Soil profile stratification under long-term organic fertilization: responses of soil fertility, structure, and microbiomes in a lucerne-based rotation

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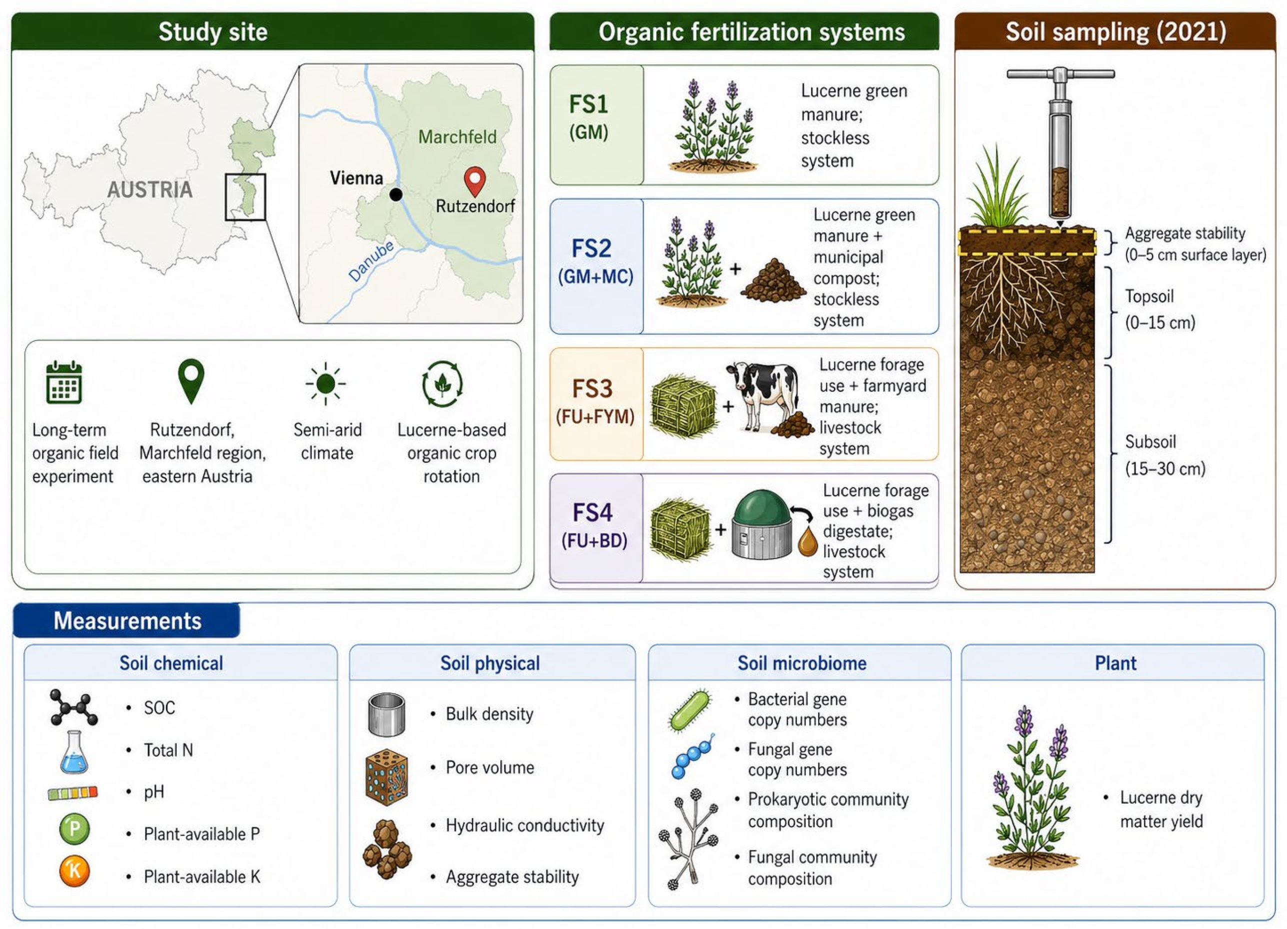
1 BACKGROUND & AIM

Long-term organic fertilization can improve soil fertility, structure and microbial functioning, but these effects are often depth-dependent. In semi-arid organic systems, where nutrient stratification is common, understanding topsoil–subsoil contrasts is essential. Lucerne-based rotations are especially relevant because lucerne supplies biologically fixed nitrogen and large root inputs. However, most studies focus on topsoil, while subsoil responses remain poorly understood.

Aim of Study

This study therefore examines how contrasting long-term organic fertilization systems affect soil chemical, physical and microbial properties along the soil profile in a lucerne-based rotation.

2 MATERIALS and METHODS



Treatment effects were assessed by ANOVA, followed by Tukey's test for mean comparisons.

3 RESULTS

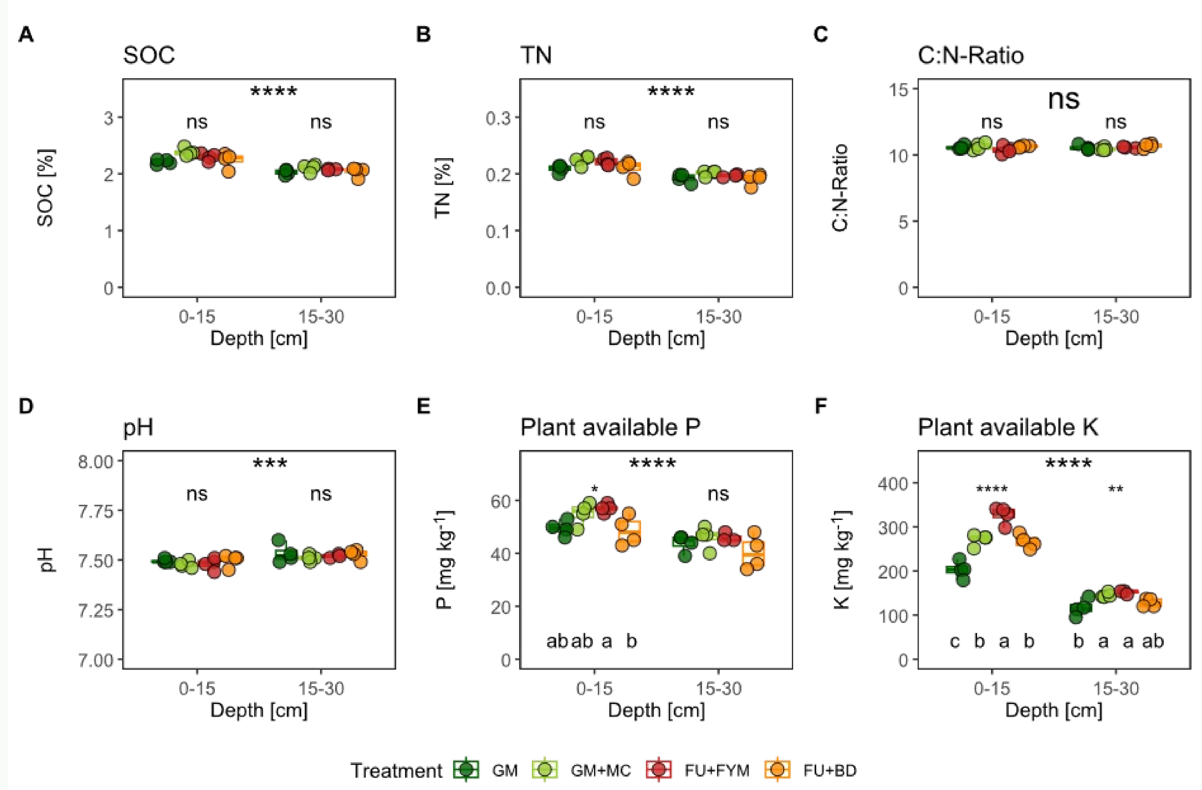


Figure 1: Soil chemical properties as influenced by different organic fertilization systems at two soil depths. (A) Soil organic carbon (SOC), (B) total nitrogen (TN), (C) C:N ratio, (D) pH, (E) plant-available phosphorus (P), and (F) plant-available potassium (K) in 0–15 cm and 15–30 cm soil layers. GM, GM+MC, FU+FYM, and FU + BD are green manure, green manure + municipal compost, forage use + farmyard manure, and forage use + biogas digestate, respectively. Asterisks indicate significant differences between the two soil depths across all fertilization systems (top center) and among fertilization systems within each soil depth (row below top). Significance codes: ns = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$. Different lowercase letters denote significant differences among fertilization systems within the same soil depth ($p < 0.05$).

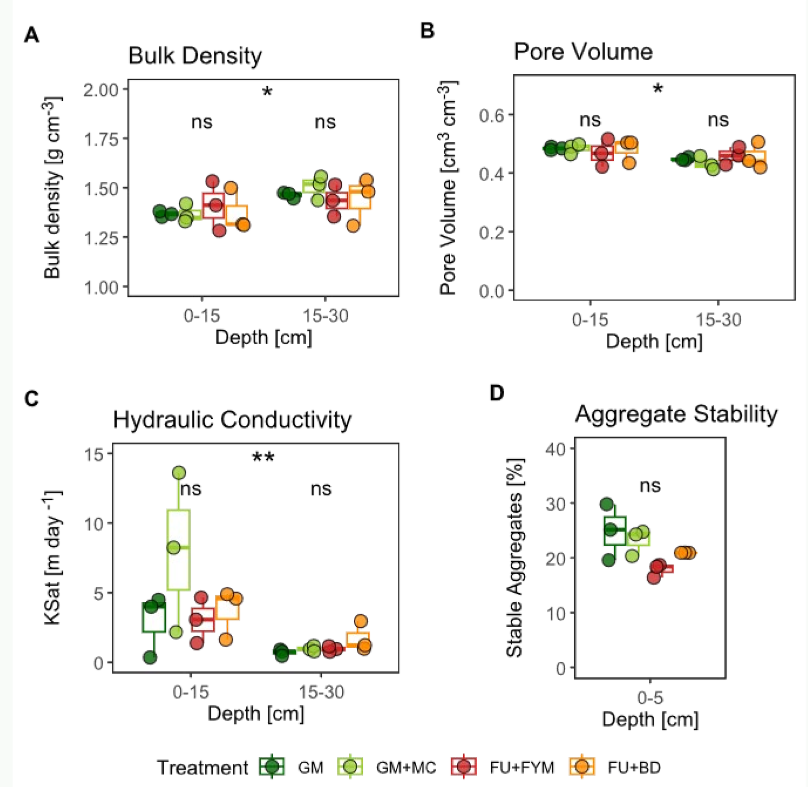


Figure 2: Soil physical properties as influenced by different organic fertilization systems and soil depth. (A) Bulk density, (B) total pore volume, (C) saturated hydraulic conductivity (KSat) at 0–15 cm and 15–30 cm soil depths, and (D) aggregate stability in the 0–5 cm surface layer. See Fig. 1 for legend.

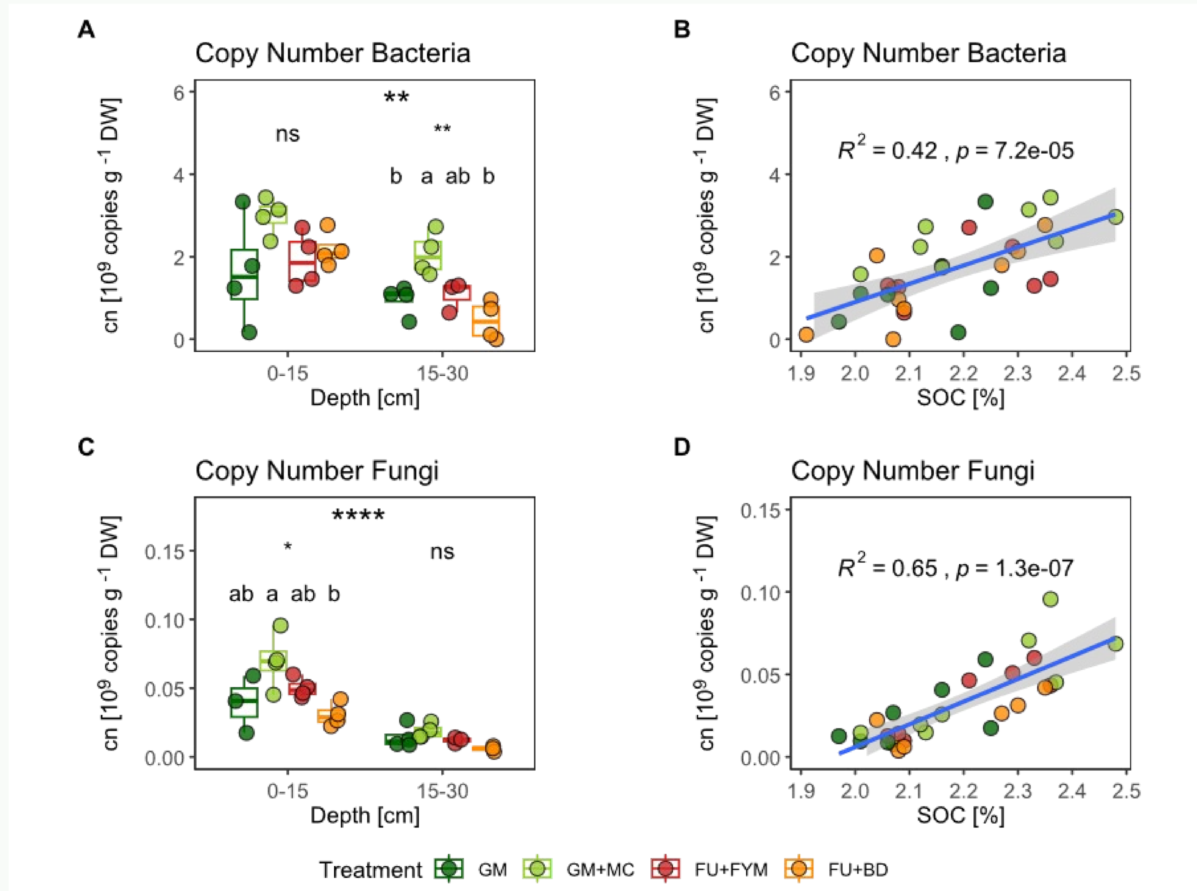


Figure 3: Gene copy numbers of bacteria and fungi. (A, B) Bacterial gene copy numbers and (C, D) fungal gene copy numbers at 0–15 cm and 15–30 cm soil depth. Panels A and C show copy numbers for each soil depth. Panels B and D show correlations of copy numbers with SOC across both soil depths and all fertilizer treatments. R^2 and p-values are indicated. See Fig. 1 for legend.

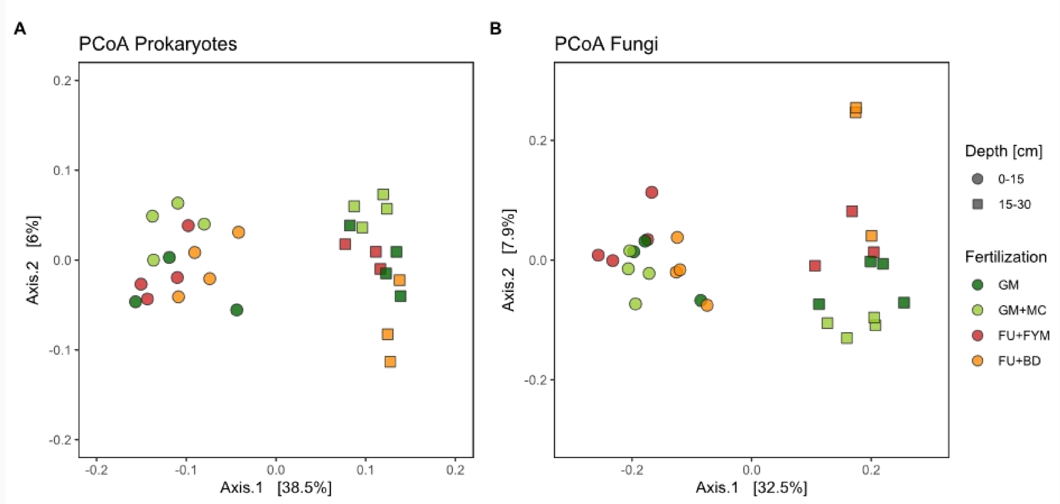


Figure 4: Principal coordinates analysis (PCoA) of soil microbial communities as influenced by different organic fertilization systems and soil depth. (A) Prokaryotic and (B) fungal communities. See Fig. 1 for legend.

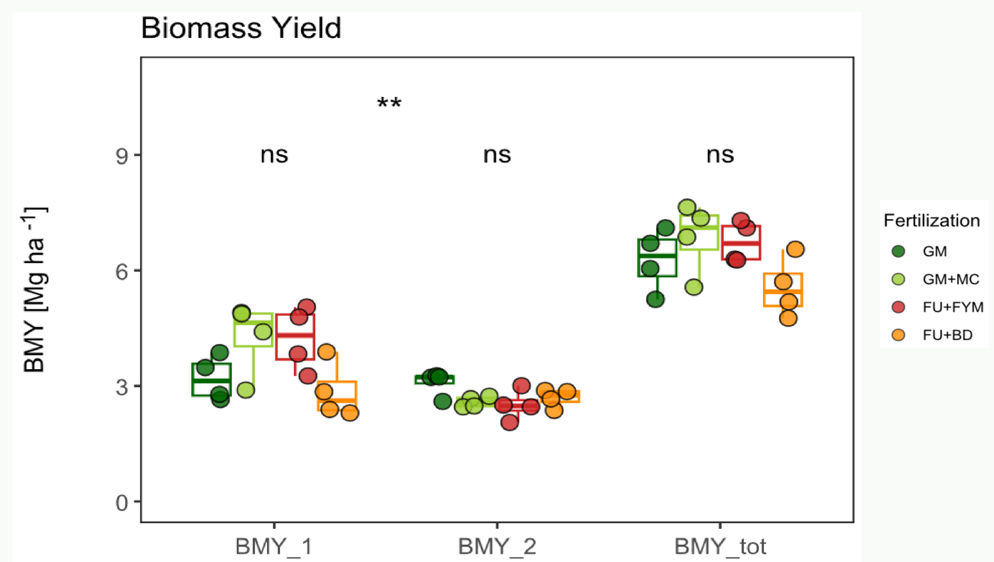


Figure 5: Biomass yield (dry matter, DM) of biannual lucerne as influenced by different organic fertilization systems. See Fig. 1 for legend.

4 DISCUSSION

- **Soil profile stratification dominated the system response,** indicating that vertical redistribution of C, nutrients and microbes was stronger than differences among fertilization systems.
- **Compost- and manure-based systems mainly improved topsoil fertility,** particularly P and K, suggesting that added organic inputs reinforced nutrient accumulation where biological activity was highest.
- **Microbiome responses were depth-dependent,** with fungi reacting more clearly to fertilization than prokaryotes, while lucerne yield remained unchanged, showing that soil quality shifts were stronger than short-term crop responses.

The main trends and key findings are summarized in **schematic Figure 6.**

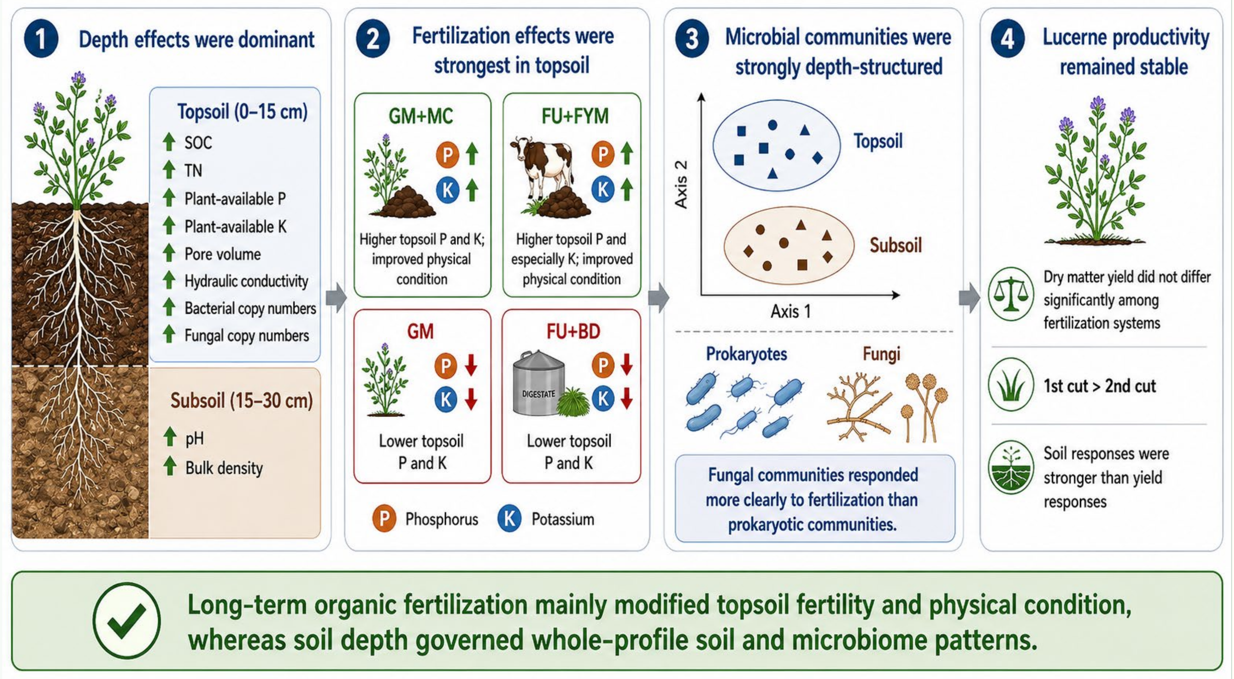


Figure 6: Schematic summary of the main findings.

5 CONCLUSIONS

- ✓ **Soil profile stratification must be explicitly considered in long-term organic systems.**
- ✓ **Targeted organic fertilization improved soil quality without reducing lucerne productivity.**
- ✓ **Biannual lucerne is a promising component of nutrient-efficient semi-arid organic rotations.**

6 ADDITIONAL MATERIALS & CONTACT

SCAN ME!