

Forty-year Storage of Radio-Carbon in a Soil of a Regenerating Forest

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Abstract

The rate at which a forest accumulates soil organic carbon is estimated in a four-decade study of a regenerating pine forest that was planted in 1957 on a long-cultivated, C-depleted soil. In the 4 to 8 years following 1964, the global atmosphere maximum in $^{14}\text{C-CO}_2$, ^{14}C in soil organic matter increased rapidly throughout the upper 60-cm of the soil rooting zone. A portion of the radio-C has been incorporated into relatively recalcitrant humus in basal layers of the O horizon and in the 0 to 7.5-cm layer of mineral soil (the A horizon). In contrast, the ^{14}C that entered the 7.5 to 60-cm soil has rapidly decomposed in the three decades since there were relatively large inputs of ^{14}C . Although the regenerating forest ecosystem is a strong C sink, accumulating $5.2 \text{ Mg ha}^{-1}\text{yr}^{-1}$ over the three decades, mineral soil accumulated <2% of this total C storage, demonstrating a limited active-storage capacity for C compared with that in tree biomass and forest floor.

Calhoun Experimental Details

- MAT 16°C ; MAP 1170 mm; 34.5°W , 82°W .
- Soils are Kanhapludults, derived from granitic gneiss, and were cultivated for cotton and other crops from 1800 to 1955.
- 16 permanent plots planted in loblolly pine 1957.
- 8 of the soil plots were sampled in 1962, 1968, 1972, 1978, 1982, 1990, and 1997.
- Plots sampled at least 20 times with 2-cm dia corer at 4 depths: 0-7.5, 7.5-15, 15-35, and 35-60 cm.
- In early to mid-1990s, soil input of C estimated in litterfall, canopy throughfall, O horizon leachate, and fine root turnover.
- Radio-C is measured by accelerated mass spectrometry (AMS) on graphite targets prepared from SOM and is reported as per mil deviation of $^{14}\text{C}/^{12}\text{C}$ compared with a decay-corrected oxalic acid standard (Trumbore 1996).
- The Duke Soil Archive stores soil air-dry at room temperature in sealed glass containers.

Bomb-C in the Atmosphere

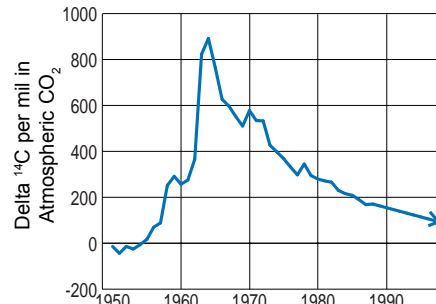


Figure 1. Delta ^{14}C in wine, atmospheric CO_2 , and forest litterfall nearly doubled by 1964 and has diminished rapidly since the Test Ban Treaty of 1963.

Bomb-C in Forest Floor

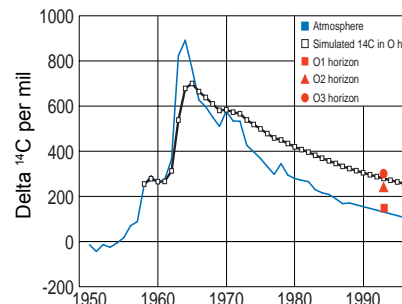


Figure 2. Simulated delta ^{14}C in the O horizon of the Calhoun pine stand planted in 1957. Decomposition coefficients are taken from the screen-sandwich experiment of Jorgensen et al. (1980). O horizons were sampled in 1992 for ^{14}C analysis and confirm dynamics of the decomposition model.

Mineral Soil C

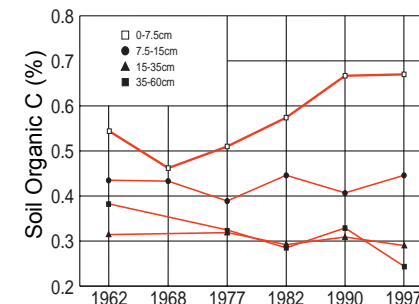


Figure 3. Organic C of mineral soils was depleted by long-term cultivation from about 1800 to 1955. The pine forest planted in 1957 is slowly rebuilding soil C, but only in the 0 to 7.5-cm layer. Surface soils are sandy loams.

Bomb-C in Mineral Soil

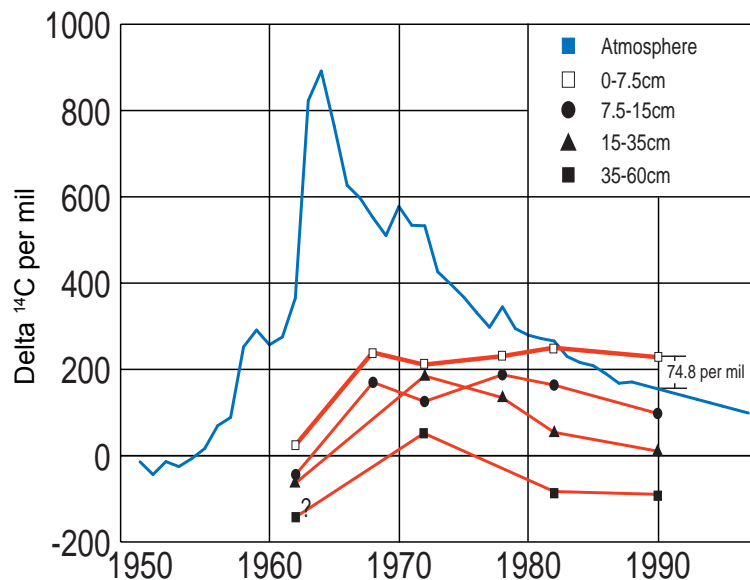


Figure 4. In the 4 to 8 years following 1964, the year of the atmospheric maximum in $^{14}\text{C-CO}_2$, ^{14}C in mineral soil increased rapidly through the upper 60 cm of soil rooting zone. A fraction of the radio-C was incorporated in basal layers of O horizons (Figure 2) and in 0-7.5-cm mineral soils. The ^{14}C that rapidly entered the 7.5 to 60-cm soil has rapidly decomposed in the three decades.

Soil Carbon Accumulations and Inputs

40-yr Accumulation and Annual C Input (kg ha ⁻¹)	O Horizon	0 to 15 cm	15 to 60 cm
40-yr Accumulation	34900	1960	0
Total Annual input	2903	877	390
Canopy litterfall	2450	-	-
Solution Doc*	81	251	135
Fine roots†	372	626	255

* O horizon inputs from dissolved organic C (DOC) in canopy throughfall (1992-1994).

† Estimated from 50% of mean fine root biomass in O horizon, 0-15 cm, and 15-30 cm soil. Fine roots sampled 1994-1995, every three weeks over 18 months.

Conclusions

- Radio-C rapidly entered the 60-cm soil profile during the era of atmospheric bomb-testing, probably by leaching of DOC and inputs from fine roots. This radio-C was rapidly decomposed, except for accumulations in relatively recalcitrant humus in O horizons and 0 to 7.5-cm mineral soil.
- Although the regenerating Calhoun pine forest is a strong C sink, accumulating $5.2 \text{ Mg ha}^{-1}\text{yr}^{-1}$ over more than 3 decades, mineral soils accumulated <2% of this C storage, demonstrating a limited active-storage capacity of soil C compared with C in tree biomass and forest floor.

Acknowledgements

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