-squared Test in the case of soil properties analysis, soil samples from the "Padurea Cenad" Protected Area, Romania

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model (macroelements)</td>
<td>29.363</td>
<td>4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Model (microelements)</td>
<td>28.912</td>
<td>1</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Model (heavy metals)</td>
<td>14.789</td>
<td>2</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

In the case of the macroelements, the PCA analysis led to the data presented in table 2, which shows the loading of each element, and the value of the correlation coefficient for each element, in relation to the position in PC1 or PC2 (r = -0.999 for pH; r = 0.991 for Nt; r = 0.973 for K; r = 0.970 for Ca; r = 0.951 for P; r = 0.770 for Mg).

The graphic representation of the framing of the components (soil reaction and macroelements) is presented in figure 2 and figure 3.

### Table 2. Component loadings in the case of macroelements, soil samples from the "Padurea Cenad" Protected Area, Romania

<table>
<thead>
<tr>
<th>Soil parameter</th>
<th>PC1</th>
<th>PC2</th>
<th>Uniqueness</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-0.999</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Nt</td>
<td>0.991</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0.973</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>-0.970</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.951</td>
<td>0.038</td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>0.770</td>
<td>0.059</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Path diagram in the case of macroelements, soil samples from the "Padurea Cenad" Protected Area, Romania

In the case of microelements, the PCA analysis led to the data presented in table 3. The values in table 3 show the framing of the correlations on the two components, and the value of the correlation coefficient for each element, in relation to the position in PC1 or PC2 (r = 0.985 for Zn; r = 0.915 for Mn; r = 0.847 for pH; r = 0.989 for Cu; r = 0.877 for Fe).

The graphic representation of the framing of the components (pH, and microelements) is presented in figure 4 and figure 5.
Figure 3. Graphic representation of Eigenvalue in relation to Component, in the case of macroelements, soil samples from the "Padurea Cenad" Protected Area, Romania

Table 3. Component loadings in the case of microelements, soil samples from the "Padurea Cenad" Protected Area, Romania

<table>
<thead>
<tr>
<th>Soil parameter</th>
<th>PC1</th>
<th>PC2</th>
<th>Uniqueness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>0.985</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>0.915</td>
<td>0.063</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.847</td>
<td>0.181</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>0.989</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>0.877</td>
<td>0.009</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Path diagram in the case of microelements, soil samples from the "Padurea Cenad" Protected Area, Romania
In the case of heavy metals, the PCA analysis led to the data presented in table 4, which shows the classification of the components in a single class (PC1), and the value of the correlation coefficient for each element (pH, heavy metals), in relation to the position in PC1 ($r = 0.984$ for Pb; $r = 0.973$ for Ni; $r = -0.972$ for pH; $r = 0.576$ for Cr).

The graphic representation of the classification of the components (pH, heavy metals) is presented in figure 6 and figure 7. In the case of the analyzed heavy metals, it was found that all the components are classified in one class (the main component), along with the pH value.

**Table 4. Component loadings in the case of heavy metals, soil samples from the "Padurea Cenad" Protected Area, Romania**

<table>
<thead>
<tr>
<th>Soil parameter</th>
<th>PC1</th>
<th>Uniqueness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>0.984</td>
<td>0.032</td>
</tr>
<tr>
<td>Ni</td>
<td>0.973</td>
<td>0.053</td>
</tr>
<tr>
<td>pH</td>
<td>-0.972</td>
<td>0.055</td>
</tr>
<tr>
<td>Cr</td>
<td>0.576</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6. Path diagram in the case of heavy metals soil samples from the "Padurea Cenad" Protected Area, Romania**
Figure 7. Graphic representation of Eigenvalue in relation to Component, in the case of heavy metals, soil samples from the "Padurea Cenad" Protected Area, Romania

From the analysis of the recorded results, it was found that the soil reaction (pH) was positioned in all three cases in the PC1 component, with the value \( r = -0.999 \) in relation to the macroelements, with the value \( r = 0.847 \) in relation to the microelements, and respectively with the value \( r = -0.972 \) in relation to heavy metals. The values of the correlation coefficient indicated a negative action of the soil reaction (pH) in relation to macroelements and in relation to heavy metals, and a positive action in relation to microelements, in the study conditions.

In the case of macroelement analysis, nitrogen (Nt), potassium (K) and calcium (Ca) were positioned in PC1, and phosphorus (P) and magnesium (Mg) were positioned in PC2. Calcium showed a negative action \( (r = -0.970) \), and the other elements showed a positive action. The soil reaction (pH) was placed in PC1, with a negative action.

In the case of microelements, zinc (Zn) and manganese (Mn) were positioned in PC1, and copper (Cu) and iron (Fe) were positioned in PC2, with positive action. Soil reaction (pH) was placed in PC1, with positive action.

In the case of heavy metals, it was found that all three elements, lead (Pb) and nickel (Ni) and chromium (Cr) were positioned in PC1. The soil reaction was positioned in PC1, with negative action.

Simfukwe et al. (2021) used factorial analysis to analyze twenty soil attributes, in assessing soil quality indices. The authors of the study identified certain parameters, in relation to soil quality indices as well as vegetation classes.

Chandran et al. (2023) identified certain soil parameters (pH, active carbon reserve, Zn content) as common indicators in the analysis and description of two agroecological subregions. The authors of the study analyzed the correlation between the cotton production and the respective indices and concluded that the considered indicators are representative for the quantification of soil quality.

In studies to assess soil health and quality, Sharma et al. (2023) determined different indices of soil quality. Based on the recorded results, the authors identified indices with the predominant influence, interdependence relationships between the indices and the overall influence on soil health.

The results communicated through this research, contributed to the understanding of the relationships between certain soil quality indices, in the conditions of agricultural lands and forest lands, which were taken into account in the study.

**CONCLUSIONS**

According to the PCA, it was possible to group soil quality indices, in the analysis of agricultural land and forest land, specific in the "Cenad Forest" Protected Area, Timis County, Romania.

In the case of macroelements, pH, Nt, K, and Ca were grouped in PC1, and P and Mg were grouped in PC2. In the case of microelements, pH, Zn, and Mn were grouped in PC1, and Cu and Fe were grouped in PC2. In the case of heavy metals, Pb, Ni, pH and Cr were grouped in PC1.
Soil reaction (pH) showed a negative action in relation to macroelements ($r = -0.999$) and in relation to heavy metals ($r = -0.972$). Among the mineral elements, calcium (Ca) had a negative effect in relation to the macronutrients ($r = -0.970$).

The values of the $p$ parameter ($p<0.001$) indicated the statistical reliability of the analysis for each grouping of elements considered in the study.

REFERENCES
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