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Thermal fractionation of soil organic matter reveals qualitative shifts under long-term organic farming in Japan

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Evaluating soil carbon storage requires quantifying carbon stocks and assessing the distribution of carbon among stable pools. This study examines how long-term organic farming influences both the quantity and stability of soil organic carbon (SOC) in volcanic ash soils (Andosols) in Japan.

Surface soil samples were collected from long-term certified organic, recently converted, and conventionally managed reference fields. SOC stability was assessed using temperature-resolved thermal oxidation with an automated combustion analyzer, allowing partitioning of carbon into thermally labile, intermediate, and resistant (carbonate) fractions. These thermally defined fractions were used as proxies for differences in relative carbon persistence.

Long-term organic fields showed higher total SOC contents compared to recently converted and conventional fields. In addition to quantitative increases, soils under prolonged organic management exhibited a greater proportion of thermally resistant carbon fractions. This shift suggests a gradual redistribution of SOC toward more stable pools over time. Given the high content of reactive Al and Fe phases characteristic of Andosols, mineral-associated stabilization may contribute to the observed patterns, although further investigation is required to clarify specific mechanisms.

Field-to-field variability indicates that management history and amendment inputs influence SOC accumulation pathways. The present results provide a geochemical perspective on how agricultural practices affect carbon storage at the field scale. Planned future comparisons with non-volcanic soils will help evaluate the extent to which the mineralogical context modulates thermal stability patterns under similar management regimes.

Overall, temperature-resolved thermal carbon analysis offers a practical approach for tracing changes in SOC stability and contributes to understanding how local agricultural systems influence long-term carbon storage dynamics.