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Field-aged Pyrogenic Carbon Migration Enhances Electrochemical Properties in Deep Soil: Evidence from a Decade-Long Study

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Pyrogenic carbon (PyC) promotes interfacial electron transfer in soil, enhancing soil health, carbon sequestration, and climate change mitigation. However, it remains a cutting-edge development to determine whether the soil electron transfer capacity in calcareous deep soil (>100 cm) can be improved in the long term after PyC migration. This paradigm could expand our understanding of potential changes in carbon cycling through PyC-driven soil carbon sequestration. In this study, we compared field-aged PyC (10 years) with fresh PyC, assessed changes in electron exchange capacity (EEC) and electron transfer rate (k_c) following aging, and further explored how field-aged PyC affects soil electrochemical properties in both topsoil and deep soil in a decadal field site. Our findings revealed that field-aged PyC significantly increased EEC and k_c compared to fresh PyC, along with a notable increase in the relative content of oxygen-containing functional groups on the field-aged PyC particle. In the soil containing PyC, the significant increase in soil electron accepting capacity (EAC), faster k_c values, larger electron-donating capacity (EDC), and specific capacitance values from topsoil to deep soil within the 0-200 cm profile corresponded to significant increases in the content of soil surface C=O, quinone, and phenolic−OH functional groups down the profile. This study provides field evidence of the long-term positive impact of aged PyC on deep soil electrochemical performance, which could play a crucial role in deep soil biogeochemical processes for carbon sequestration.