Turnover Time in Grassland and Forest Soils as Indicated by Radiocarbon Measurements

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For the past fifteen years we have been measuring ^{14}C and ^{13}C in soils under pastures and forests. For measurements under pasture we now have a good series of data, and from the rise in ^{14}C levels due to the atom-bomb effect, it has been possible to predict turnover times for carbon in soils under pastures.

In the Judgeford silt loam, near Wellington, which has been covered with a ryegrass pasture for 100 years, ^{14}C data are available from 1959 to the present time, for both topsoil and deeper layers. There has been a 15% increase in the ^{14}C activity in the top, 0–10 cm, layer of soil.

Measurements of herbage and fresh litter under forests indicate ^{14}C levels essentially the same as in air, and this is also true for earthworms under a pasture.

In general the ^{14}C age of carbon in soil increases greatly with depth, in the case of the Judgeford silt loam, the age at a depth of 90 cm was about 6000 years. This is hard to reconcile with the fact that measured respiration rates, determined by the oxygen uptake rate, indicate carbon turnover rates of less than 100 years. One interpretation of this is that the soil carbon is not homogeneous but that there is an old fraction that does not respire or does so only slowly.

The Judgeford soil has been modelled (O'Brien and Stout, 1978), using a combined diffusion respiration model, under the assumption that there is a mobile fraction of carbon that turns over fairly rapidly, plus an old immobile fraction. The concentration of the old fraction was found to be constant with depth, while that of the mobile fraction decreased exponentially with depth, as predicted by the model. The fit of the model to the data indicated a mean turnover time of 63 years and a steady state flux of carbon of 0.03 g $cm^{-2}yr^{-1}$.

The ^{13}C concentration in the soil carbon also changed with depth, the deeper soils being enriched in ^{13}C. This can be interpreted as a fractionation due to respiration, or to a mixture of two fractions of carbon with different ^{13}C contents.

There is a need to carry out similar studies on forest soils. We are continuing to measure ^{14}C and ^{13}C in the carbon of forest soils in New Zealand. Measurements made in beech and kauri forests indicate that respiration rates in the deeper soil layers are considerably faster than those in soils under pastures (Stout and O'Brien

1972). Under forests, a much greater fraction of the carbon appears to be present as litter, and measured respiration rates in the litter are several times those in the soil. We are making measurements of ^{14}C in forest litter and soils over a long term in an attempt to model carbon turnover, by using the pulse of ^{14}C from nuclear weapon tests.

However the use of the weapon-produced ^{14}C for these studies has certain drawbacks, one of which is the lack of sufficient samples collected prior to the time of the nuclear tests. We are now carrying out some long-term experiments on soils, into which a pulse of ^{14}C has been injected, by exposing the herbage to ^{14}C-enriched CO_2. The work at present is being carried out on a pasture soil which will then be monitored for five years or more. Studies will later be instigated on soils under native forests. There is a need to know more about the amount of carbon stored as litter and humus under a forest and what its turnover rate is. The transfer of large areas of land in the pioneer countries in the last century, from forest cover to pasture lands, would have caused a perturbation to the global carbon cycle balance. The magnitude of such a perturbation depends upon the difference between forest and pasture soils in terms of stored carbon and mean turnover times.

REFERENCES

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