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Biodiversity assessment of soil macro-fauna under organic and conventional farming ecosystems

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Abstract

Soil animals do most of the physical labour beneath our feet, yet they are rarely counted when farm management decisions are made. This research compared soil macro-fauna communities across paired organic and conventional soybean–maize fields at EMBRAPA’s Cerrado Research Station near Brasília, Brazil (15°36’S, 47°42’W) from October 2019 to September 2021. Macro-fauna were sampled using TSBF monoliths (25 × 25 × 30 cm) at four seasonal intervals per year. Organic fields supported significantly higher species richness (mean 18.7 vs. 8.4 taxa; $p < 0.001$) and total abundance (648 vs. 273 individual’s m^{-2}). Earthworms dominated organic plots (84.3 m^{-2}), while ants dominated conventional ones (42.8 m^{-2}). Shannon diversity index was 2.41 in organic and 1.53 in conventional systems. These results confirm that organic management supports a richer, more even soil macro-fauna community under tropical Cerrado conditions.

Keywords: Soil macro-fauna, biodiversity assessment, organic farming, conventional farming, species richness, Shannon index, earthworms, Cerrado, TSBF monolith, soybean-maize rotation

Introduction

Soil macro-fauna-organisms visible to the naked eye, loosely defined as those exceeding 2 mm in body width—are among the most reliable living indicators of soil health. Earthworms, beetles, ants, termites, millipedes, and spiders collectively regulate decomposition, nutrient cycling, water infiltration, and pest suppression ^[1]. When pesticide applications or intensive tillage remove these organisms, the ecosystem services they provide diminish in ways that are expensive or impossible to replace with external inputs ^[2].

Brazil’s Cerrado biome, sometimes called the “inverted forest” because more biomass sits below ground than above, hosts exceptional soil biodiversity ^[3]. But the region has lost roughly half its native vegetation to cropland since the 1970s, and conventional soybean–maize rotations now dominate ^[4]. Organic acreage in the Cerrado is growing (up 18% between 2017 and 2020) yet remains below 2% of total cropland ^[5]. Whether organic management can rebuild macro-fauna communities in these heavily mechanised landscapes hasn’t been tested with standardised sampling protocols over multiple seasons. This research addressed that gap using the Tropical Soil Biology and Fertility (TSBF) monolith method across two full cropping cycles.

Research area description

Sampling was conducted at EMBRAPA’s Cerrado Research Station, located 35 km south of Brasília (15°36’S, 47°42’W, elevation 1,014 m). The climate is classified as Aw (tropical savanna) with a distinct wet season from October to March and a dry season from April to September. Mean annual temperature is 21.3 °C and mean annual rainfall 1,478 mm. Soils are deep, well-drained Ferralsols (Oxisols) with clay content of 58–64% and pH 5.2 in the top 20 cm.

Material and methods

Material

Three paired field blocks were selected, each containing one organic plot (managed without synthetic inputs since 2012) and one conventional plot under standard herbicide–insecticide

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Programmes. Both followed a soybean–maize rotation. Organic plots received composted poultry litter ($8 \text{ t ha}^{-1} \text{ yr}^{-1}$) and cover-cropped with *Crotalaria juncea* between main crops. Conventional plots received mineral NPK ($80\text{--}60\text{--}40 \text{ kg ha}^{-1}$), glyphosate pre-emergence, and lambda-cyhalothrin for lepidopteran pests. Equipment for macro-fauna extraction included steel monolith frames ($25 \times 25 \times 30 \text{ cm}$), hand-sorting trays, 4% formaldehyde preservation solution, and a stereomicroscope (Leica S9i) for identification.

Methods

Sampling followed the TSBF protocol [6]. Five monoliths per

plot were excavated at each of four seasonal time points (early wet, late wet, early dry, late dry) from October 2019 to September 2021, giving 240 monoliths per treatment over the research period. Each monolith was hand-sorted on-site within two hours; all organisms $\geq 2 \text{ mm}$ were collected, counted, and preserved. Identification was carried out to family or genus level using regional taxonomic keys [7]. Diversity was quantified using species richness (S), Shannon–Wiener index (H'), and Pielou's evenness (J'). Treatment differences were tested by repeated-measures ANOVA with season as the within-subject factor in R v4.2.1.

Results

Table 1: Community-level diversity metrics for soil macro-fauna under organic and conventional management (mean $\pm$ SD)

Parameter	Organic	Conventional
Species richness (S)	18.7 ± 3.2	8.4 ± 2.1
Total abundance (ind. m^{-2})	648 ± 87	273 ± 54
Shannon index (H')	2.41 ± 0.18	1.53 ± 0.24
Pielou's evenness (J')	0.82 ± 0.05	0.71 ± 0.08
Dominant group	Earthworms (84.3 m^{-2})	Ants (42.8 m^{-2})

Organic fields supported more than double the species richness and total abundance of conventional ones (Table 1). Shannon index differed significantly between treatments ($F = 34.7$,

$p < 0.001$). Evenness was also higher in organic plots, indicating a more balanced community structure rather than dominance by a single taxon.

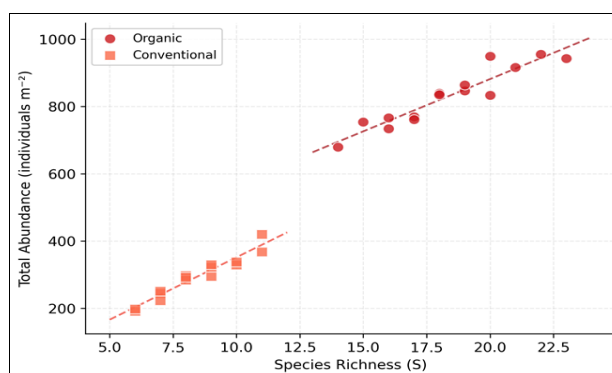


Fig 1: Relationship between species richness and total macro-fauna abundance under organic and conventional farming systems

Table 2. Mean abundance (individuals' m^{-2}) of major taxonomic groups by farming system

Taxon	Organic	Conventional	p-value
Earthworms	84.3	31.2	< 0.001
Beetles (Coleoptera)	62.7	28.4	< 0.001
Ants (Formicidae)	51.4	42.8	0.089
Termites (Isoptera)	38.6	22.1	0.004
Millipedes (Diplopoda)	29.1	11.6	< 0.001
Spiders (Araneae)	18.7	9.3	0.002

Earthworms showed the largest absolute difference between systems ($84.3 \text{ vs. } 31.2 \text{ m}^{-2}$; Table 2). Ants were the only group without a significant treatment effect ($p = 0.089$), likely because

several ant species tolerate or even benefit from disturbed habitats.

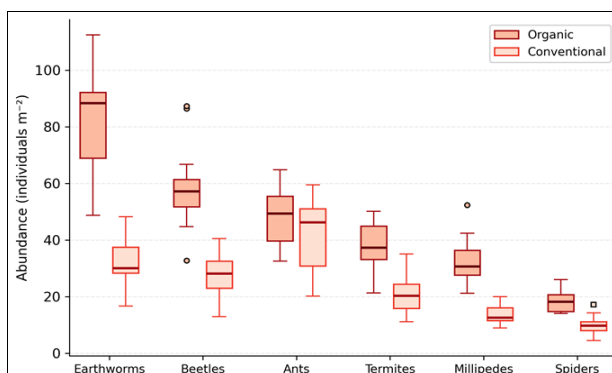


Fig 2: Distribution of macro-fauna abundance by major taxonomic group under organic and conventional farming ecosystems

Comprehensive interpretation

Species richness and abundance peaked during the late wet season (January–March) in both systems, but organic plots maintained higher baseline populations even during the dry season. This buffering effect may reflect the continuous ground cover provided by *Crotalaria* residues in organic plots, which sustains surface moisture and litter resources through the dry months.

Discussion

The 2.2-fold difference in species richness between organic and conventional Cerrado fields is consistent with a global meta-analysis that reported 30–50% higher soil faunal richness under organic management [8]. However, the absolute abundances recorded here—particularly earthworm densities above 80 m⁻²—exceed values from temperate organic systems, reflecting the Cerrado's intrinsically high below-ground biological activity [3]. The dominance of earthworms in organic plots contrasts with ant dominance in conventional plots, a pattern also documented in Brazilian Atlantic Forest fragments [9].

Ants were the exception to the general organic advantage, showing no significant difference. Several common Cerrado ant genera (*Solenopsis*, *Pheidole*) are disturbance-tolerant generalists that colonise bare or compacted soil surfaces [10]. Their persistence under conventional management doesn't necessarily signal ecosystem health. Millipedes and spiders, by contrast, are more sensitive to pesticide exposure and habitat simplification, making them better indicator taxa for management comparisons [11].

Conclusion

Organic soybean–maize fields on Cerrado Ferralsols supported more than double the species richness and total abundance of soil macro-fauna compared to conventional counterparts. Earthworms, beetles, and millipedes showed the strongest positive responses to organic management, while ants remained largely unaffected. The Shannon index confirmed both higher diversity and greater community evenness in organic plots. These findings support the use of macro-fauna surveys as practical monitoring tools for soil health under tropical farming conditions.

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