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Soil Macrofauna Community Structure and Integrated Quality Indicators as Measures of Ecosystem Recovery in Reclaimed Agricultural Land in Gharbia Governorate, Egypt

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ABSTRACT

This study investigates the effects of land use and seasonal variation on soil properties and macrofauna communities in reclaimed agricultural land of Gharbia Governorate, Egypt. A comparative analysis across cultivated, reclaimed, and degraded sites was conducted to assess physicochemical parameters (organic matter, pH, salinity, macro- and micronutrients) and soil macrofauna over four seasons. Reclaimed soils exhibited the highest organic matter and carbon content, particularly in spring, indicating the effectiveness of restoration practices. Degraded soils showed the lowest nutrient levels and faunal diversity, while cultivated soils showed intermediate conditions with higher faunal density but lower diversity. Seasonal dynamics significantly influenced soil properties, with autumn and spring being the most favourable for biological activity. Canonical Correspondence Analysis (CCA) revealed strong correlations between soil fauna and environmental factors such as moisture, organic matter, and nutrient availability. The study concludes that sustainable land management should incorporate seasonal variability and site-specific strategies to enhance soil health, nutrient cycling, and biodiversity. Although reclamation practices significantly promote ecosystem recovery, long-term monitoring and adaptive management remain essential for sustaining soil resilience in Egyptian agroecosystems.

Introduction

Soil is one of the most vital natural resources supporting life on earth. It forms the foundation for plant growth, which in turn provides food for humans and animals. However, in many regions across the globe, soil is facing increasing degradation due to both natural processes and human activities. This degradation results in reduced fertility, loss of biodiversity, erosion of topsoil, and ultimately poses serious threats to food security and environmental sustainability (FAO, 2020). However, in the Anthropocene, unprecedented levels of soil degradation have emerged. Current estimates indicate that 33–50% of global soils are moderately to severely degraded (FAO, 2022). This degradation manifests through: (1) **Physical degradation**, including compaction and erosion, affecting over 1.5 billion hectares worldwide (Borrelli et al., 2020); (2) **Chemical degradation**, through salinization, acidification, and pollution, with approximately 22% of agricultural lands showing reduced productivity due to chemical imbalances (Rengasamy, 2010); and (3) **Biological degradation**, marked by 40–60% declines in soil organic carbon and microbial biomass in intensively managed systems (Tsiafouli et al., 2015).

Different land uses, such as forests, grasslands, croplands, and degraded lands, create distinct soil environments that affect soil fauna. Natural forests and undisturbed grasslands typically support higher abundance and diversity of soil fauna due to greater organic matter, stable moisture, and less disturbance. In contrast, agricultural and degraded lands often show reduced faunal diversity and altered community structure, primarily due to lower organic carbon, nutrient depletion,

and physical disturbance from tillage or grazing. For example, conversion from forest to agriculture reduces soil microbial biomass and faunal abundance, while irrigated agriculture in semiarid regions can increase soil fauna by providing continuous water availability and altering community structure (Agbeshie et al., 2020; Singh et al., 2020; Da Silva Santana et al., 2021; Liu et al., 2024; Ligrone et al., 2024; Galli et al., 2025).

Key soil properties, such as organic carbon, nitrogen, phosphorus, pH, texture, and moisture, directly impact soil fauna. Higher organic matter and nutrient content support greater abundance and diversity, while soil pH and texture can select for specific faunal groups. For instance, soil pH is positively correlated with fauna density in acidic soils but negatively in alkaline soils. Soil texture (e.g., clay content) can restrict mobility and habitat availability for some taxa. (Kudureti et al., 2023; Lee et al., 2020; Heydari et al., 2020; Galli et al., 2025). Changes in these properties, driven by both land use and seasonal dynamics, alter the structure and function of soil faunal communities (Hermans et al., 2020; Heydari et al., 2020; Rakotonindrina et al., 2025; Galli et al., 2025).

Seasonal changes, such as shifts between wet and dry periods, affect soil moisture, temperature, nutrient availability, and pH, all of which influence soil fauna (Fu et al., 2020; Da Silva Santana et al., 2021; Solanki et al., 2024). Wet seasons generally increase soil moisture and organic matter decomposition, supporting higher faunal abundance and activity. Conversely, dry seasons can reduce soil porosity and water holding capacity,

leading to lower faunal populations and shifts in community composition. Seasonal variation also modulates the effects of land use, with differences in faunal communities often more pronounced during wetter periods (**Wang et al., 2022, Wu et al., 2023; Ligrone et al., 2024**).

Soil microarthropods, including groups such as Collembola and Acari, are integral to the functioning of agricultural ecosystems, contributing to nutrient cycling, organic matter decomposition, and pest suppression. Their diversity and abundance are closely linked to soil health, as these organisms respond sensitively to changes in soil structure, moisture, organic content, and management practices (**Neher & Barbercheck, 2019; Menta & Remelli, 2020; Galli et al., 2025**). Agricultural intensification, characterized by frequent tillage, monoculture, and high-input farming, often leads to a simplification of soil habitats, resulting in reduced microarthropod diversity and altered community composition (**Joimel et al., 2017; Galli et al., 2025; Tóth et al., 2025**).

The use of soil microarthropods as bioindicators has gained prominence due to their ability to reflect the biological quality of soils. Indices such as the QBS-ar (Biological Soil Quality Index) leverage the richness and eco-morphological traits of microarthropod communities to assess soil health, with higher index values indicating more diverse and resilient communities adapted to stable soil environments (**Menta & Remelli, 2020; Galli et al., 2025; Gallese et al., 2025**). These indices are effective for monitoring the impacts of different land uses and management regimes, providing a holistic measure that

integrates physical, chemical, and biological soil properties (**Tóth et al., 2025; Gallese et al., 2025; Mantoni et al., 2021**).

Land degradation, driven by intensive agriculture, soil compaction, and loss of organic matter, negatively affects soil fauna by reducing habitat quality and resource availability. This leads to declines in microarthropod abundance and diversity, which in turn can impair essential ecosystem services such as decomposition and nutrient cycling (**Joimel et al., 2017; Van Eekeren et al., 2022; Tóth et al., 2025**). Conversely, sustainable practices like organic farming, reduced tillage, and land protection have been shown to support higher microarthropod diversity and improve soil biological quality (**Coletta et al., 2025; Mantoni et al., 2021; Meyer et al., 2021**).

Construction and demolition activities on agricultural lands significantly disrupt soil fauna and soil microarthropods, impacting the ecological balance and soil health. These activities often lead to soil compaction, habitat destruction, and contamination with debris and pollutants, which directly reduce the abundance and diversity of soil fauna such as microarthropods.

Agricultural reclamation transforms degraded or abandoned lands into productive ecosystems, offering a powerful approach to restore soil fertility and ecological function. Through interventions such as soil reconstruction, vegetation restoration, and targeted fertilization, reclamation enhances soil physicochemical properties, boosting organic carbon, nitrogen, and microbial biomass, while reducing salinity and compaction. These improvements accelerate soil maturation and nutrient

cycling, supporting the reestablishment of productive landscapes and sustainable land use (Wang et al., 2016; Feng et al., 2019; Qi et al., 2020; Mao et al., 2024; Tang et al., 2025). A critical, yet often underappreciated, aspect of reclamation is its influence on soil fauna—organisms such as nematodes, earthworms, and microarthropods that drive decomposition, nutrient cycling, and soil structure formation. Studies show that comprehensive reclamation programs incorporating organic amendments (e.g., 10–20 tons/ha of compost) can increase soil organic matter by 35–150% within 3–5 years. Similarly, targeted mineral supplementation can correct nutrient deficiencies by 40–90% (FAO, 2021). Yet fertility restoration often follows nonlinear trajectories; severely degraded soils may require 5–15 years to regain 80% of native fertility (USDA, 2022). Although reclamation may not fully restore pre-degradation conditions, well-managed programs typically recover 60–90% of optimal agricultural productivity, making it an essential tool for sustainable land management (IPBES, 2020; IPBES 2023).

This study examines how land use and seasonal variation influence soil properties and macrofauna community structure in reclaimed agricultural lands of Gharbia Governorate, Egypt. The specific objectives are: (1) to compare soil characteristics and macrofaunal diversity among cultivated, reclaimed, and degraded sites across different seasons; and (2) to identify the key environmental drivers shaping community composition and evaluate soil and macrofaunal indicators of ecosystem recovery. It is hypothesized that reclaimed soils, benefiting from improved management practices and

organic inputs, will exhibit enhanced soil quality and greater macrofaunal diversity.

Materials and Methods

Study Site

The present study was conducted in Gharbia Governorate, Egypt, within the Nile Delta region, between Tanta City and Kafr El-Hima Village. Geographically, the study area is situated between latitudes 30°45′–30°52′ N and longitudes 30°55′–31°05′ E. Tanta City is located at coordinates 30°47′00″ N, 31°00′30″ E, while Kafr El-Hima Village lies at 30°48′30″ N, 31°01′45″ E. Fig. (1)

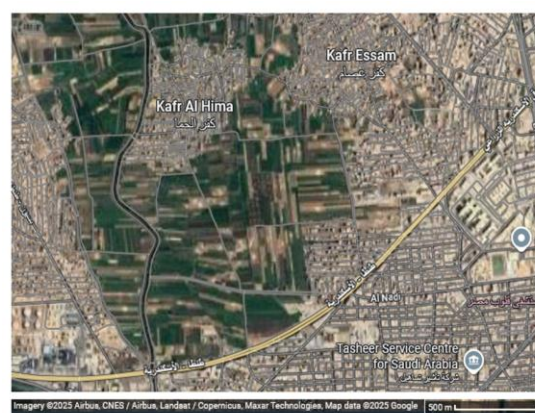


Fig. (1): Map of the study sites in Tanta City and Kafr El-Hima Village Gharbia Governorate, Egypt.

Sampling was conducted across four distinct seasons from November 2022 to August 2023. Soil samples were collected during each season, with the corresponding ambient temperatures recorded as follows: autumn (November 2022) ranged from 17°C (min) to 26°C (max), winter (February, 2023) 12°C (min) / 23°C (max), spring (May 2023) from 16°C (min) / 25°C (max), and summer (August 2023) 23°C (min) / 32°C (max). At each sampling location, three land-use types were selected for comparison: (1) cultivated agricultural soils, supporting seasonally rotated crops such as corn (*Zea mays*) in summer, and wheat (*Triticum aestivum*) in winter; (2)

degraded soils, which had been left fallow and repurposed for construction activities; and (3) reclaimed soils, which were previously cultivated, later abandoned for construction purposes, and subsequently rehabilitated for agricultural use with seasonal crops. From each land-use type, five random soil samples were collected using a cylindrical metal core (10 × 10 cm) to a depth of 10 cm. The samples were transported to the laboratory and processed using a Berlese-Tullgren funnel apparatus under gentle heat and light exposure for 5–7 days to extract soil fauna. Organisms were collected from the funnel base, preserved and fixed in 70% ethanol, and then cleared using lactic acid for taxonomic identification. Identification of soil oribatid mites to species level was conducted under a compound microscope, following the taxonomic keys and protocols provided by **Balogh (1972)**; **Al-Assiuty and Khalil (1991)**; **Balogh and Balogh (1992)**.

Physicochemical analyses

Physical and chemical analyses included measurements of temperature, moisture (oven-drying at 105°C), organic matter (loss-on-ignition at 550°C), pH (1:5 soil-water suspension), electrical conductivity (1:2.5 extract). The analytical methods for soil properties, including elemental composition (Ca, Mg, K via AAS; N via Kjeldahl method; P via NaHCO₃ extractable colourimetry. All procedures followed standard guidelines outlined in **Page et al. (1982)**, **Sparks et al. (1996)** and **Bashour and Sayegh, (2007)**

Statistical analysis

All data were expressed as mean ± standard deviation (SD). Statistical analyses were performed using SPSS version 27, Minitab version 21, Microsoft

Office 365 and GraphPad Prism version 8.3 for data processing and visualization. General Linear Models (GLM) and two-way ANOVA were applied to evaluate the effects of land-use type and seasonal variation on soil parameters. Tukey's Honest Significant Difference (HSD) post-hoc test ($p < 0.05$) was used for pairwise comparisons. Ecological diversity indices, including Shannon–Wiener diversity, Simpson dominance, and Pielou's evenness, were computed using PAST software (**Hammer et al., 2001**). Canonical Correspondence Analysis (CCA) was conducted to examine relationships between macrofaunal community composition and environmental variables (e.g., soil moisture, organic matter, pH, and nutrient availability) following the approach of **Ter Braak (1986)**; **Hammer et al., (2001)**.

Ethical clearance

Ethical clearance was obtained from the Ethics Committee of the Faculty of Science Tanta University (License Code: IACUC-SCI-TU-04268).

Result

The data analysis revealed significant variations in soil properties and biological communities across the three land-use types; cultivated (CUL), reclaimed (REC), and degraded (DEG), with pronounced seasonal dynamics.

Soil Physicochemical Properties

The foundational soil properties of organic matter, moisture, pH, and salinity exhibited distinct patterns driven by both land-use and season Table (1) and Fig. (2). Soil moisture content varied significantly between sites and seasons, with reclaimed and cultivated sites generally retaining higher moisture than degraded sites, especially after irrigation or rainfall events Table (1), Fig. (2a). Soil organic matter (OM) was highly significantly

influenced by site type ($p < 0.001$), season ($p < 0.001$), and their interaction ($p < 0.001$). Reclaimed soils exhibited the highest OM content, peaking in spring ($3.96 \pm 0.4\%$), while degraded soils consistently had the lowest levels, particularly in summer and spring ($1.55 \pm 0.14\%$ and $1.63 \pm 0.18\%$, respectively). Cultivated soils maintained intermediate OM levels Table (1), Fig. (2b). Soil salinity, measured by total dissolved salts (TDS), showed dramatic fluctuations. Reclaimed sites experienced extreme salt accumulation in summer (845.6 ± 80.43 ppm), whereas degraded soils showed a distinct winter peak (366.6 ± 74.23 ppm). Cultivated soils maintained relatively stable, low TDS levels (119-167.4 ppm) throughout the year. A two-way ANOVA confirmed highly significant effects of land-use, season, and their interaction (all $p < 0.001$) Table (1) and Fig. (2c).

Soil pH was primarily affected by land-use type ($p < 0.006$). Cultivated soils were consistently the most alkaline (peaking at pH 8.26 ± 0.36 in autumn), while reclaimed sites were the least alkaline (lowest at pH 7.24 ± 0.36 in spring). Degraded lands exhibited intermediate, stable pH levels (Fig 2d)

Macronutrient Dynamics

Carbon (C), nitrogen (N), phosphorus (P), and potassium (K) cycles displayed distinct and often decoupled patterns Table (2). Soil carbon content was highly significantly different among sites ($p < 0.001$) and seasons ($p < 0.001$). Reclaimed soils had the highest C levels in spring ($2.3 \pm 0.23\%$), followed by cultivated soils in autumn ($2.04 \pm 0.2\%$). Degraded soils consistently had the lowest C content (e.g., $0.9 \pm 0.08\%$ in summer). In contrast to carbon, nitrogen levels did not show significant main

effects for site or season alone, but a significant interaction was found ($p < 0.012$). Degraded soils had the highest N in autumn ($0.92 \pm 0.12\%$), likely due to reduced plant uptake, while cultivated soils peaked in spring ($0.92 \pm 0.07\%$) aligning with fertilization.

Phosphorus availability was strongly seasonal ($p < 0.001$). Degraded soils showed the highest available P in autumn (13.74 ± 2.06 mg/kg), whereas reclaimed soils exhibited low availability in winter (2.01 ± 0.28 mg/kg) but higher levels in spring and summer, indicating effective reclamation processes during growing seasons Table (2).

Potassium dynamics revealed that degraded soils consistently had the highest available K, particularly in autumn (1564.44 ± 187.73 mg/kg). Cultivated soils maintained intermediate levels, while reclaimed soils had the lowest available K, all sites showed a seasonal decline in available K during spring and summer due to increased plant uptake Table (2).

Secondary cation dynamics

Sodium (Na), magnesium (Mg), and calcium (Ca) exhibited contrasting mobilities. Reclaimed soils consistently showed the highest Na accumulation, peaking in summer (860 ± 103.2 mg/kg), indicating a potential risk from irrigation practices. Magnesium levels showed extreme seasonal fluctuations in reclaimed soils, ranging from 1500 mg/kg in autumn to 4800 mg/kg in winter Table (2). In contrast, calcium distribution was remarkably stable across seasons and sites, suggesting a strong buffering capacity in these soil systems Table (2).

Table (1): Soil properties of organic matter, moisture, Salinity and pH, across land-use types and seasons. Data expressed as (Mean $\pm$ SD)

Soil parameters	Season	Site			2 Way ANOVA	
		Cultivated	Reclaimed	Degraded	Source	p-value
SM %	autumn	25.4 $\pm$ 3.35 ^{a,b}	21.62 $\pm$ 2.56 ^{a,b,c}	17.43 $\pm$ 6.57 ^{c,d,e}	Type	< 0.001
	winter	27.76 $\pm$ 2.66 ^a	24.62 $\pm$ 3.33 ^{a,b}	18.77 $\pm$ 4.55 ^{b,c,d,e}	Season	< 0.001
	spring	20.52 $\pm$ 4.33 ^{b,c,d}	16.89 $\pm$ 5.47 ^{c,d,e}	14.31 $\pm$ 1.55 ^{d,e,f}	Type x Season	0.36 n.s.
	summer	19.70 $\pm$ 4.32 ^{b,c,d}	11.78 $\pm$ 1.24 ^{e,f}	9.80 $\pm$ 3.45 ^f		
OM %	autumn	3.51 $\pm$ 0.35 ^{a,b}	3.28 $\pm$ 0.36 ^{a,b}	2.91 $\pm$ 0.23 ^{b,c}	Type	< 0.001
	winter	2.19 $\pm$ 0.18 ^{c,d}	2.95 $\pm$ 0.35 ^{b,c}	2.32 $\pm$ 0.37 ^{c,d}	Season	< 0.001
	spring	2.85 $\pm$ 0.43 ^{b,c}	3.96 $\pm$ 0.4 ^a	1.63 $\pm$ 0.18 ^d	Type x Season	< 0.001
	summer	3.05 $\pm$ 0.25 ^{b,c}	2.94 $\pm$ 0.26 ^{b,c}	1.55 $\pm$ 0.14 ^d		
Salinity ppm	autumn	167.4 $\pm$ 14.03 ^d	260.8 $\pm$ 22.15 ^c	119 $\pm$ 40.97 ^d	Type	< 0.001
	winter	123.4 $\pm$ 14.36 ^d	146.25 $\pm$ 18.39 ^d	366.6 $\pm$ 74.23 ^b	Season	< 0.001
	spring	131.4 $\pm$ 14.77 ^d	168.53 $\pm$ 22.17 ^d	100.8 $\pm$ 32.9 ^d	Type x Season	< 0.001
	summer	161.4 $\pm$ 21.97 ^d	845.6 $\pm$ 80.43 ^a	152.6 $\pm$ 32.25 ^d		
pH	autumn	8.26 $\pm$ 0.36 ^a	7.38 $\pm$ 0.51 ^{b,c}	7.74 $\pm$ 0.11 ^{a,b,c}	Type	= 0.006
	winter	7.96 $\pm$ 0.27 ^{a,b}	7.74 $\pm$ 0.24 ^{a,b,c}	7.7 $\pm$ 0.16 ^{a,b,c}	Season	= 0.18
	spring	7.78 $\pm$ 0.3 ^{a,b,c}	7.24 $\pm$ 0.36 ^c	7.7 $\pm$ 0.16 ^{a,b,c}	Type x Season	= 0.004
	summer	7.6 $\pm$ 0.07 ^{a,b,c}	7.92 $\pm$ 0.58 ^{a,b,c}	7.62 $\pm$ 0.19 ^{a,b,c}		

p-value < 0.05 is considered significant. p-value < 0.001 is considered highly significant. Means that do not share the same subscript small letter (a,b,c,... etc) are significantly different (Tukey's test, $p < 0.05$).

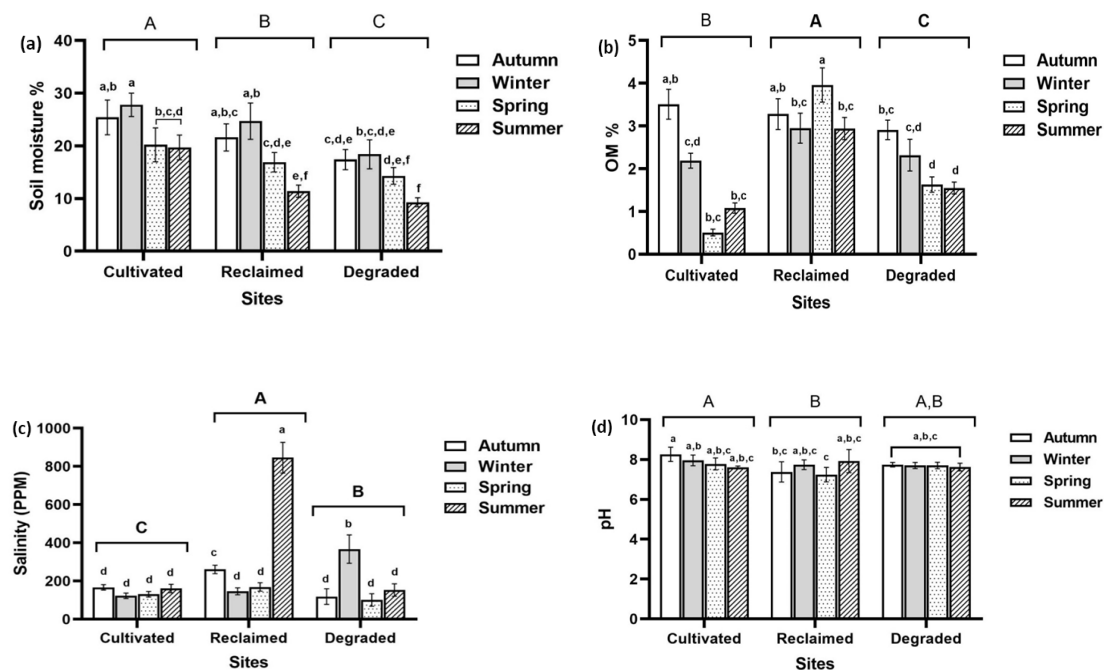
**Fig. (2):** Seasonal dynamics of core soil properties. (A) Organic Matter (OM%), (B) Soil Moisture (SM%), (C) pH, and (D) (Salinity, ppm) in cultivated (CULT), reclaimed (REC), and degraded (DEG) sites across four seasons

Table (2): Seasonal dynamics of macronutrient availability carbon (C%), Nitrogen (N%), Available Phosphorus (mg/kg), and Available Potassium (mg/kg) in cultivated (CULT), reclaimed (REC), and degraded (DEG) sites. Data expressed as (Mean $\pm$ SD)

Soil parameters	Season	Site			2 Way ANOVA	
		Cultivated	Reclaimed	Degraded	Source	p-value
C %	autumn	2.04 $\pm$ 0.2 ^{a,b}	1.9 $\pm$ 0.21 ^{a,b}	1.69 $\pm$ 0.14 ^{b,c}	Type	< 0.001
	winter	1.27 $\pm$ 0.1 ^{c,d}	1.71 $\pm$ 0.21 ^{b,c}	1.35 $\pm$ 0.22 ^{c,d}	Season	< 0.001
	spring	1.65 $\pm$ 0.25 ^{b,c}	2.3 $\pm$ 0.23 ^a	0.95 $\pm$ 0.1 ^d	Type x Season	< 0.001
	summer	1.77 $\pm$ 0.14 ^{b,c}	1.71 $\pm$ 0.15 ^{b,c}	0.9 $\pm$ 0.08 ^d		
N%	autumn	0.68 $\pm$ 0.09 ^{a,b}	0.76 $\pm$ 0.1 ^{a,b}	0.92 $\pm$ 0.12 ^a	Type	= 0.461
	winter	0.81 $\pm$ 0.09 ^{a,b}	0.78 $\pm$ 0.09 ^{a,b}	0.77 $\pm$ 0.08 ^{a,b}	Season	= 267
	spring	0.92 $\pm$ 0.07 ^a	0.69 $\pm$ 0.08 ^{a,b}	0.78 $\pm$ 0.06 ^{a,b}	Type x Season	< 0.012
	summer	0.62 $\pm$ 0.08 ^b	0.79 $\pm$ 0.17 ^{a,b}	0.73 $\pm$ 0.09 ^{a,b}		
P_{avi} mg/kg	autumn	9.23 $\pm$ 1.2 ^b	9.81 $\pm$ 1.28 ^b	13.74 $\pm$ 2.06 ^a	Type	< 0.001
	winter	5.05 $\pm$ 0.56 ^{c,d}	2.01 $\pm$ 0.28 ^e	4.8 $\pm$ 0.43 ^{c,d,e}	Season	< 0.001
	spring	2.57 $\pm$ 0.21 ^{d,e}	10.14 $\pm$ 1.12 ^b	5.45 $\pm$ 0.71 ^{c,d}	Type x Season	< 0.001
	summer	7.45 $\pm$ 0.82 ^{b,c}	9.65 $\pm$ 0.97 ^b	7.66 $\pm$ 0.61 ^{b,c}		
K_{avi} mg/kg	autumn	996.6 $\pm$ 129.56 ^b	613.13 $\pm$ 67.44 ^c	1564.44 $\pm$ 187.73 ^a	Type	= 0.006
	winter	968.52 $\pm$ 106.54 ^b	697.08 $\pm$ 90.62 ^{b,c}	1357.09 $\pm$ 149.28 ^a	Season	= 0.18
	spring	793.49 $\pm$ 71.41 ^{b,c}	752.68 $\pm$ 90.32 ^{b,c}	586.09 $\pm$ 58.61 ^c	Type x Season	= 0.004
	summer	704.24 $\pm$ 105.64 ^{b,c}	612.8 $\pm$ 73.54 ^c	883.81 $\pm$ 106.06 ^{b,c}		
Na mg/kg	autumn	360 $\pm$ 46.8 ^e	660 $\pm$ 79.2 ^{b,c}	440 $\pm$ 44 ^{d,e}	Type	< 0.001
	winter	560 $\pm$ 50.4 ^{b,c,d}	660 $\pm$ 92.4 ^{b,c}	500 $\pm$ 40 ^{c,d,e}	Season	= 0.016
	spring	390 $\pm$ 39 ^{d,e}	740 $\pm$ 81.4 ^{a,b}	460 $\pm$ 50.6 ^{d,e}	Type x Season	= 0.004
	summer	410 $\pm$ 49.2 ^{d,e}	860 $\pm$ 103.2 ^a	470 $\pm$ 37.6 ^{d,e}		
Ca mg/kg	autumn	7300 $\pm$ 949 ^{a,b}	6900 $\pm$ 828 ^{a,b}	6700 $\pm$ 737 ^{a,b}	Type	= 0.01
	winter	7700 $\pm$ 616 ^{a,b}	5700 $\pm$ 798 ^b	7000 $\pm$ 1050 ^{a,b}	Season	= 0.830
	spring	6900 $\pm$ 1104 ^{a,b}	6600 $\pm$ 726 ^{a,b}	7500 $\pm$ 825 ^{a,b}	Type x Season	= 0.147
	summer	7100 $\pm$ 852 ^{a,b}	6100 $\pm$ 610 ^{a,b}	8300 $\pm$ 747 ^a		
Mg mg/kg	autumn	1900 $\pm$ 247 ^{d,e}	1500 $\pm$ 150 ^{e,f}	2900 $\pm$ 232 ^{b,c}	Type	< 0.001
	winter	2600 $\pm$ 208 ^{c,d}	4800 $\pm$ 576 ^a	3000 $\pm$ 480 ^{b,c}	Season	< 0.001
	spring	2400 $\pm$ 384 ^{c,d,e}	2400 $\pm$ 264 ^{c,d,e}	3100 $\pm$ 341 ^{b,c}	Type x Season	< 0.001
	summer	2800 $\pm$ 336 ^{b,c,d}	3700 $\pm$ 370 ^b	800 $\pm$ 72 ^f		

p-value < 0.05 is considered highly significant. Means that do not share the same letter are significantly different (Tukey's test, $p < 0.05$)

Composition and diversity of soil fauna

The abundance and diversity of soil fauna varied substantially among land-use types and seasons (Tables 3 and 4). Across all sites, ten species were identified within seven families, dominated by Oribatid mites and Collembola.

In autumn, cultivated soils showed the highest total abundance (139 individuals)

compared to degraded ones (38 individuals). Dominant taxa included *Scheloribates laevigatus* and *S. confundatus* (D5) in cultivated and reclaimed soils. Diversity indices were high ($H' = 2.07$ - 2.15 ; $1-D = 0.85$ - 0.87), with evenness ($E \approx 0.9$) indicating balanced communities.

During winter, total abundance increased markedly in cultivated (272 individuals)

and degraded (187 individuals) soils. *Lohmannia hispaniola* and *S. laevigatus* were dominant species. Shannon diversity declined ($H' = 1.52-1.87$) due to stronger species dominance and reduced evenness.

In spring, *S. confundatus* and *Collembola* dominated cultivated and reclaimed soils, whereas degraded soils showed reduced abundance (29 individuals). Diversity ranged between $H' = 1.40-1.94$, with evenness 0.81- 0.93.

By summer, total abundance declined markedly (50 individuals in degraded soils), though *S. confundatus* remained dominant across all sites. Diversity indices ($H' = 1.50-1.91$) reflected the seasonal decline in fauna activity and microhabitat availability.

Overall, cultivated soils supported the most diverse and abundant communities across all seasons, while degraded soils exhibited simplified assemblages dominated by few tolerant taxa.

CCA analysis:

The Canonical Correspondence Analysis (CCA) revealed clear seasonal shifts in the relationships between soil fauna assemblages, land-use types, and environmental variables. In autumn, soil

fauna communities were mainly structured by organic matter and moisture, showing post-drought recovery in cultivated and reclaimed soils. During winter, moisture and nitrogen were the dominant drivers, supporting higher faunal abundance in cultivated soils, while reclaimed and degraded soils were influenced by salinity and sodium accumulation. In spring, organic matter, carbon, and nutrient availability governed community structure, producing the greatest differentiation among land-use types and the highest biodiversity. By summer, desiccation and salinity stress became the main controlling factors, resulting in reduced abundance and simplified communities dominated by xerophilic taxa.

Overall, the CCA indicates a seasonal ecological gradient where moisture and nutrient availability drive faunal diversity in cooler, wetter seasons, while salinity and drought stress constrain communities during hot, dry periods. This demonstrates that both land-use management and seasonal climate jointly regulate soil fauna distribution and ecosystem functioning.

Table (3): Abundance and relative contribution (%) of soil fauna in all studied sites in autumn and winter

Species	Autumn			Winter		
	Abundance (R.C. %) D			Abundance (R.C. %) D		
	Cultivated	Reclaimed	Degraded	Cultivated	Reclaimed	Degraded
Family Oribatulidae						
<i>Scheloribates laevigatus</i>	31 (22.3%) D5	11 (17.2%) D5	5 (13.2%) D5	91 (33.5%) D5	8 (5.8%) D4	47 (25.1%) D5
<i>Scheloribates confundatus</i>	12 (8.6%) D4	10 (15.6%) D5	-	1 (0.4%) D1	1 (0.7%) D1	2 (1.1%) D2
Family Haplozetidae						
<i>Xylobates capucinus</i>	5 (3.6%) D3	11 (17.2%) D5	10 (26.3%) D5	1 (0.4%) D1	5 (3.6%) D3	19 (10.2%) D5
Family Oribatellidae						
<i>Lamellobates h. egyptica</i>	-	8 (12.5%) D5	1 (2.6%) D3	-	-	-
Family Oppiidae						
<i>Oppia trifurcata</i>	10 (7.2%) D4	4 (6.3%) D4	4 (10.5%) D5	3 (1.1%) D2	8 (5.8%) D4	-
<i>Oppia variance</i>	1 (0.7%) D1	1 (1.6%) D2	-	2 (0.7%) D1	-	-
Family Euphthiracaridae						
<i>Rhysotritia ardua ardua</i>	-	2 (3.1%) D3	-	1 (0.4%) D1	10 (7.3%) D4	3 (1.6%) D2
Family Epilohmannidae						
<i>Epilohmannia pallida</i>	11 (7.9%) D4	-	1 (2.6%) D3	-	4 (2.9%) D3	4 (2.1%) D3
<i>Epilohmannia cylindrica</i>	23 (16.5%) D5	-	-	8 (2.9%) D3	-	1 (0.5%) D1
Family Lohmannidae						
<i>Lohmania hispaniola</i>	-	-	-	-	13 (9.5%) D4	58 (31%) D5
Prostigmata	8 (5.8%) D4	11 (17.2%) D5	8 (21.1%) D5	20 (7.4%) D4	34 (24.8%) D5	38 (20.3%) D5
Collembola	7 (5%) D4	2 (3.1%) D3	5 (13.2%) D5	87 (32%) D5	49 (35.8%) D5	10 (5.3%) D4
Other	31 (22.3%) D5	4 (6.3%) D4	4 (10.5%) D5	58 (21.3%) D5	5 (3.6%) D3	5 (2.7%) D3
Total abundance per samples	139	64	38	272	137	187
Number of species	10	10	8	10	10	10
Dominance (D)	0.14	0.12	0.14	0.26	0.21	0.21
Simpson (1-D)	0.85	0.87	0.85	0.74	0.79	0.79
Equitability	0.89	0.93	0.94	0.65	0.80	0.76
Shannon (H')	2.07	2.15	1.97	1.52	1.87	1.77
Evenness	0.79	0.86	0.89	0.46	0.65	0.59

R.C. = relative contribution (%), D = Dominance classes for the identified mites are eudominants (D5) with D > 10.0%, dominants (D4) with D of 5.1–, 10.0%, subdominants (D3) with D of 2.1–5.0%, recedents (D2) with D of 1.1–2.0 and subrecedents (D1) with D < 1.1%. (Engelmann, 1978)

Table (4): Abundance and relative contribution (%) of soil fauna in all studied sites in spring and summer

Species	Spring			Summer		
	Abundance (R.C.%) D			Abundance (R.C.%) D		
	Cultivated	Reclaimed	Degraded	Cultivated	Reclaimed	Degraded
Family Oribatulidae						
<i>Scheloribates laevigatus</i>	3 (1.6%) D2	-	-	11 (10.3%) D5	3 (8.3%) D4	-
<i>Scheloribates confundatus</i>	41 (21.5%) D5	18 (28.6%) D5	15 (51.7%) D5	16 (15%) D5	12 (33.3%) D5	18 (36%) D5
Family Haplozetidae						
<i>Xylobates capucinus</i>	7 (3.7%) D3	-	-	30 (28%) D5	5 (13.9%) D5	-
Family Oribatellidae						
<i>Lamellobates h. egyptica</i>	-	-	-	1 (0.9%) D1	-	1 (2%) D3
Family Oppiidae						
<i>Oppia trifurcata</i>	5 (2.6%) D3	3 (4.8%) D3	-	-	-	-
<i>Oppia variance</i>	-	-	-	-	-	-
Family Euphthiracaridae						
<i>Rhysotritia ardua ardua</i>	5 (2.6%) D3	6 (9.5%) D4	2 (6.9%) D4	3 (2.8%) D3	1 (2.8%) D3	4 (8%) D4
Family Epilohmannidae						
<i>Epilohmannia pallida</i>	1 (0.5%) D1	12 (19%) D5	-	13 (12.1%) D5	3 (8.3%) D4	17 (34%) D5
<i>Epilohmannia cylindrica</i>	-	-	-	-	-	-
Family Lohmannidae						
<i>Lohmania hispaniola</i>	-	3 (4.8%) D3	-	-	-	-
Prostigmata	37 (19.4%) D5	6 (9.5%) D4	2 (6.9%) D4	12 (11.2%) D5	7 (19.4%) D5	3 (6%) D4
Collembola	61 (31.9%) D5	11 (17.5%) D5	6 (20.7%) D5	1 (0.9%) D1	-	-
Other	31 (16.2%) D5	4 (6.3%) D4	4 (13.8%) D5	20 (18.7%) D5	5 (13.9%) D5	7 (14%) D5
Total abundance per samples	191	63	29	107	36	50
Number of species	9	8	5	9	7	6
Dominance (D)	0.20	0.16	0.28	0.16	0.17	0.26
Simpson (1-D)	0.79	0.83	0.71	0.83	0.82	0.73
Equitability	0.78	0.93	0.87	0.87	0.94	0.84
Shannon (H')	1.73	1.94	1.40	1.91	1.83	1.50
Evenness	0.62	0.87	0.81	0.75	0.89	0.75

R.C. = relative contribution (%), D = Dominance classes for the identified mites are eudominants (D5) with D > 10.0%, dominants (D4) with D of 5.1–, 10.0%, subdominants (D3) with D of 2.1–5.0%, recedents (D2) with D of 1.1–2.0 and subrecedents (D1) with D < 1.1%. (Engelmann, 1978)

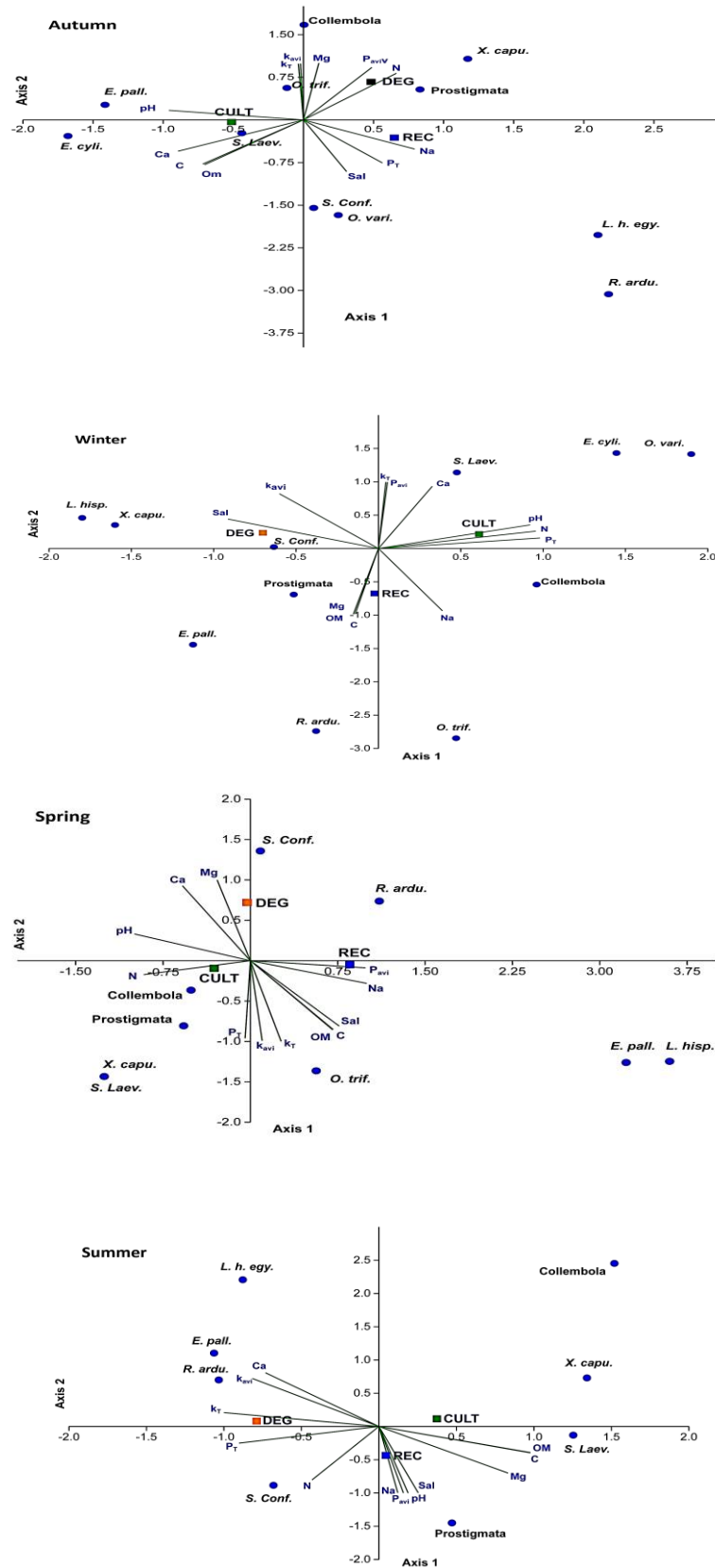


Fig. (3): Canonical correspondence analysis (CCA) ordination of soil fauna composition in relation to abiotic factors and land-use types (CULT = cultivated; REC reclaimed; DEG = degraded) in different seasons

Discussion

This study reveals significant variations in soil physicochemical properties and faunal communities across three distinct land-use types across cultivated, reclaimed, and degraded land-use types, considering seasonal variations in an arid agricultural context in the Nile Delta. The results demonstrate that both land-use management and seasonal dynamics jointly regulate soil ecosystem functioning, with cultivated soils generally supporting the most diverse and abundant faunal communities, while degraded soils exhibited simplified assemblages dominated by stress-tolerant taxa. Reclaimed soils, with their elevated organic matter and balanced fauna, represent a promising model for sustainable soil rehabilitation.

Soil Physicochemical Properties

The study revealed significant variations in fundamental soil properties, organic matter (OM), salinity (electrical conductivity, EC), pH, and moisture content, driven by both land-use type and seasonal dynamics. Reclaimed soils consistently exhibited the highest OM content, particularly in spring, while degraded soils maintained the lowest levels throughout the year. Cultivated soils showed intermediate OM levels. This aligns with findings by **Asmare et al., (2023)** and **Abile et al. (2025)**, who also reported significant impacts of land-use type on soil physicochemical properties. The higher OM in reclaimed soils suggests successful rehabilitation efforts or specific management practices that enhance carbon sequestration, contrasting with the depleted OM in degraded lands, a common characteristic of disturbed ecosystems (**Chen et al., 2024**).

Soil salinity demonstrated dramatic fluctuations, with reclaimed sites experiencing extreme salt accumulation in summer, while degraded soils showed a distinct winter peak. Cultivated soils maintained relatively stable, low salinity levels. This seasonal and land-use specific salinity pattern is critical, as high salinity negatively correlates with soil organic carbon content and can impact nutrient availability and microbial diversity (**Hassani et al., 2024; Akkacha et al., 2025**). The observed high salinity in reclaimed soils during summer could indicate issues with irrigation practices or insufficient drainage, a challenge often faced in reclamation projects (**Pessoa et al., 2022**).

Soil pH was primarily influenced by land-use type, with cultivated soils being the most alkaline and reclaimed sites the least alkaline. Degraded lands exhibited intermediate, stable pH levels. Soil pH plays a crucial role in nutrient availability and microbial activity, and its variation across land uses underscores differing biogeochemical processes (**Lallaouna et al., 2025**). Soil moisture content also varied significantly, with reclaimed and cultivated sites generally retaining higher moisture than degraded sites, especially after irrigation or rainfall. This highlights the importance of land management in maintaining soil water holding capacity, which is vital for ecosystem functioning, particularly in arid or semi-arid regions (**Kurylo et al., 2024**).

Key soil properties, such as organic carbon, nitrogen, phosphorus, pH, texture, and moisture, directly impact soil fauna. Higher organic matter and nutrient content support greater abundance and diversity, while soil pH and texture can select for specific faunal groups. For instance, soil pH is positively correlated

with fauna density in acidic soils but negatively in alkaline soils. Soil texture (e.g., clay content) can restrict mobility and habitat availability for some taxa. Changes in these properties, driven by both land use and seasonal dynamics, alter the structure and function of soil faunal communities (Kudureti et al., 2023; Lee et al., 2020; Rakotonindrina et al., 2025; Heydari et al., 2020; Galli et al., 2025; Xu et al., 2025).

Macronutrient and Secondary Cation Dynamics

Phosphorus availability was strongly seasonal, with degraded soils showing the highest available P in autumn, while reclaimed soils exhibited low availability in winter but higher levels in spring and summer, suggesting effective reclamation processes during growing seasons. Potassium dynamics revealed that degraded soils consistently had the highest available K, while reclaimed soils had the lowest. Seasonal declines in available K were observed across all sites during spring and summer due to increased plant uptake. These patterns reflect the complex interplay between nutrient cycling, plant demand, and soil management practices, as highlighted by Mandah et al., (2024) and Thant et al., (2025).

Secondary cations, sodium (Na), magnesium (Mg), and calcium (Ca), also showed varied mobilities. Reclaimed soils consistently exhibited the highest Na accumulation, peaking in summer, indicating a potential risk from irrigation practices. Magnesium levels showed extreme seasonal fluctuations in reclaimed soils, while calcium distribution was remarkably stable across seasons and sites. High sodium levels in reclaimed soils are a common problem in saline-sodic soils, which can negatively

impact soil structure and nutrient availability (Meng et al., 2025; Rakotonindrina et al., 2025). The stability of calcium, conversely, suggests a strong buffering capacity within these soil systems, crucial for maintaining soil health (Ozlu et al., 2024).

Soil Fauna Composition and Diversity

The abundance and diversity of soil fauna varied substantially among land-use types and seasons, dominated by Oribatid mites and Collembola. Cultivated soils generally supported the most diverse and abundant communities across all seasons, while degraded soils exhibited simplified assemblages dominated by few tolerant taxa. This is in line with research indicating that land-use intensity and disturbance significantly impact soil biodiversity, with more diverse and stable communities found in less disturbed or well-managed systems (Lacerda-Júnior, et al., 2019).

Overall, cultivated soils maintained the most stable physicochemical environment and supported the highest abundance and diversity of soil fauna across seasons. For reclaimed sites exhibited more balanced communities with moderate densities and high diversity, suggesting successful ecological restoration. Degraded soils maintained the lowest densities but relatively high evenness, characterized by generalist species (*Scheloribates confundatus*) adapted to harsh conditions. Seasonal analysis revealed autumn and spring as optimal periods for soil biodiversity, benefiting from favorable temperature and moisture conditions, while summer and winter showed dominance effects despite high densities. Notably, reclaimed sites demonstrated remarkable temporal stability (summer-autumn similarity=0.60), compared to the

stochastic communities in degraded soils. Species exhibited clear habitat preferences, with *Xylobates capucinus* and *Epilohmannia pallida* thriving in cultivated lands versus *Oppia trifurcata* and *Rhysotritia ardua* in reclaimed sites, while *Scheloribates confundatus* served as a reliable disturbance indicator.

The seasonal decline in fauna activity and microhabitat availability observed in summer across all sites underscores the influence of environmental stressors, such as desiccation, on soil invertebrate populations. Many studies revealed reclamation practices can significantly increase the abundance and diversity of soil fauna by improving food resources and habitat quality, especially when organic amendments and diverse vegetation are introduced (Wang et al., 2016; Yang et al., 2021; Józefowska et al., 2023; Zhu et al., 2023). Enhanced soil fauna communities, in turn, contribute to the maturation and resilience of the soil food web, further promoting soil fertility and ecosystem multifunctionality (Yang et al., 2021; Zhu et al., 2023; Mamabolo et al., 2024). However, the effects of reclamation on soil fauna are shaped by management choices: sustainable practices that minimize disturbance and prioritize organic inputs tend to support richer and more functional soil faunal communities, while intensive or conventional approaches may reduce their abundance and diversity (Mamabolo et al., 2024; Menezes-Oliveira et al., 2021). The Canonical Correspondence Analysis (CCA) provides critical insights into the mechanistic drivers of community assembly. The analysis revealed three critical insights: (1) distinct environmental gradients structuring communities in cultivated, degraded and

reclaimed sites, (2) identification of indicator species (e.g., salinity-tolerant mites) reflecting specific management histories, and (3) seasonal shifts in biodiversity patterns demonstrating ecosystem resilience.

Canonical Correspondence Analysis (CCA) further elucidated the relationships between soil fauna assemblages, land-use types, and environmental variables. The analysis revealed three critical insights: (1) distinct environmental gradients structuring communities in cultivated, degraded and reclaimed sites, (2) identification of indicator species (e.g., salinity-tolerant mites) reflecting specific management histories, and (3) seasonal shifts in biodiversity patterns demonstrating ecosystem resilience. In autumn, organic matter and moisture were key drivers, while in winter, moisture and nitrogen became dominant. Spring saw organic matter, carbon, and nutrient availability governing community structure, leading to the greatest differentiation among land-use types and highest biodiversity. By summer, desiccation and salinity stress became the main controlling factors, resulting in reduced abundance and simplified communities. This seasonal ecological gradient, where moisture and nutrient availability drive faunal diversity in cooler, wetter seasons and salinity/drought stress constrain communities during hot, dry periods, demonstrates the joint regulation of soil fauna distribution and ecosystem functioning by both land-use management and seasonal climate (Ding and Yu 2025).

Conclusion

In conclusion, this study provides compelling evidence that both land-use

practices (cultivated, reclaimed, degraded) and seasonal variations exert significant control over soil physicochemical properties, nutrient dynamics, and soil faunal communities. Reclaimed soils, while showing promise in organic matter accumulation, face challenges with seasonal salinity. Degraded soils consistently exhibit lower fertility and simplified biological communities, highlighting the long-term impacts of environmental stress. Cultivated soils generally maintain more stable conditions and support higher biodiversity. The intricate interactions revealed by this research underscore the necessity of adaptive and sustainable land management strategies that account for both anthropogenic impacts and natural seasonal cycles to preserve and enhance soil health and ecosystem services.

Reference

- Abile, H.; Fituma, K.; Mammo, S. (2025).** "Impact of land use types on selected soil physicochemical parameters in the case of Liben Jawi district, Ethiopia." *Sci. Rep.*, 15: 27944.
- Agbeshie, A.; Abugre, S.; Adjei, R.; Atta-Darkwa, T.; Anokye, J. (2020).** "Impact of land use types and seasonal variations on soil physico-chemical properties and microbial biomass dynamics in a tropical climate, Ghana." *Artif. Intell. Rev.*, 21(1): 34-49.
- Akkacha, A.; Douaoui, A.; Younes, K.; El Sawda, C.; Alsyouri, H.; El-Zahab, S.; Grasset, L. (2025).** "Investigating the impact of salinity on soil organic matter dynamics using molecular biomarkers and principal component analysis." *Sustainability*, 17(7): 2940.
- Al-Assiuty, A.I.; Khalil, M.A. (1991).** "The Egyptian soil acarina of suborder Oribatei with description of two new species of family Galumnidae (Jacot, 1925)." *J. Egypt. Ger. Soc. Zool.*, 6(B): 491–502.
- Altieri, M.A.; Nicholls, C.I. (2016).** "Traditional soil carbon management." In *Global Encyclopedia of Soil Science*. Springer, pp. 345–358.
- Asmare, T.K.; Abayneh, B.; Yigzaw, M.; Birhan, T.A. (2023).** "The effect of land use type on selected soil physicochemical properties in Shihatig watershed, Dabat district, Northwest Ethiopia." *Heliyon*, 9(5): e16038.
- Balogh, J. (1972).** *The Oribatid Genera of the World*. Akadémiai Kiadó, Budapest.
- Balogh, J.; Balogh, P. (1992).** *The Oribatid Mites Genera of the World*. Hungarian Natural History Museum Press, Budapest.
- Borrelli, P.; Robinson, D.A.; Panagos, P.; Lugato, E.; Yang, J.E.; Alewell, C.; Wuepper, D.; Montanarella, L.; Ballabio, C. (2020).** "Land use and climate change impacts on global soil erosion by water (2015–2070)." *Proc. Natl. Acad. Sci. U.S.A.*, 117(36): 21994–22001.
- Chen, H.; Rahmati, M.; Montzka, C.; Gao, H.; Vereecken, H. (2024).** "Soil physicochemical properties explain land use/cover histories in the last sixty years in China." *Geoderma*, 446: 116908.
- Coletta, M.; Monticelli, M.; D'Alessandro, A.; Gentili, C.; Torresi, A.; Waris, N.; La Terza, A. (2025).** "Managing soil to support soil biodiversity in protected areas agroecosystems: a comparison between arable lands, olive groves, and vineyards in the Conero Park (Italy)." *Environ. Monit. Assess.*, 197(2): 200.
- Da Silva Santana, M.; De Andrade, E.; De Oliveira, V.; Costa, B.; Da Silva, V.; De Freitas, M.; Cunha, T.; Giongo, V. (2021).** "Trophic groups of soil fauna in semiarid: impacts of land use change, climatic seasonality and environmental variables." *Pedobiologia*, 89(10):150774
- Ding, J.; Yu, S. (2025).** "Integrating soil physicochemical properties and microbial functional prediction to assess land-use impacts in a cold-region wetland ecosystem." *Life (Basel)*, 15(6): 972.
- Falkowski, P.; Fenchel, T.; Delong, E.F. (2008).** "The microbial engines that

- drive Earth's biogeochemical cycles." *Science*, 320(5879): 1034–1039.
- FAO. (2020).** State of the World's Soil Resources. Food and Agriculture Organization of the United Nations.
- FAO. (2021).** *Global Soil Fertility Guidelines*. Food and Agriculture Organization of the United Nations Rome
- FAO. (2022).** Global Soil Organic Carbon Map (GSOCmap) (3rd ed.). Rome: Food and Agriculture Organization of the United Nations.
- Feng, Y.; Wang, J.; Bai, Z.; Reading, L. (2019).** "Effects of surface coal mining and land reclamation on soil properties: A review." *Earth-Sci. Rev.* 191:12-25
- Fu, D.; Wu, X.; Qiu, Q.; Duan, C.; Jones, D. (2020).** "Seasonal variations in soil microbial communities under different land restoration types in a subtropical mountain region, Southwest China." *Appl. Soil Ecol.* 153, 103634
- Gallese, F.; Gismero-Rodriguez, L.; Govednik, A.; Giagnoni, L.; Lumini, E.; Suhadolc, M.; Vaccari, F.; Maienza, A. (2025).** "Soil microarthropods as tools for monitoring soil quality: The QBS-ar index in three European agroecosystems." *Agriculture*, 15(1): 89.
- Galli, L.; Molyneux, T.; Trombini, E.; Zinni, M. (2025).** "Effects of land use on soil arthropod communities." *Diversity*, 17(4): 247.
- Hammer, Ø.; Harper, D.A.T.; Ryan, P.D. (2001).** "PAST: Paleontological statistics software package for education and data analysis." *Palaeontol. Electron.*, 4: 9 p.
- Hassani, A.; Smith, P.; Shokri, N. (2024).** "Negative correlation between soil salinity and soil organic carbon variability." *Proc. Natl. Acad. Sci. U.S.A.*, 121(18): e2317332121.
- Hermans, S.; Buckley, H.; Case, B.; Curran-Cournane, F.; Taylor, M.; Lear, G. (2020).** "Using soil bacterial communities to predict physico-chemical variables and soil quality." *Microbiome*, 8: 79.
- Heydari, M.; Eslaminejad, P.; Kakhki, F.; Mirab-Balou, M.; Omidipour, R.; Prévosto, B.; Kooch, Y.; Lucas-Borja, M. (2020).** "Soil quality and mesofauna diversity **relationship are modulated** by woody species and seasonality in semiarid oak forest." *For. Ecol. Manage.*, 473: 118332.
- IPBES. (2020).** IPBES-8/3: *Land Degradation and Restoration Assessment*. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
- IPBES. (2023).** Technical Report on Soil Biodiversity and Ecosystem Services: Assessment Framework and Methodological Guidelines. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
- Joimel, S.; Schwartz, C.; Hedde, M.; Kiyota, S.; Krogh, P.; Nahmani, J.; Pérès, G.; Vergnes, A.; Cortet, J. (2017).** "Urban and industrial land uses have a higher soil biological quality than expected from physicochemical quality." *Sci. Total Environ.*, 584–585: 614–621.
- Józefowska, A.; Woś, B.; Sierka, E.; Kompała-Bąba, A.; Bierza, W.; Klamerus-Iwan, A.; Chodak, M.; Pietrzykowski, M. (2023).** "How applied reclamation treatments and vegetation type affect soil fauna in a novel ecosystem developed on a spoil heap of carboniferous rocks." *Eur. J. Soil Biol.* 119, 103571
- Kremen, C.; Merenlender, A.M. (2018).** "Soil food web enhancement in working landscapes: Pathways to biodiversity conservation and sustainable agriculture." *Science*, 362(6412): eaau6020.
- Kudureti, A.; Zhao, S.; Zhakyp, D.; Tian, C. (2023).** "Responses of soil fauna community under changing environmental conditions." *J. Arid Land*, 15: 620–636.
- Kurylo, J.S.; Le, J.T.; Mehring, A.; Ambrose, R.F. (2024).** "Management dampens seasonal variability in soil microclimates and alters its chemical

- and physical properties in a semi-arid region." *J. Urban Ecol.*, 10(1): juae001.
- Lacerda-Júnior, G.V.; Noronha, M.F.; Cabral, L.; Delforno, T.P.; de Sousa, S.T.P.; Fernandes-Júnior, P.I.; Melo, I.S.; Oliveira, V.M. (2019).** "Land use and seasonal effects on the soil microbiome of a Brazilian dry forest." *Front. Microbiol.*, 10: 648.
- Lallaouana, R.; Ababsa, N.; Chenchouni, H. (2025).** "Soil physiochemical properties and soil fertility indicators of two cropping systems under semiarid climate conditions." *Environ. Adv.*, 21: 100663.
- Lee, S.; Kim, J.; Kim, Y.; Joa, J.; Kang, S.; Ahn, J.; Kim, M.; Song, J.; Weon, H. (2020).** "Different types of agricultural land use drive distinct soil bacterial communities." *Sci. Rep.*, 10: 74193.
- Ligrone, A.; Alvarez, M.; Jorge-Escudero, G.; Piñeiro, G. (2024).** "Seasonal dynamics of agricultural land use impacts on earthworm communities: Insights into diversity, abundance, and functional composition." *Eur. J. Soil Biol.* 120,103588
- Liu, X.; Liang, S.; Tian, Y.; Wang, X.; Liang, W.; Zhang, X. (2024).** "Effect of land use on soil nematode community composition and co-occurrence network relationship." *J. Integr. Agric.* 23, (8): 2807-2819
- Mamabolo, E.; Gaigher, R.; Pryke, J. (2024).** Conventional agricultural management negatively affects soil fauna abundance, soil physico-chemical quality and multif-unctionality. *Pedobiologia.* 104, 150961
- Mandah, V.P.; Tematio, P.; Onana, A.A.; Fiaboe, K.K.M.; Arthur, E.; Giweta, M.H.; Ndango, R.; Silatsa, F.B.T.; Voulemo, D.D.I.; Biloa, J.B.; Nguemezi, C.; Masso, C. (2024).** Variability of soil organic carbon and nutrient content across land uses and agriculturally induced land use changes in the forest-savanna transition zone of Cameroon. *Geoderma Regional*, 37: e00808. in coastal agricultural fields (Publication No. AG-439-87). *NC State*
- Mantoni, C.; Pellegrini, M.; Dapporto, L.; Del Gallo, M.; Pace, L.; Silveri, D.; Fattorini, S. (2021).** Comparison of soil biology quality in organically and conventionally managed agro-ecosystems using microarthropods. *Agriculture.* 11(10), 1-18
- Mao, Z.; Harris, J.; Zhang, Z. (2024).** Responses of natural micro-organisms to land reclamation and applications of functional microorganisms in bioremediation of coal mining area. *Diversity.* 16(2):86
- Menezes-Oliveira, V.; Bianchi, M.; Espíndola, E. (2021).** Changes in soil mesofauna structure due to different land use systems in south Minas Gerais, Brazil. *Environmental Monitoring and Assessment*, 193, 431
- Meng, Y.; Wang, T.; Zhou, X.; Yang, X.; Hernández, M.; Zhou, T.; Lv, Q.; Ren, X.; Feng, H.; Pan, H.; Hu, S. (2025).** Evaluating the optimal land use pattern for saline-sodic soils from the perspective of nitrogen metabolism. *Environmental Technology & Innovation*, 40: 104363.
- Menta, C.; Remelli, S. (2020).** Soil health and arthropods: from complex system to worthwhile investigation. *Insects*, 11(1), 54.
- Meyer, S.; Kundel, D.; Birkhofer, K.; Fliessbach, A.; Scheu, S. (2021).** Soil microarthropods respond differently to simulated drought in organic and conventional farming systems. *Ecology and Evolution*, 11: 10369–10380.
- Neher, D.A.; Barbercheck, M.E. (2019).** Soil microarthropods and soil health: intersection of decomposition and pest suppression in agroecosystems. *Insects*, 10(12): 414.
- Ozlu, E.; Hardy, D.; Gatiboni, L.; Ricker, M. (2024).** Effects of sodium salts on soils *Extension.*
- Page, A.L.; Miller, R.H.; Keeney, D.R. (1982).** Methods of Soil Analysis, Part 2: Chemical and Micro-biological Properties. American Society of Agronomy, Soil Science Society of America.
- Pessoa, L.G.M.; Freire, M.B. dos S.; Green, C.H.M.; Miranda, M.F.A.; de A. Filho, J.C.; Pessoa, W.R.L.S. (2022).** Assessment of soil salinity status under different land-use conditions in the

- semiarid region of Northeastern Brazil. *Ecological Indicators*, 141: 109139.
- Pointing, S.B.; Belnap, J. (2012).** Microbial colonization and controls in dryland systems. *Nature Reviews Microbiology*, 10(8): 551–562.
- Qi, L.; Zhou, P.; Yang, L.; Gao, M. (2020).** Effects of land reclamation on the physical, chemical, and microbial quantity and enzyme activity properties of degraded agricultural soils. *Journal of Soils and Sediments*, 20: 973–981.
- Rakotonindrina, V.; Andriamananjara, A.; Razafimbelo, T.; Okamoto, T.; Sarr, P. (2025).** Land cover and seasonal variations shape soil microbial communities and nutrient cycling in Madagascar tropical forests. *Microbial Ecology*, 88(1), 60.
- Rengasamy, P. (2010).** Soil processes affecting crop production in salt-affected soils. *Functional Plant Biology*, 37(7): 613–620.
- Santana, M.S.; Andrade, E.M.; Oliveira, V.R.; Costa, B.B.; Silva, V.C.; Freitas, M.S.C.; Cunha, T.J.F.; Giongo, V. (2021).** Trophic groups of soil fauna in semiarid: impacts of land use change, climatic seasonality and environmental variables. *Pedobiologia*, 89: 150774.
- Singh, A.; Jiang, X.; Yang, B.; Wu, J.; Rai, A.; Chen, C.; Ahirwal, J.; Wang, P.; Liu, W.; Singh, N. (2020).** Biological indicators affected by land use change, soil resource availability and seasonality in dry tropics. *Ecological Indicators*, 115: 106369.
- Solanki, A.; Gurjar, N.; Sharma, S.; Wang, Z.; Kumar, A.; Solanki, M.; Divvela, P.; Yadav, K.; Kashyap, B. (2024).** Decoding seasonal changes: soil parameters and microbial communities in tropical dry deciduous forests. *Frontiers in Microbiology*, 15:1258934
- Sparks, D.L.; Huang, P.M. (Eds.) (1996).** Potassium in Agriculture. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.
- Tang, Y.; Zhao, Y.; Li, Z.; He, M.; Sun, Y.; Hong, Z.; Ren, H. (2025).** A comprehensive evaluation of land reclamation effectiveness in mining areas: an integrated assessment of soil, vegetation, and ecological conditions. *Remote Sensing*, 17(10), 1744.
- Ter Braak, C.J.F. (1986).** Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology*, 67(5): 1167–1179.
- Thant, M.; Nakamura, A.; Ashton, L.A.; Liu, S.; Yang, X. (2025).** Assessing the impacts of forest conversion and seasonal dynamics on soil nutrient heterogeneity associated with termite mounds. *Forest Ecology and Management*, 589: 122768.
- Torsvik, V.; Øvreås, L. (2002).** Microbial diversity and function in soil: from genes to ecosystems. *Current Opinion in Microbiology*, 5(3): 240–245.
- Tóth, Z.; Vasileiadis, V.; Dombos, M. (2025).** An arthropod-based assessment of biological soil quality in winter wheat fields across Hungary. *Agriculture, Ecosystems & Environment*, 378, 109325
- Tsiafouli, M.A.; Thébault, E.; Sgardelis, S.P.; de Ruiter, P.C.; van der Putten, W.H.; Birkhofer, K.; Hemerik, L.; de Vries, F.T.; Bardgett, R.D.; Brady, M.V.; Bjornlund, L.; Jørgensen, H.B.; Christensen, S.; Hertefeldt, T.D.; Hotes, S.; Gera Hol, W.H.; Frouz, J.; Liiri, M.; Mortimer, S.R.; Setälä, H.; Hedlund, K. (2015).** Intensive agriculture reduces soil biodiversity across Europe. *Global Change Biology*, 21(2): 973–985.
- U.S. Department of Agriculture (USDA). (2022).** *Drought Resilience Interagency Working Group Summary Report*.
- Van Eekeren, N.; Jongejans, E.; Van Agtmaal, M.; Guo, Y.; Van Der Velden, M.; Versteeg, C.; Siepel, H. (2022).** Microarthropod communities and their ecosystem services restore when permanent grassland with mowing or low-intensity grazing is installed. *Agriculture, Ecosystems and Environment*, 323, 107682
- Wang, S.; Chen, H.; Tan, Y.; Fan, H.; Ruan, H. (2016).** Fertilizer regime impacts on abundance and diversity of

- soil fauna across a poplar plantation chronosequence in coastal Eastern China. *Scientific Reports*, 6, 20816
- Wang, Y.; Huang, B.; Yan, G.; Liu, G.; Xing, Y.; Wang, Q. (2022).** Effects of long-term nitrogen addition and seasonal variation on soil faunal community structure in a temperate natural secondary forest. *European Journal of Forest Research*, 141: 547–560.
- Wu, B.; Jiao, X.; Sun, A.; Li, F.; He, J.; Hu, H. (2023).** Precipitation seasonality and soil pH drive the large-scale distribution of soil invertebrate communities in agricultural ecosystems. *FEMS Microbiology Ecology*. 97, 1–9
- Xu, S.; Wang, C.; Zhou, J.; Shan, H.; Li, B.; Shi, W.; Zhang, D.; Zhu, G.; Yang, X.; Wei, W.; Ma, H. (2025).** Impacts of land use on soil carbon, nitrogen, and phosphorus in the Eastern Qilian Mountains. *PLoS One*, 20(7): e0326316.
- Yang, L.; Zhang, F.; Luo, Y. (2021).** A soil nematode community response to reclamation of salinized abandoned farmland. *Zoological Studies*, 60: e72.
- Zhu, Y.; Bian, H.; Ju, C.; Xu, C.; Zhou, Y.; Zhang, H.; Xu, X. (2023).** Fertilization alters the abundance but not the diversity of soil fauna: a meta-analysis. *Global Ecology and Biogeography*. 32: 482–494

بنية مجتمعات الحيوانات الأرضية الكبيرة ومؤشرات الجودة المتكاملة كمقاييس لاستعادة النظم البيئية في الأراضي الزراعية المستصلحة بمحافظة الغربية، مصر

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تتناول هذه الدراسة تأثيرات استخدامات الأراضي والتغيرات الموسمية على خصائص التربة ومجتمعات الحيوانات الأرضية الكبيرة (المكروفونا) في الأراضي الزراعية المستصلحة بمحافظة الغربية، مصر. وقد أُجري تحليل مقارنة بين مواقع مزرعة ومستصلحة ومتدهورة لتقييم الخصائص الفيزيائية والكيميائية للتربة (مثل المحتوى العضوي، ودرجة الحموضة، والملوحة، والعناصر الغذائية الكبرى والصغرى)، بالإضافة إلى دراسة مجتمعات المكروفونا خلال أربعة فصول من السنة. أظهرت التربة المستصلحة أعلى محتوى من المادة العضوية والكربون، خاصة في فصل الربيع، مما يدل على فعالية ممارسات الاستصلاح في تحسين جودة التربة. في المقابل، أظهرت التربة المتدهورة أدنى مستويات من العناصر الغذائية وأقل تنوعاً في مجتمعات الحيوانات الأرضية، بينما جاءت التربة المزروعة في موقع متوسط من حيث الخصائص، إذ سُجِّل فيها ارتفاع في كثافة المكروفونا ولكن بانخفاض في التنوع الحيوي. كما تبين أن الديناميكيات الموسمية تؤثر تأثيراً ملحوظاً في خصائص التربة، حيث كان فصلا الخريف والربيع الأكثر ملاءمة للنشاط الحيوي. وكشفت نتائج تحليل الارتباط المعباري (CCA) عن وجود علاقات قوية بين مجتمعات المكروفونا والعوامل البيئية مثل الرطوبة والمادة العضوية وتوافر العناصر الغذائية. وتخلص الدراسة إلى أن الإدارة المستدامة للأراضي يجب أن تراعي التغيرات الموسمية والاستراتيجيات الخاصة بكل موقع من أجل تعزيز صحة التربة ودورات العناصر الغذائية والتنوع البيولوجي. وعلى الرغم من أن ممارسات الاستصلاح تسهم بشكل كبير في استعادة النظم البيئية، إلا أن الرصد طويل الأمد والإدارة التكيفية يظلان ضروريين للحفاظ على مرونة التربة واستدامتها في النظم الزراعية المصرية.