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Monitoring soil physicochemical properties under different land use conditions

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Soil is a major environmental factor that plays a crucial role in environmental productivity and sustainability. The effect on soil quality was measured by monitoring key physicochemical parameters from 2017 to 2019. Case studies have been conducted on various soil types, including garden, uncultivated, and greenhouse soils. Parameters chosen for analysis include pH, moisture content, porosity, electrical conductivity with soluble salt content, alkalinity, acidity, and Ca^{2+} and Mg^{2+}. The results highlighted the significant influence of land use, climatic conditions, and anthropogenic activities on soil quality. Changes in soil pH revealed a general trend toward alkalization, while parameters such as soil moisture, porosity, and soluble salt levels were largely influenced by rainfall and agrotechnical practices. Alkalinity, hydrolytic acidity, and Ca^{2+} and Mg^{2+} values reflected the impact of agrotechnical practices on the environment. Overall, the findings emphasize the importance of continuous monitoring of soil physico-chemical parameters as an essential tool for assessing soil quality, preventing degradation processes, and supporting sustainable soil management.

Keywords: Soil quality, physico-chemical parameters, agrotechnical practices, land use.

Introduction

The soil system is composed of mineral particles derived from the weathering of rocks, organic matter originating from plant and animal residues, soil water, and soil air. These components interact continuously through physical, chemical, and biological processes that determine the structure, fertility, and overall functioning of soils (Alnaser & Alkhafagi, 2020). Organic matter plays a key role in soil fertility by contributing to humus formation and supporting microbial activity, while soil water and air regulate nutrient availability and biological processes within the soil environment (Sofo *et al.,* 2022; Delgado, 2024).

Soil properties are strongly influenced by environmental factors such as parent material, climate, vegetation, topography, and time. In addition to these natural factors, human activities, especially land use practices such as agriculture, horticulture, or land abandonment, significantly affect soil characteristics. Changes in land use may lead to variations in soil structure, nutrient availability, pH, salinity, and other physicochemical parameters that influence soil productivity and ecological stability (Schoenholtz et al., 2000; Javed *et al.,* 2022; *Mihuț et al.,* 2023).

Monitoring soil physicochemical parameters is therefore essential for understanding soil quality, evaluating the effects of different land use practices, and ensuring sustainable soil management. Parameters such as pH, moisture content, porosity, electrical conductivity, alkalinity, acidity, and concentrations of essential cations (e.g., calcium and magnesium) provide important information about soil fertility, nutrient cycling, and the capacity of soils to support plant growth (Masto *et al.,* 2008; Dewangan *et al.,* 2024). Continuous monitoring of these indicators allows the identification of soil degradation processes and supports the development of effective strategies for soil conservation and sustainable land use. Consequently, studying the physicochemical properties of soils under different land-use conditions is an important approach to assessing soil quality and understanding how anthropogenic activities influence soil ecosystems (Muche *et al.,* 2015; Schoenholtz *et al.,* 2000). Therefore, the objective of this study was to evaluate the main physicochemical characteristics of soils collected from different land-use types to analyze how these parameters vary over time. The results contribute to a better understanding of soil quality dynamics and provide useful information for sustainable soil management and environmental monitoring.

Materials and methods

Sample collection. Three types of soils were monitored: garden soil, uncultivated soil, and flower soil. The garden soil samples were collected from a cultivated garden area located in Galați, Romania. This soil is regularly used for growing vegetables and ornamental plants and is periodically subjected to agricultural practices such as irrigation, soil preparation, and fertilization. The uncultivated soil samples were collected from the same geographical area, from locations that had not been subjected to agricultural activity for several years. Unlike the garden soil, this area was not tilled, irrigated, or fertilized, allowing the soil to maintain its natural structure and composition. The flower soil was obtained from a local market.

For the garden soil, monitoring was conducted every six months over two years to observe variations in physicochemical parameters resulting from soil cultivation. For the uncultivated soil, measurements were performed in November 2017, November 2018, and June 2019, as the soil was not subjected to agricultural practices and therefore significant variations from one year to another were not expected. An additional sampling was conducted in June 2019 to assess whether the monitored physico-chemical parameters show seasonal variability, since the previous measurements were carried out in November. For the flower soil, only a single determination of the physico-chemical parameters was performed, as these parameters are considered relatively constant. Sampling was conducted using a knife, a spatula, or a soil spade. Composite samples were obtained by mixing subsamples collected from five points arranged in an envelope pattern, resulting in representative samples with a minimum mass of 1 kg of soil. Each composite sample consisted of three subsamples weighing 200–250 g, collected from two depth intervals: 0–5 cm and 5–20 cm. The soil samples were placed in clean, labelled polyethene bags and then transported to the laboratory for further analysis.

Analysis of soil samples. The investigated physicochemical parameters included soil pH, moisture content, porosity, alkalinity, acidity, and the concentrations of calcium and magnesium cations.

For physicochemical analyses, an aqueous soil extract was prepared at a 1:5 soil-to-water ratio by mixing 50 g of soil with 250 mL of distilled water. The mixture was homogenized by continuous agitation for approximately 1 h, after which the soil suspension was filtered. The obtained extract was subsequently used for laboratory analyses.

Soil moisture content was measured by the oven-drying method (Su et al., 2014). Soil pH was determined according to FAO (2021). Total alkalinity was measured by titration of the soil extract with 0.01 N HCl using methyl orange as an indicator (Van Ranst et al., 1999). Calcium and magnesium cations were determined following the method described by El Mahi *et al.,* 1987, while soil porosity was calculated as the ratio between the volume of absorbed water and total soil volume (Mureșan, 2018).

Statistical analysis. Data were expressed as mean ± standard error of the mean for analytical replicates. Statistical differences in soil characteristics among land-use types were analyzed using a one-way analysis of variance (ANOVA) at the $p<0.05$.

Results and discussion

Soil pH values showed slight variation over the study period, with values generally within the neutral to slightly alkaline range (7.3–8.2) (Figure 1). Garden soil exhibited relatively stable pH values between 2017 and 2018 (7.42±0.98 in November 2017; 7.44±0.72 in June 2018; 7.45±0.45 in November 2018), followed by a significant increase ($p<0,05$) in June 2019 (8.07± 0.65). A similar trend was observed in the uncultivated soil, where the pH decreased slightly in November 2018 (7.33±0.87) and then increased significantly ($p<0.05$) to 8.22±0.68 in June 2019, indicating a shift toward more alkaline conditions. The flower soil presented a pH value of 7.31±0.45, suggesting a nearly neutral soil reaction.

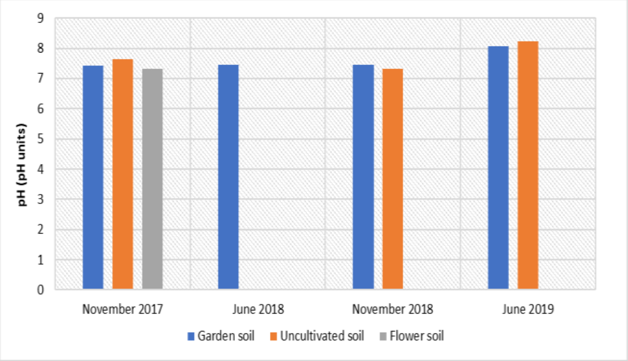

Figure 1. Variation of soil pH values in garden, uncultivated, and flower soils during the sampling period

Overall, the observed increase in pH values in 2019 may reflect changes in soil chemical composition, possibly influenced by agricultural practices, mineral accumulation, or reduced organic matter decomposition. Similar pH values (7.8–8.3) were reported by Mihuț *et al.,* 2023 in agricultural soils from western Romania, where alkaline reactions were associated with intensive agricultural management and reduced organic matter turnover. Likewise, Zhang *et al.,* 2021 demonstrated that prolonged irrigation and fertilization practices can significantly increase soil pH by enhancing the accumulation of exchangeable base cations. Elevated pH conditions may negatively affect micronutrient bioavailability, particularly Fe, Zn and Mn, potentially reducing long-term soil fertility and crop productivity. Guo *et al.,* 2019, observed that soil alkalinization can significantly affect nutrient availability and microbial activity. Moreover, humus formation is favoured under neutral pH conditions, while alkaline environments may reduce organic matter stabilization and overall soil fertility (Javed *et al.,* 2022). Agricultural practices, including fertilization regimes, influence both soil pH and organic matter dynamics (Rengel, 2011).

The variation in garden soil moisture during the period November 2017 – June 2019 is presented in Figure 2. Soil moisture plays a crucial role in plant development, being involved in physiological processes from germination to fruiting (Sharma and Kumar, 2023).

For garden soil, the moisture content showed noticeable temporal variability, with values ranging between 7.63% and 17.05%. The highest moisture value was recorded in June 2018 (17.05±2.16%), indicating a period with higher precipitation and favourable water availability in the soil. In contrast, in November 2018, soil moisture showed a significant decrease ($p<0.05$) to 7.63±1.23%, corresponding to drier environmental conditions. During periods of reduced soil moisture, irrigation was applied in the cultivated garden area to maintain suitable conditions for plant growth. In contrast, the uncultivated soil exhibited natural fluctuations in moisture content, primarily driven by precipitation patterns and evapotranspiration processes, in the absence of anthropogenic interventions. The highest moisture level was recorded in November 2017 (15.64±1.16%), reflecting favourable hydrological conditions. This was followed by a significant decrease ($p<0.05$) in November 2018 (5.53±1.45%), likely associated with reduced precipitation and increased water loss. Moisture levels remained relatively low in June 2019 (8.77±1.02%), indicating continued limited water availability in the soil. Regarding the flower soil, it was observed a significantly higher ($p<0.05$) moisture content (36.15±1.63% in November 2017), compared with the natural soils. This elevated value is likely attributable to the composition of commercial horticultural substrates, which typically contain peat or other organic materials, components that enhance soil porosity and water-holding capacity, allowing for prolonged retention of moisture (Gruda, 2012).

The strong seasonal variability of soil moisture observed in cultivated soils is consistent with findings reported by Cai *et al.,* 2024, who demonstrated that precipitation variability and evapotranspiration are dominant drivers of temporal soil water dynamics in agricultural systems. The higher water retention capacity of flower soil may be attributed to elevated organic matter content and peat-based substrate composition, which improves pore connectivity and water-holding capacity (Gruda, 2010). Similar observations were reported by Raviv et al. (2019), who showed that horticultural substrates enriched with organic amendments exhibit significantly higher moisture retention than natural mineral soils.

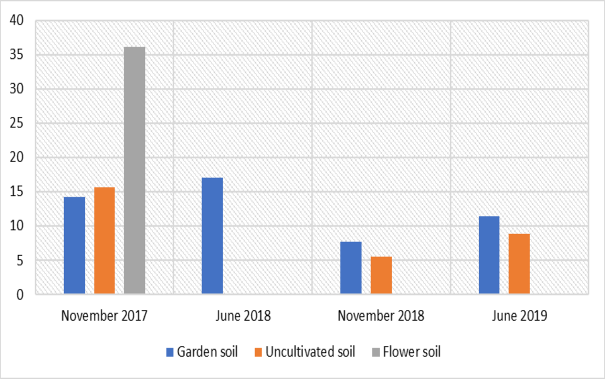

Figure 2. Variation of soil humidity values in garden, uncultivated, and flower soils during the sampling period

Overall, the results emphasize that soil moisture variability is controlled by a combination of climatic factors and land management practices (Cho and Choi, 2014; Cai *et al.,* 2024). While natural soils respond directly to environmental conditions, cultivated soils benefit from irrigation, which mitigates moisture deficits. Furthermore, substrate composition plays a crucial role in determining water retention capacity, as evidenced by the significantly higher values observed in flower soil. In addition to its importance for plant growth, soil moisture also plays a key role in regulating land–atmosphere exchanges. Dry soils tend to release lower amounts of latent heat and water vapor, which can influence soil temperature and local microclimatic conditions. This highlights the broader ecological significance of soil moisture beyond plant productivity, particularly in the context of climate–soil interactions (Cai *et al.,* 2024).

Soil porosity is a key physical parameter that controls water movement, aeration, and root development, thereby playing a crucial role in determining soil functionality and plant productivity. Figure 3 illustrates the variation in the porosity of garden soil during the period November 2017 – June 2019. The initial value recorded in November 2017 (60±6.12%) increased significantly ($p<0.05$) in June 2018, suggesting improved soil structure, most likely due to active cultivation practices, root development, and regular irrigation. These factors are known to enhance soil aggregation (Brady and Weil, 2008). The slight decrease observed in November 2018 (64±2.25%) may reflect seasonal compaction effects or reduced biological activity. A notable finding is the significant decrease in porosity recorded in June 2019 (42±2.64%; $p<0.05$), which can be explained by the absence of crop cultivation during this period and reduced irrigation, which likely affected soil structure. Similar patterns have been reported in studies highlighting the importance of vegetation cover and soil management in maintaining soil structure (Hillel, 2003). High soil porosity is generally associated with enhanced water retention, increased permeability, and good soil aeration, conditions that favour plant growth. However, excessively high porosity may sometimes be associated with lower soil bearing capacity (Wall & Heiskanen, 2009).

Regarding the porosity of uncultivated and flower soil, the results show that the porosity was 60±2.11% in November 2017, respectively 62±1.14% in November 2018, while in June 2019 decreased to 50±4.60%. The porosity of the commercial flower soil was 56±2.21%. Except for the garden soil porosity recorded in June 2019, all other garden soil porosity values observed during the monitoring period are higher than those measured for the uncultivated soil and the commercial flower soil. This indicates that garden soil generally exhibits a higher porosity compared to the other two soil types, suggesting improved soil structure, higher permeability, and better aeration under the monitored conditions.

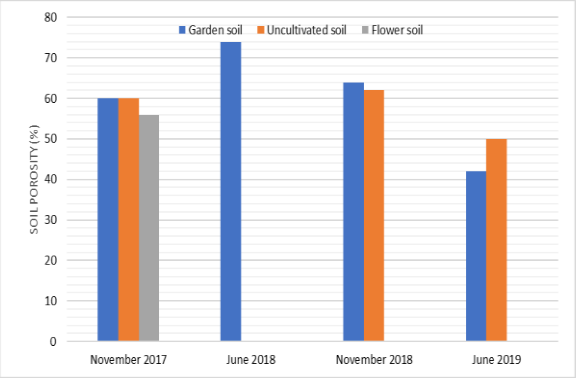

Figure 3. Variation of soil porosity values in garden, uncultivated, and flower soils during the sampling period

Soil alkalinity is a critical parameter influencing nutrient availability, microbial activity, and overall soil structure. Soil alkalinity for the monitoring samples is presented in Figure 5.

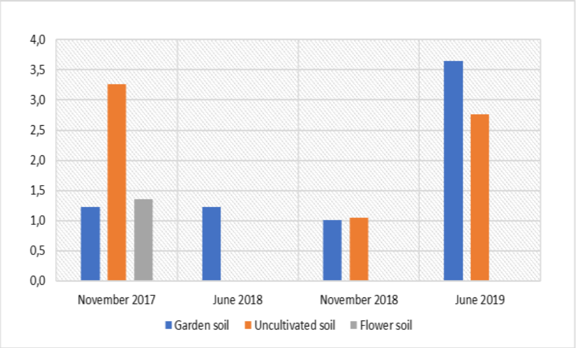

Figure 4. Variation of soil alkalinity values in garden, uncultivated, and flower soils during the sampling period

The results obtained in the present study indicate relatively stable alkalinity values between November 2017 and November 2018, followed by a significant increase ($p<0.5$) in June 2019. This abrupt rise can be attributed to anthropogenic inputs, particularly compost application and irrigation with bicarbonate-rich water. Similar increases in soil alkalinity following irrigation with $NaHCO_3$-rich water have been reported in agricultural systems, where dissolved carbonates contribute to the accumulation of exchangeable bases and increased soil pH (Yang et al., 2024).

The alkalinity values recorded in the present study (approximately 1–3.26 meq/100 g soil) fall within the range reported for moderately alkaline soils in temperate agricultural environments (Brady and Weil, 2008). Higher alkalinity observed in uncultivated soil compared to garden soil suggests a reduced buffering capacity and limited management intervention, which allows natural accumulation of basic cations. Comparable findings have been reported by Hussain *et al.,* (2026), who showed that unmanaged soils tend to accumulate soluble salts and carbonates, leading to increased alkalinity over time. The significant decrease in alkalinity observed in November 2018 (1.04±0.16 meq/100 g soil) may be associated with the absence of sodium carbonate (Na_2CO_3) and the occurrence of physiological drought. Reduced soil moisture limits ion mobility and carbonate dissolution, leading to lower measurable alkalinity. Similar seasonal fluctuations have been described in studies examining soil chemical dynamics under varying moisture regimes (Sparks, 2003). Flower soil showed a slightly alkaline reaction (1.358±0.05 meq/100 g soil), whereas uncultivated soil recorded higher values (3.26±0.23 meq/100 g in November 2017 and 2,76±0.18 meq/100 g in June 2019).

Regarding the hydrolytic acidity across the monitored soils during the period, an increasing trend was observed. Particularly in the garden and uncultivated soil. In November 2017–June 2019 is presented in Figure 5. The results indicate distinct temporal dynamics depending on land use type. In garden soil, hydrolytic acidity showed relatively low values at the beginning of the monitoring period (approximately 1.12±0.05 meq H^+/100 g soil in November 2017), followed by a decrease in June 2018 (0.8±0.01 meq H^+/100 g soil). A significant increase was recorded in November 2018 (4.2±0.04 meq H^+/100 g soil), reaching a maximum in June 2019 (6.2±0.03 meq H^+/100 g soil). This trend suggests an accumulation of acidic cations (H^+ and Al^{3+}) in the soil solution, likely influenced by agricultural practices and nutrient dynamics.

Uncultivated soil exhibited a continuous increase in hydrolytic acidity throughout the monitoring period, from 0.97±0.02 meq H^+/100 g soil in November 2017 to 5.04±0.01meq H^+/100 g soil in November 2018, reaching the highest recorded value of 7.61±0.05 meq H^+/100 g soil in June 2019. This pronounced increase may reflect natural soil processes such as mineral weathering and leaching, leading to progressive acidification.

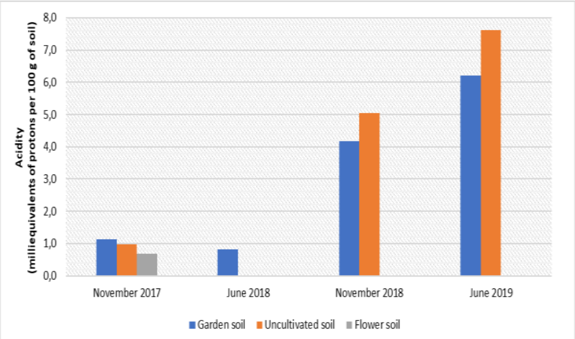

Figure 5. Variation of soil acidity values in garden, uncultivated, and flower soils during the sampling period

In contrast, flower soil showed comparatively low hydrolytic acidity, with values around 0.6±0.02 meq H^+/100 g soil in November 2017, indicating a more stable chemical status. Overall, the results highlight a significant increase in hydrolytic acidity over time, particularly in uncultivated and garden soils, suggesting ongoing soil acidification processes. These findings are in agreement with global trends reported in agricultural and natural ecosystems, where soil acidification is driven by both anthropogenic inputs and natural biogeochemical processes (Guo *et al.,* 2010). Hydrolytic acidity is a key parameter for estimating cation exchange capacity and determining lime amendment requirements, emphasizing the need for appropriate soil management practices to maintain optimal soil reaction.

Soil salinity, expressed as total soluble salts, is an important indicator of soil fertility and plant stress, influencing water uptake, osmotic balance, and nutrient availability. Figure 6 illustrates the variation in total soluble salt content in garden soil during the period November 2017 – June 2019. The values ranged between 0.69±0.02 (November 2017) and 1.68±0.02 g/100 g soil November 2018).

The lowest value was recorded in November 2017, followed by an increase in June 2018 (1.07 ±0.02 g/100 g soil) and a maximum in November 2018 (1.68±0.04 g/100 g soil). Subsequently, a decrease was observed in June 2019 (1.35±0.02 g/100 g soil). This variation is likely associated with plant uptake and differences in crop requirements for soluble salts.

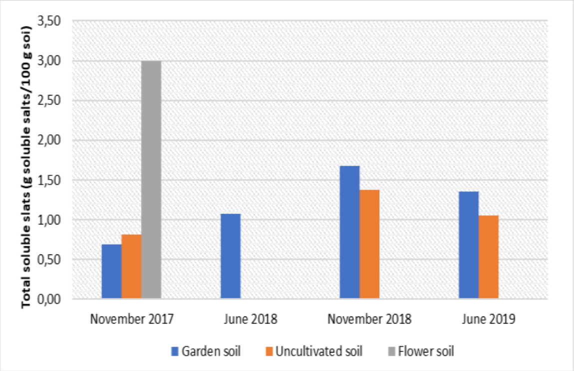

Figure 6. Variation of the total soluble salts of soil values in garden, uncultivated, and flower soils during the sampling period

Compared to garden soil, uncultivated soil exhibited generally lower values of total soluble salts. The content increased from 0.82±0.05 g/100 g soil in November 2017 to 1.38±0.02 g/100 g soil in November 2018, followed by a decrease to 1.05±0.04 g/100 g soil in June 2019.

In contrast, flower soil showed the highest concentration of total soluble salts (2.99±0.01 g/100 g soil), reflecting its higher content of organic matter and mineral nutrients, which are essential for supporting plant growth. Seasonal dynamics of soluble salts in soil can be explained by two main processes: accumulation during spring and summer, driven by intense evapotranspiration that increases solute concentration, and dilution during autumn and winter, when higher soil moisture promotes leaching and reduces salt concentration.

Ca^{2+} and Mg^{2+} varied significantly among soil types and sampling periods, reflecting both natural processes and anthropogenic influences, and are presented in Figure 7.

For flower soil, Ca^{2+} concentration reached 119.50±2.16 mg Ca^{2+}/100 g soil, indicating a relatively stable and balanced nutrient status. In garden soil, Ca^{2+} content showed a significant decreasing trend from November 2017 to November 2018, reaching a minimum of 17.70±1.14 mg Ca^{2+}/100 g soil, likely due to plant uptake, insufficient fertilization, and improper irrigation practices. A marked increase was recorded in June 2019 (78,90±2,15 mg Ca^{2+}/100 g soil), approaching the values observed in greenhouse soil, suggesting the effect of amendments and improved management.

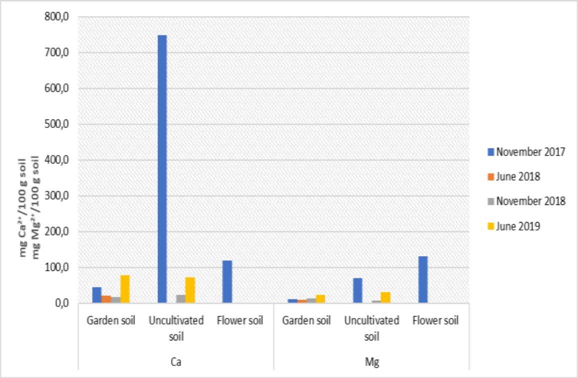

Figure 7. Variation of soil Ca^{2+} and Mg^{2+} values in garden, uncultivated, and flower soils during the sampling period (2017–2019).

Uncultivated soil exhibited extremely high Ca^{2+} levels at the beginning of the monitoring period (748.30±4.16 mg Ca^{2+}/100 g soil in November 2017), most likely due to contamination with construction residues rich in calcium carbonates. This value significantly decreased ($p<0.05$) in November 2018 (23.08±4.16 mg Ca^{2+}/100 g soil), indicating natural soil recovery processes, followed by a moderate increase in June 2019 (71.70 mg Ca^{2+}/100 g soil).

Magnesium content showed lower variability compared to calcium. In greenhouse soil, Mg^{2+} reached 131.20 mg Mg^{2+}/100 g soil. In garden soil, Mg^{2+} concentrations remained relatively stable between November 2017 and November 2018 (9.63±2.08; 12.53±1.18 mg Mg^{2+}/100 g soil), with a slight decrease in June 2018, likely due to plant uptake. A significant increase was observed in June 2019 (23.94±2.01 mg Mg^{2+}/100 g soil), associated with fertilization and irrigation inputs.

Overall, the results highlight the strong influence of land use and management practices on soil cation dynamics, with cultivated soils showing depletion-recovery patterns, while uncultivated soils exhibit initial anomalies followed by gradual stabilization.

Conclusions

The study demonstrated that soil physicochemical properties are strongly influenced by both environmental conditions and land use practices. Garden soil exhibited a slightly alkaline reaction with a gradual increase in pH and alkalinity, indicating a tendency toward alkalization, most likely driven by anthropogenic inputs such as irrigation and compost application.

Furthermore, seasonal variations in soil moisture and soluble salts revealed a clear interaction between water dynamics and salt accumulation, with evapotranspiration promoting salt concentration and wetter periods facilitating leaching processes. Changes in soil porosity reflected the impact of agricultural practices, with reduced porosity indicating potential structural degradation under limited management.

The increase in hydrolytic acidity suggests ongoing soil chemical transformations, including mineral weathering and the accumulation of acidic cations (H^+ and Al^{3+}), which influence soil buffering capacity and nutrient availability.

Variations in Ca^{2+} and Mg^{2+} concentrations highlighted the combined effects of plant uptake, fertilization, and external inputs. The depletion–recovery pattern observed in cultivated soils contrasts with the initially high cation concentrations in uncultivated soil, followed by gradual stabilization.

Overall, the findings demonstrate that soil physicochemical parameters are highly interconnected and represent sensitive indicators of soil quality and ecosystem functioning. Continuous monitoring of these parameters is essential for understanding soil degradation processes, improving nutrient management, and supporting sustainable agricultural practices. The study provides valuable information for the development of long-term soil conservation strategies aimed at maintaining soil fertility, structural stability, and environmental sustainability under different land-use conditions.

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