Carbon sequestration and soil fertility management in sandy and clayey soils revealed by over four decades of long-term field experiments in Thailand

Since soil is the largest terrestrial carbon (C) reservoir, even small changes in soil C storage can significantly impact the global C cycle. To better understand soil C dynamics in agricultural soils, it is essential to conduct long-term field experiments on the effects of various land management practices on the same farmland. However, long-term field experiments in tropical regions are limited, making it difficult to assess the impact of agricultural management on soil C sequestration accurately. JIRCAS, in collaboration with the Department of Agriculture (DOA) of Thailand, has analyzed data from over 45 years of long-term field experiments involving the continuous application of chemical fertilizer and organic matter (OM) on cropland.

The data from three long-term field experiments (hereafter referred to as Khon Kaen, Nakhon Ratchasima, and Rayong) were analyzed. Compared to the control without any amendment, soil C sequestration was 2.0 ± 2.1 and 2.8 ± 2.0 Mg C ha^{-1} 0.2 m^{-1} for chemical fertilizer and crop residue incorporation, respectively. The largest soil C sequestration occurred when chemical fertilizers were combined with OM applications. Specifically, when chemical fertilizer was combined with crop residue incorporation or compost application, soil C sequestration reached 5.6 ± 3.1 and 10.1 ± 6.5 Mg C ha^{-1} 0.2 m^{-1}, respectively (Fig. 1). Furthermore, the trend of C sequestration varied depending on soil type. In clayey soils (Nakhon Ratchasima), C was concentrated in the surface layer, whereas in sandy soils (Khon Kaen), the effect was significant across all layers up to a depth of 1.0 m (Fig. 2). Structural equation modeling indicated that the increase in soil C in sandy soils significantly improved basal soil fertility, such as soil pH, available phosphorus, and exchangeable potassium, resulting in higher cassava yields (Fig. 3). In contrast, no significant relationship was found between soil C content and cassava yield in clayey soils.

These results are expected to contribute to the establishment of a soil C dynamics model optimized for tropical regions by providing reliable estimates of soil carbon sequestration rates in low-latitude regions, where studies have been limited. Furthermore, the Intergovernmental Panel on Climate Change (IPCC) sets the standard for soil carbon sequestration assessment at a depth of 0.3 m (or tillage depth) from the surface. The results of this study indicate that in sandy soils, it is necessary to evaluate even deeper layers.

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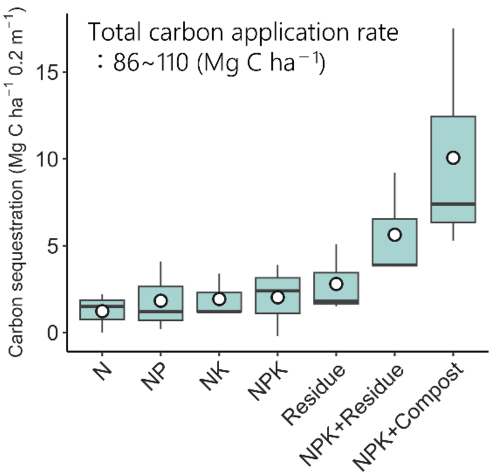

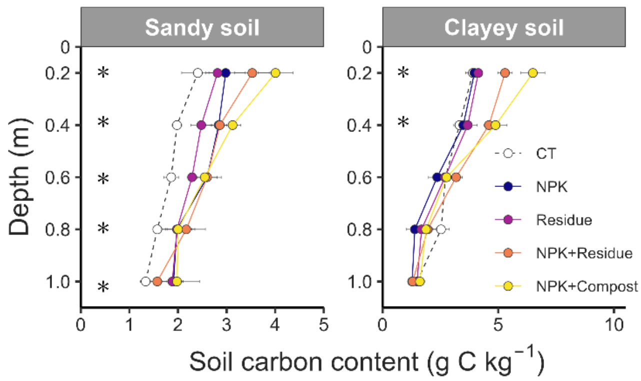

Fig. 1. Soil carbon sequestration rate

Calculated from long-term field experiments in Khon Kaen, Nakhon Ratchasima, and Rayong. Soil carbon sequestration is expressed as the difference from the control plot without any application. In the residue and NPK + residue treatments, cassava stems and leaves were returned to the field after harvest. The box plot represents the maximum, third quartile, median, first quartile, and minimum values. The ○ symbol indicates the mean value.

Fig. 2. Soil carbon content at five different depths

Soil samples were collected from five depth intervals (0–0.2 m, 0.2–0.4 m, 0.4–0.6 m, 0.6–0.8 m, and 0.8–1.0 m) in 2021. Values are presented as the mean ± standard error. The asterisk (*) indicates a significant difference between treatments at $p < 0.05$. Results from Khon Kaen represent sandy soil, while those from Nakhon Ratchasima represent clayey soil.

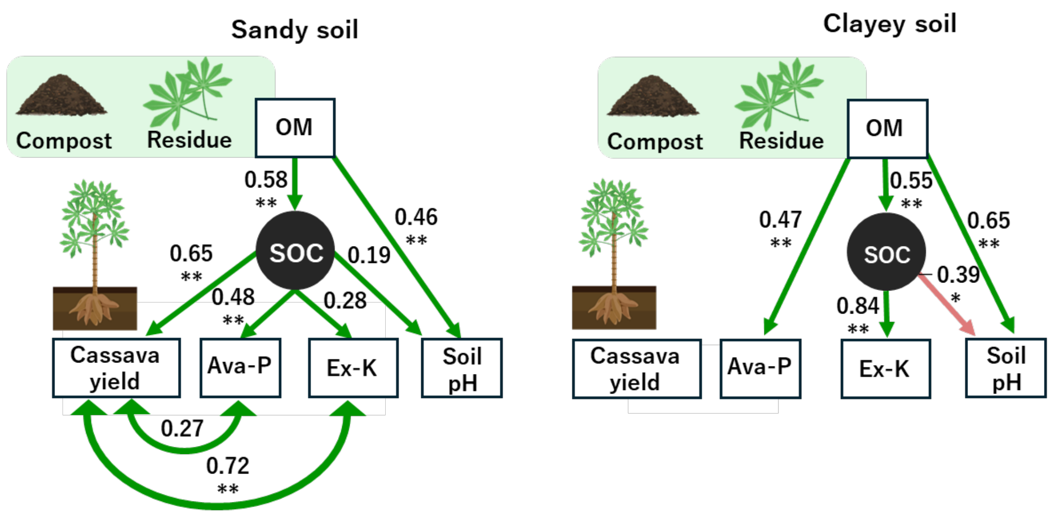

Fig. 3. Structural equation modeling of cassava yield

The relationships among organic matter application (OM), soil carbon concentration (SOC), available phosphorus (Ava-P), exchangeable potassium (Ex-K), soil pH, and cassava yield were analyzed using a structural equation model. Unidirectional arrows indicate causal relationships, while bidirectional arrows represent correlations. The numbers indicate the contribution coefficient. * and ** represent statistical significance at $p < 0.05$ and $p < 0.01$, respectively.

Reference: Tancharoen et al. (2024) *Land Degradation & Development* 35: 5488–5503.