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Soil carbon persistence linked to mineralogy across sub-Saharan Africa

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Recent compilations of global soil radiocarbon data suggest that current Earth System Models underestimate the mean age of soil carbon (C). The discrepancy between data-derived estimates and model calculations might be due to an inadequate representation of processes that control C persistence in soils – especially in understudied regions.

Here, we investigate the relationships between soil mineralogy, soil properties, climate and radiocarbon ($\Delta^{14}C$) in soils sampled as part of a comprehensive soil survey (AfSIS) for sub-Saharan Africa. A total of 510 samples were analyzed, comprised of soils collected from two depths (0–20 cm and 20–50 cm) at 30 sites in 14 countries. To determine soil mineralogy, we analyzed X-ray powder diffraction (XRPD) data, which provides a precise and detailed mineralogical signature of each soil sample. The studied soil profiles vary greatly in their mineralogy, reflecting a diverse range of parent materials and soil forming factors.

The median soil C age is 182 years in the topsoils and 563 years in the subsoils, corresponding to a total $\Delta^{14}C$ value range of -432 to 95 ‰. In general, $\Delta^{14}C$ values decrease (older mean C ages) with increasing clay particle size fractions. This corresponds to an increase in short range-order minerals expressed as oxalate-extractable aluminum and iron (Al_{ox} and Fe_{ox}). Separately, mineralogically defined variables – derived from the XRPD data using principal component analysis – are found to correlate strongly with a range of soil properties (pH, weathering status, exchangeable calcium, Al_{ox} and Fe_{ox}, and soil texture) and climatic variables (aridity index and mean annual temperature). This provides a holistic assessment of the processes that have formed each soil along with the properties that it currently exhibits. Our analyses with random forests show that these XRPD-derived mineralogical variables alone can explain up to 30% of the variation in $\Delta^{14}C$ across sub-Saharan Africa. They also allow the identification of specific minerals that contribute to this variation and how they are linked to the C mean age of the soil. In conclusion,

our results suggest that soil mineral data can help to better understand C persistence in subtropical and tropical soils.