SOC stabilization mechanisms and temperature sensitivity in old terrace soils

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Context and research questions

Context
• Agricultural terrace: most common man-made landform
• 50% of them are under high potential risk of abandonment
• Terracing significantly affect SOC dynamics by land-use change/reshape landscape

Research questions
• Factors controlling SOC stabilization in agricultural terraces
• Controls on SOC temperature sensitivity ($Q_{10}$)
Studying area

- Northumberland National Park, UK
- multi-period archaeological landscapes
- Early Bronze Age c. 1800–1500 BC
- Maritime temperate climate
SOC fractionation

- Unprotected C (POM)
- Micro-aggregated C (53–250 µm)
- Silt & clay (<53 µm)
- Physically protected C (M)
- Chemically protected C (S+C)

Stability: low → high

SOC respiration - soil incubation (8 weeks)
30 g 2 mm sieved bulk soil; 350 ml sealed jars; 20 °C and 30 °C; soil respiration + SOC temperature sensitivity ($Q_{10}$)

Elemental composition and pedogenic oxides

- Rubidium/Strontium (weathering indicator)
- Sequential pedogenic extractions (Fe, Al, Mn)

Soil burial age — field pOSL

- Optically stimulated luminescence (OSL)
Results —— SOC respiration (SPR) and temperature sensitivity ($Q_{10}$)

Overall, SOC from old soil layers have been protected, but they show higher sensitivity to warming.

Fig. 1 Depth profile of (a) soil potential respiration rates (SPR) and (b) SOC temperature sensitivity ($Q_{10}$). Values are expressed as the ratio between the terrace and control profiles.
Results —— Stabilization mechanisms of terracing SOC

- older soil horizons (buried layers) tended to have a lower SPR
- The shift to more processed recalcitrant SOC (S+C fraction) with terrace age contributes to SOC stability in terraced soils (Fig. 2b)
Results —— controls on SOC temperature sensitivity

Fig. 3 Relationship between SOC temperature sensitivity to decomposition (Q10) and relative terrace soil burial age (total photo counts).

Fig. 4 Relationship between SOC temperature sensitivity (Q10) and (a) unprotected SOC (cPOM%), (b) physical protected SOC (M%) and (c) mineral protected SOC (S+C%) for relative younger and older terrace soil horizons, respectively. *= P<0.05; **P<0.01.

Table 1 Correlation between SOC fractions and pedogenic oxides

| Young soil layers | cPOM | m Al<sub>p</sub> | Fe<sub>p</sub> | Mn<sub>p</sub> | Al<sub>o</sub> | Fe<sub>o</sub> | Mn<sub>o</sub> | Al<sub>d</sub> | Fe<sub>d</sub> | Mn<sub>d</sub> |
|------------------|------|-----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| cPOM m s+c       | 0.78 | -0.88           | 0.89        | 0.88        | 0.83        | 0.84        | 0.88        |
| Old soil layers  | cPOM m s+c |

SOC mineral protection attenuate the SOC intrinsic temperature sensitivity by reducing the availability of SOC substrate to decomposers.

Young soil horizons

Old horizons?
Results —— controls on SOC temperature sensitivity

**Table 2** Relationship between SOC temperature sensitivity ($Q_{10}$) and C:N ratios of bulk soil and SOC fractions.

|       | Bulk soil | cPOM | M   | S+C |
|-------|-----------|------|-----|-----|
| $Q_{10}$ | 0.60*     | 0.03 | 0.61* | 0.62* |

* $P<0.05$. N=13.

**Fig. 5** C:N ratios for bulk soil and SOC fractions along with the gradient of terrace soil burial age (total photon counts). Significant differences in C:N ratios between soil age gradient are indicated by different lowercase letters ($P<0.05$).

Old horizons

Higher C:N ratio (lower quality) of SOC lead to a higher temperature sensitivity of SOC stored in buried horizons.
Conclusions

- Soil burial due to terracing provides a C stabilization mechanism.
- With increasing burial age, the SOC pool composition shifts from particulate OC to mineral protected OC pool.
- Both soil C:N ratio (C quality) and SOC mineral protection regulate $Q_{10}$
- The dominant mechanism controlling this temperature sensitivity depends on the burial age
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