

INTERNAL REPORT 77
ENERGY FLOW AS DETERMINED
BY RATES OF LITTER DECOMPOSITION

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INTRODUCTION

Litter decomposition is a dissimilation process mediated by a succession of organisms and associated enzyme systems (Alexander 1971, Halworth and Crawford 1965). Of primary importance are the hydrolytic and oxidative processes which characterize the conversion of raw litter carbon to carbon dioxide and stabilized organic matter or humus. The mineralization of organic carbon to carbon dioxide represents a major carbon loss or output route whereas humus formation may be regarded as a key carbon reservoir or conservation pathway.

The decomposition process is initiated prior to litter fall and may be recognized by the physical-chemical changes which the forest canopy undergoes. The decomposition which occurs on live standing trees may be measured in part by net loss in foliage weight and by changes in chemical constituents of the needles. However, it should be recognized that the breakdown of canopy carbon is extremely difficult to follow in terms of tree accessibility problems and an acceptable data retrieval procedure. At the soil surface the fallen needles undergo an initial rapid mineralization of organic carbon (Jenkinson 1965). Subsequently, decomposition occurs at a much slower rate and may indeed attain an approximate steady state. These decomposition rate trends may be depicted as shown in Figure 1.

It is evident that when attempting to simulate the rate of the net change in energy of input litter carbon that such rates may be expressed for various carbon species and also for more stabilized humus fractions. Various investigators (Olson 1963) have expressed the rate of loss from all reservoirs and related accumulation of organic matter by the parameter k (carbon loss per unit of time). It follows that composite forest litter samples will exhibit variable experimental k values depending upon the degree to which decomposition has previously proceeded under field conditions. For example, under "climax" or steady state conditions litter samples should exhibit slow turnover rates characteristic of phases b , c and d whereas canopy needles and possibly newly fallen needles will have higher values peculiar to phase a .

The influence of temperature, moisture and pH on rates of decomposition is well documented. Suffice to say that such factors also influence the turnover rate of litter carbon.

The primary objectives of the Oregon State and University of Idaho research team was: 1. to measure the net weight and chemical composition of surface litter, and 2. to determine the net loss or output of carbon by decomposition of litter organic carbon.

METHODS

Site Selection and Sampling Design

The initial phases of the study were carried out at the H. J. Andrews Experimental Forest. Sampling sites were selected in stands already being studied by the biome investigators. At four randomly selected litter traps, forest floor samples were obtained from a cluster of four 30.48 cm square plots located 1 m from the center of the trap. The forest floor was sampled by layers of horizons representing various stages of human development. In two reference stands on Watershed #10 samples were collected along a transect in the buffer zone around the stand. Litter samples were dried and weighed to determine mass in kg/ha. After grinding (Wiley Mill) to give a homogeneous mix, samples were stored in cardboard containers at 5°C.

Determination of Rates of Carbon Turnover

Ten gram samples of the stored litter samples were placed in respiration flasks and the moisture level adjusted to 60 percent of the litter water saturation value. The flasks were then placed in an incubator at a temperature of 25°C ± 1°C. Time course interval and cumulative recoveries of evolved carbon dioxide in sodium hydroxide and titration of the resulting carbonates. Data was expressed as mgC evolved as carbon dioxide per unit time interval.

In addition to the above procedure, carbon dioxide evolution and oxygen uptake were measured by means of an Electrolytic Respirometer (McGarity et al. 1958).

Total Carbon and Persulfate Oxidizable Carbon

Total carbon was determined by wet combustion using acidified dichromate (Walkley and Black 1934). Water soluble carbon was performed by persulfate oxidation of litter extracts and solid litter samples (Gilmour et al. 1961).

RESULTS

Observed Decomposition Rates

Reference to the litter decomposition trends shown both in Figures 2 and 3 show that approximately 7 percent of the input carbon from stands III and IV has evolved as carbon dioxide over the three-month experimental period. This must be regarded as an extremely slow turnover rate and would indicate that the surface litter had reached stabilization prior to sampling. Essentially similar rate trends were obtained for sites 1, 3, 6 and 9 - forest stand II, and sites 2, 6, 7 and 8 - forest stand VIII.

The data shown in Tables 1 and 2 again attest to slow carbon turnover rate. In stand III, the composite litter sample obtained at site 1 exhibited the slowest rate of carbon turnover whereas sites 2, 5 and 6 showed approximately similar decomposition rates. An essentially similar decomposition trend was observed for stand IV.

The short term oxygen uptake and carbon dioxide evolution values measured by means of the electrolytic respirometer were quite similar to the long term trends obtained by conventional absorption in alkali. Representative data are shown in Table 3.

Water Soluble Carbon (P O C)

The high degree of litter stabilization noted previously decreased the effectiveness of the water soluble carbon fraction as a predictor of carbon dioxide output. The following percent persulfate oxidizable carbon were obtained for the various test stands: II - 12%, III - 13%, IV - 10%, VI - 11% and VIII - 12%. Approximately equal values were obtained attesting to the similar maturity of the litter samples. Interestingly enough, Broadfoot and Pierre (1939) obtained water soluble carbon values for Scrub and Pine pine needles in the same range (10-11%) as was observed in the present study.

Calculation of Carbon Losses

Various approaches and formulas have been used to determine decay rates of forest litter. These have been reviewed by Olson (1963). Ordinarily, the net rates of change for a specific period of time may be modeled in terms of an exponential decay equation as follows:

$$k = \frac{2,303 \log \frac{C_0}{C}}{t}$$

$$\text{Half-life} = t_{1/2} = \frac{0.693}{k}$$

Under simulation conditions the decay rates obtained for the H. J. Andrews forest litter samples are based on the following assumptions:

1. Input carbon is the carbon contained in the respiration flask.
2. No additional input of carbon takes place.
3. No carbon losses occur as a result of surface runoff and leaching.
4. Major loss route is via oxidation of litter carbon to carbon dioxide.
5. The litter has reached a steady state and constant reaction (k value).

The variable reaction rates shown in Table 4 indicate that the litter samples under study have not attained a true steady state. In consequence, first order kinetics and the related calculation of decay rates applicable

to such litter samples cannot be regarded as valid predictable values. However, the half-life calculation based on the time interval between 10 and 12 weeks may be regarded as the minimum time for turnover of the input organic carbon.

At lower temperatures, the 3.0 year half-life would at least double in value and for the complete decay of these samples, ten-year decay intervals would not overstate the decomposition time period.

SUMMARY

1. A methodology has been developed for the determination of litter decomposition rates.
2. Decomposition rates for five H. J. Andrews forest litter samples have been determined.
3. All samples exhibited an extremely slow carbon turnover rate but on the basis of variable reaction, rates had not attained a constant decomposition rate.
4. Under optimum conditions, a minimum half-life of 3.0 years is proposed until such time as additional information is obtained.

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Table 1. Losses of surface litter carbon as carbon dioxide (Stand III)^a

| Time | Sampling Site | | | | avg. |
|------|---------------|------|------|------|------|
| | 1 | 2 | 5 | 6 | |
| 2 | 10.3 | 17.7 | 13.2 | 12.9 | 13.5 |
| 4 | 16.0 | 24.6 | 19.9 | 19.9 | 20.1 |
| 6 | 19.9 | 28.6 | 23.3 | 24.4 | 24.1 |
| 8 | 22.9 | 31.6 | 26.3 | 28.5 | 27.3 |
| 10 | 26.0 | 34.0 | 29.0 | 32.4 | 30.4 |
| 12 | 29.0 | 36.3 | 31.6 | 36.7 | 33.4 |

^aData expressed as mg C as CO₂/gm of litter

Table 2. Losses of surface litter carbon as carbon dioxide (Stand IV)^a

| Time | Sampling Site | | | | avg. |
|------|---------------|------|------|------|------|
| | 1 | 2 | 7 | 8 | |
| 2 | 15.0 | 13.8 | 12.2 | 15.8 | 14.2 |
| 4 | 21.5 | 20.0 | 19.0 | 23.1 | 20.9 |
| 6 | 25.7 | 24.2 | 22.9 | 27.6 | 25.1 |
| 8 | 29.3 | 28.6 | 26.5 | 32.1 | 29.1 |
| 10 | 32.6 | 32.7 | 29.6 | 36.4 | 32.8 |
| 12 | 35.9 | 36.8 | 32.5 | 40.7 | 36.5 |

^aData expressed as mg C as CO₂/gm of litter.

Table 3. Comparative carbon dioxide evolution values obtained with conventional cabinet incubation and the electrolytic respirometer^a

| Site | mg C as CO ₂ per 10 gm litter | |
|------|--|---------------------------|
| | Cabinet incubator | Electrolytic Respirometer |
| III | | |
| 1 | 65 | 85 |
| 2 | 115 | 108 |
| 5 | 82 | 80 |
| 6 | <u>85</u> | <u>84</u> |
| avg. | 86 | 89 |
| IV | | |
| 1 | 95 | 96 |
| 2 | 84 | 83 |
| 7 | 74 | 74 |
| 8 | <u>90</u> | <u>93</u> |
| avg. | 85 | 86 |

^aCumulative CO₂ values over a 6 day period.

Table 4. Litter half-life determinations

| Stand | Time | Half-life (weeks) | <i>k</i> value |
|---|-------|----------------------|----------------|
| III | | | |
| | 2 | 45.3 | 0.0150 |
| | 4 | 60.3 | 0.0110 |
| | 6 | 75.3 | 0.0090 |
| | 8 | 87.7 | 0.0080 |
| | 10 | 99.0 | 0.0070 |
| | 12 | 108.3 | 0.0060 |
| IV | | | |
| | 2 | 42.8 | 0.0160 |
| | 4 | 59.2 | 0.0120 |
| | 6 | 70.7 | 0.0009 |
| | 8 | 81.5 | 0.0080 |
| | 10 | 91.2 | 0.0076 |
| | 12 | 99.0 | 0.0070 |
| Half-life calculated for 10-12 week period in years | | | |
| III | 10-12 | 3.7 | 0.0035 |
| IV | 10-12 | 3.0 | 0.0044 |

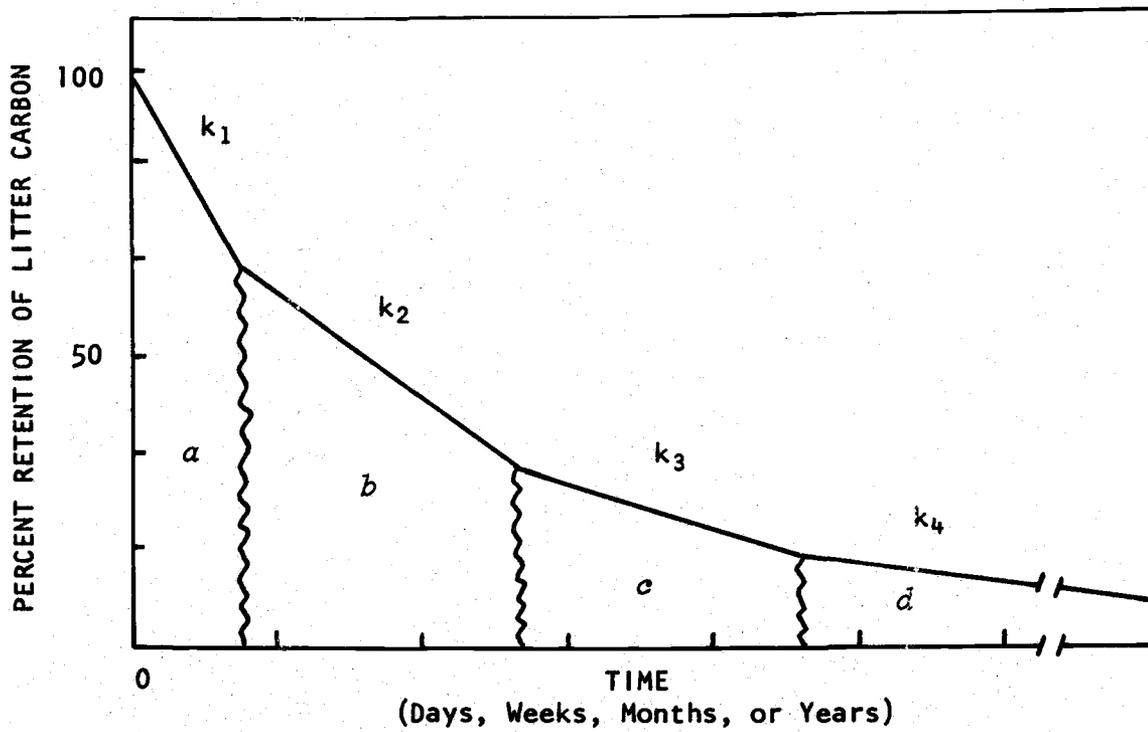


Figure 1. Decomposition rate fluctuations as a function of litter stabilization status, where a = initial rapid mineralization of litter carbon, b, c = slow turnover of litter carbon, and d = climax or steady state condition.

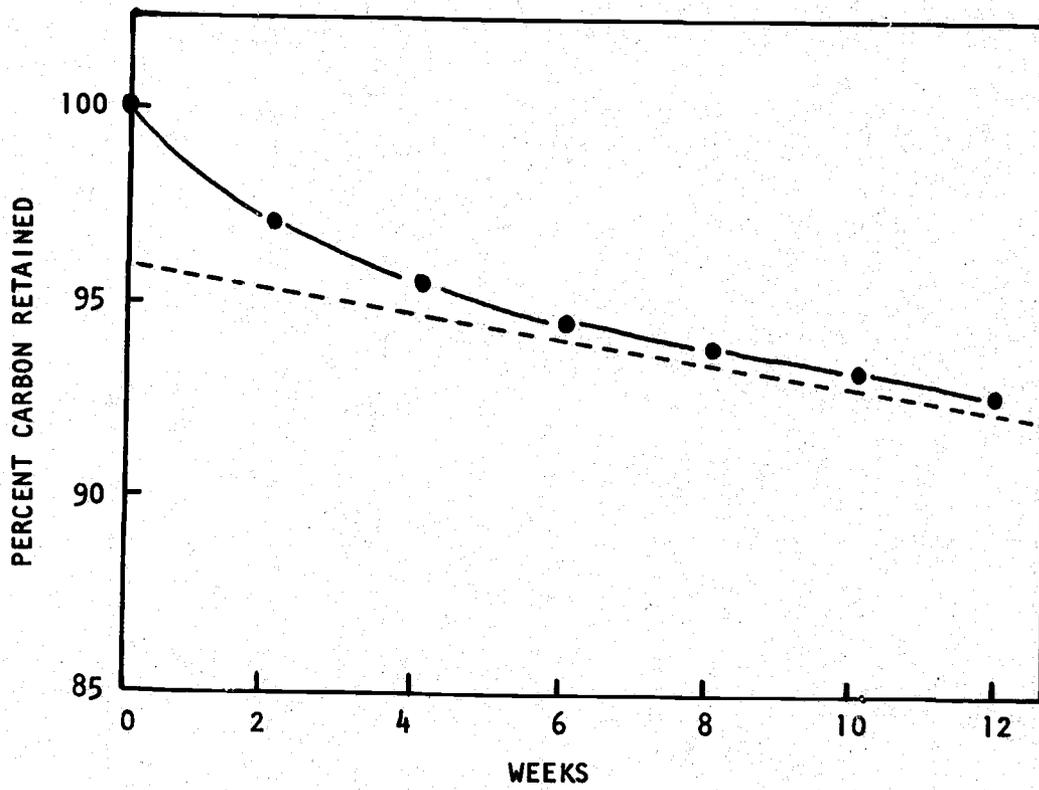


Figure 2. Percent retention of surface litter carbon over a 12-week period (Stand III).

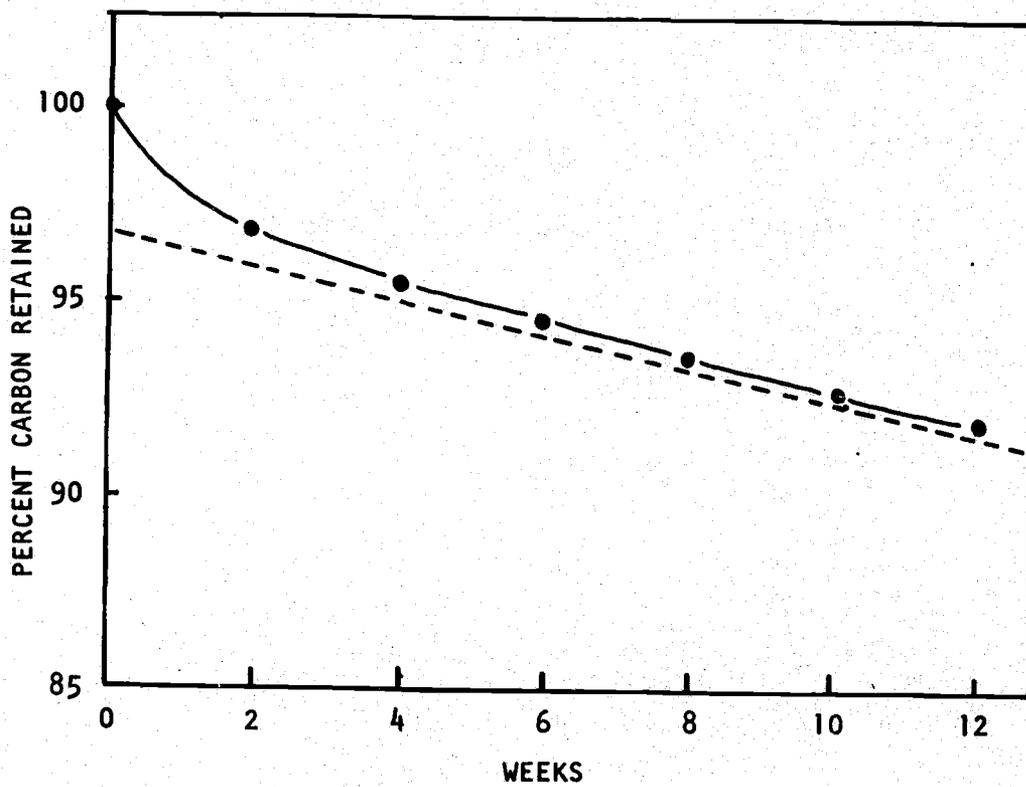


Figure 3. Percent retention of surface litter carbon over a 12-week period (Stand IV).