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Evidence for contrasting soil carbon dynamics in volcanic and non-volcanic soils: towards implications for climate change mitigation through land-use and management.

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In 1959, Athol Rafter began a substantial programme of monitoring the flow of ^{14}C produced by atmospheric thermonuclear tests through New Zealand's atmosphere, biosphere and soil.

The programme produced important publications (e.g. O'Brien and Stout, 1978) and leaves an legacy of unpublished data critical for understanding soil C dynamics. A database of over ~400 soil radiocarbon measurements spanning 50 years has now been compiled, and can be extended to ~600 measurements including systematic measurements made elsewhere (e.g., Baisden et al., 2002; Torn et al., 1997). Key aspects of the dataset are described here, with an emphasis on quantifying the differences in soil C dynamics between volcanic and non-volcanic soils, as well as the response of different soils to land-use change and management.

Among Rafter and Stout's most compelling data is a comparison of soil carbon dynamics in deforested dairy pastures under similar climate in the Tokomaru silt loam (non-allophanic) versus the Egmont black loam (allophanic), originally sampled in 1962, 1965 and 1969. After adding surface soils sampled to a similar depth in 2008, we can use a relatively simple 2-box model to calculate that the residence time of soil C in the Tokomaru soil is ~9 years compared to ~15 years for the Egmont soil. This difference represents nearly a doubling of soil C residence time, and roughly explains the doubling of the soil C stock. With three measurements in the 1960s, the data is of sufficient resolution to estimate the parameters for an "inert" or "passive pool" comprising approximately 15% of soil C, and having a residence time of 600 years in the Tokomaru soil versus 3000 years in the Egmont surface soil. While these differences are large, they are nevertheless smaller than those calculated using the single-pool model of Torn et al. (1997) to imply residence times of many millennia for allophanic soils in Hawai'i. Data examined versus soil depth adds additional knowledge.

The Tokomaru/Egmont comparison is necessarily illustrative since neither site was replicated extensively, but provides globally unique data. Moreover, the Tokomaru/Egmont comparison supports evidence that C dynamics does differ in volcanic versus non-volcanic soils. Additional lines of evidence include emerging theories of soil organic matter stabilisation processes, rates of soil organic matter change following land-use change, and chemistry data. The contrasting soil C dynamics in these different soils appear to have implications for land-use change and management schemes that could be eligible for "C credits". The residence time data enhances opportunities for robust exploration of options, including the net benefit of biochar incorporation and afforestation/deforestation scenarios.

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