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Use of the cotton strip assay to detect potential differences in soil organic matter decomposition in forests subjected to thinning

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1 *Summary*
The cotton strip assay was used to detect potential changes in rates of soil organic matter decomposition associated with different thinning treatments of Sitka spruce (*Picea sitchensis*) stands at Elwy Forest, north Wales, UK. Cotton strips were inserted in the soil over a period of one year, in 4 3-month periods. In general, the losses in the tensile strength (CTSL), used as an indicator of decomposition of the cotton strip, were greater at the surface than lower in the soil profile. With respect to the forest thinning treatments, the CTSL values were in the order: intermediate thinned >high intensity thinned>unthinned. Higher CTSL values were also detected for the so-called 'tree' areas than for the 'stump' areas within the thinned stands.

The cotton strip data are considered in relation to (i) the amounts of litter accumulated and the annual litterfall under the stands, and (ii) the possible significance of differences in soil organic matter decomposition rates induced by the thinning practice.

2 *Introduction*
The importance of leaf and branch litter decomposition and consequent nutrient release for the growth of forests ecosystems has long been recognized (Duvigneaud & Denaeyer de Smet 1970; Witkamp & Ausmus 1976; Ausmus *et al.* 1976; Miller *et al.* 1979; Harrison 1978, 1985). Accumulations of litter frequently occurring on the forest floor (Turner & Long 1975; Adams & Dickson 1973; Carey *et al.* 1982) are usually due to imbalances between the rates of production and decomposition of this litter, resulting in a slowing of nutrient cycling (Malmer 1969). Slowing of nutrient cycling in forests, particularly those on poor soils, is likely to result in a reduction of tree productivity. Under those circumstances, therefore, any forest management practice which indirectly stimulates organic matter decomposition, and thus nutrient cycling, would be beneficial to timber production.

Thinning of the forest is known to stimulate the production and timber quality of plantation forests (Assmann 1970; Hibberd 1986). It also appears to result in a reduction in the amount of litter accumulated on the forest floor, though high thinning treatments may result in high litter accumulation due to the brash left behind. A reduction in the amount of litter on the forest floor could be for 2 reasons, either a decrease in the rate of litterfall or an increase in the rate of the litter decomposition. As a preliminary test of the idea that thinning may indirectly stimulate the decomposition of the litter, the cotton strip assay was applied to a Forestry Commission thinning experiment, for which some data on litter accumulation and litterfall were available.

3 *Method*
The site selected for study was a Forestry Commission Sitka spruce plantation (Elwy), near St Asaph, north Wales (National Grid reference SJ 078767), planted in 1952 at an altitude of 260 m on an unploughed upland brown earth (brown podzolic soil *sensu* Avery 1980), with some evidence of gleying of the profile at 5–10 cm depth. The thinning treatments were arranged in a randomized block design with 3 replicates, each plot being about 0.5 ha. Line thinning was the method applied, which followed along the planting rows, and was carried out at 3 intensities: (i) unthinned; (ii) intermediate with one line in 3 removed; and (iii) high with 2 lines in 4 removed. The percentage of wood removed was approximately 0, 33 and 50 respectively. The thinning took place in 1971–72, although a few individual trees have been removed subsequently in 1978.

In July 1979, 20 cotton strips were randomly inserted in a vertical manner (Latter & Howson 1977) into the soil, in only 2 of the 3 experimental blocks. Ten were placed within the lines of the remaining standing trees 'tree' and 10 in an adjacent position within the lines of thinned stumps 'stump', as illustrated in Figure 1. Ten strips only were inserted in the soil of unthinned stands. The strips were carefully removed after 3 months, and on the day of removal new replicate strips were inserted in similar adjacent positions. The pattern of insertion and removal was continued for one year, giving 4 3-month periods. Each time, both cloth and field controls were used.

The tensile strength of the strips, prepared as described in Latter and Howson (1977), was measured using a Monsanto Type W tensometer with pneumatic jaws and an automatic chart recorder. The Shirley Soil Burial Test Fabric (1976 batch) was used, and it showed considerable variation in cloth control tensile strength values depending on the roll used. Thus, the field controls had mean tensile strength values of 55.2 kg for insertion periods 1, 2 and 3, and 44.5 kg for period 4. The results presented were adjusted to allow for this variation.

Litterfall was monitored monthly for a whole year from mid-1979, using 8 randomly placed 25 cm

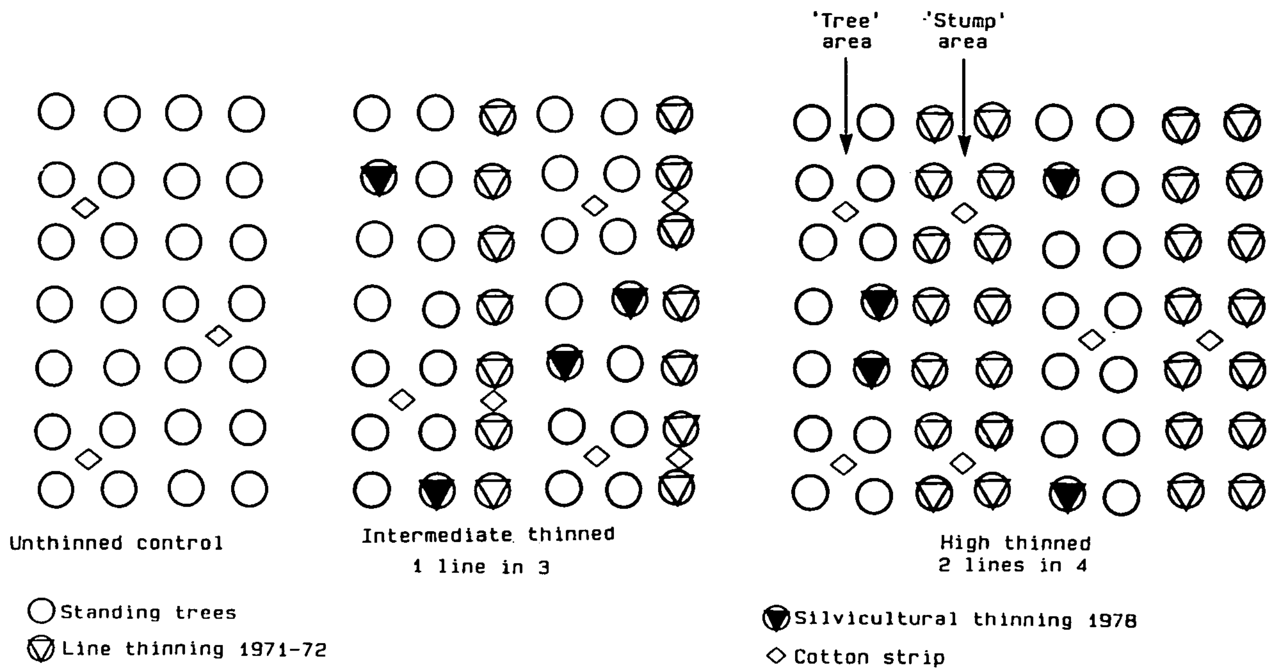

Figure 1. Within thinning treatment plot layout and cotton strip positions

diameter funnel-type litter traps, emptied at monthly intervals. Litter accumulation on the forest floor was recorded in July 1978, by removing 25 10 cm diameter cores per plot from each of the 3 blocks. For litterfall and for litter accumulation, the material was dried at 105°C and weighed. Weights were multiplied up accordingly to give quantities in t ha^{-1}.

4 *Results*

4.1 Cotton strip assay

Generally, the patterns of tensile strength loss showed that potential decomposition was highest at the soil surface and declined with depth (Figure 2 i). The unthinned plots appeared to have the lowest CTSL at all the soil depths.

To investigate the effects of the thinning treatments further, a one-way analysis of variance was carried out on the CTSL data for each of the 4 3-month periods separately, using the mean values of the 5 depths from each strip, and pooling the values from the 2 blocks and the 'stump' and 'tree' areas. Bartlett's test (Snedecor & Cochrane 1967) indicated that the within-treatment variances were homogeneous and, therefore, the data needed no transformation. Partitioning the treatment sums of squares showed that unthinned

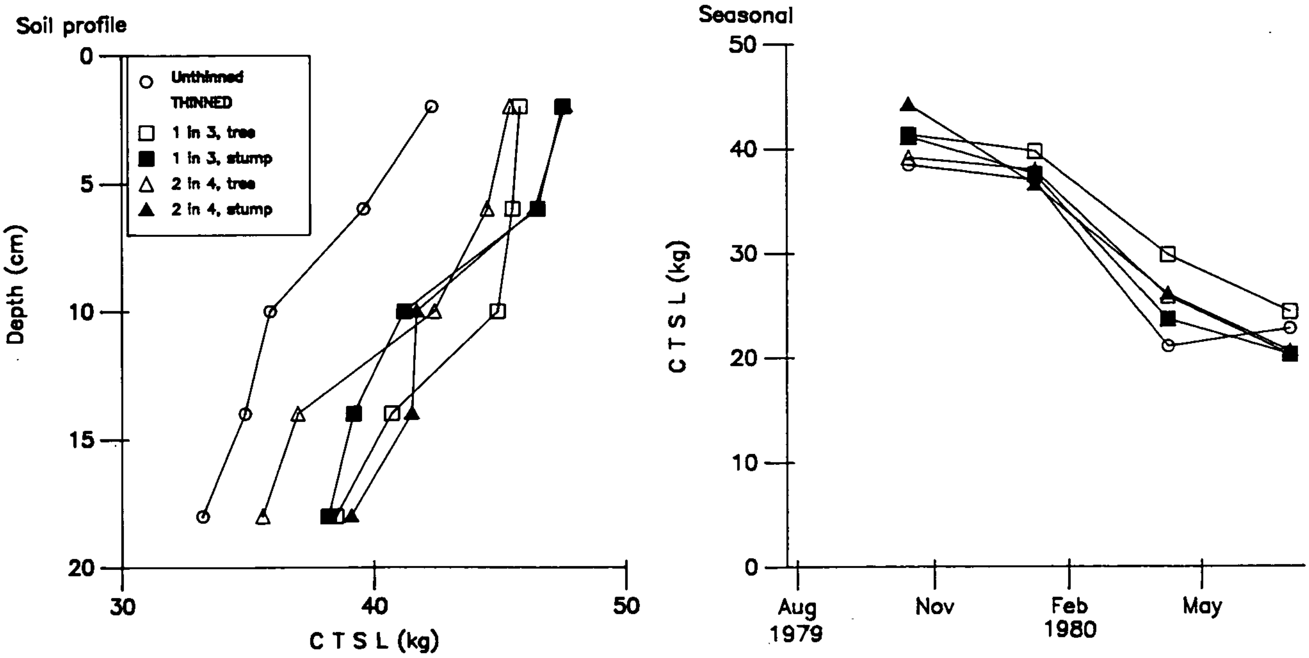

Figure 2. Tensile strength loss of cotton strips (CTSL) in thinning treatment plots

i. change down profile for one block, autumn 1979

ii. change throughout season, means of 2 blocks for the 5 treatments. Points are placed at retrieval dates plots had significantly lower CTSL values than the combined thinned plots in July–October 1979 (P <0.05) and in January–April 1980 (P<0.01), but that there was no significant difference between the intermediate and high thinned treatments (Table 1). A multiple comparison of means using Tukey's Honestly Significant Difference (HSD) test then revealed that the unthinned plots had a significantly lower CTSL than both the high thinned (P<0.05) and intermediate thinned (P<0.01) treatments, in January–April 1980. In addition, the strips inserted in the 'tree' and 'stump' areas gave significantly different (P<0.05) CTSL values for each depth (Table 1). Clearly, therefore, there appears to be an interactive effect on potential decomposition between the thinning treatments themselves and the zonation within the thinned plots. There was a further subordinate interaction of the seasonal factor with a higher rate of decomposition of strips in the 'tree' position and a lower rate for those in the 'stump' position for the period January–July, the reverse situation occurring in the period July–October (Table 1).

Table 1. Cellulose decomposition in the thinned and unthinned plots and in the 'tree' and 'stump' areas of the thinned plots. The mean is for 5 depths for each strip, both blocks combined

i. The difference between thinned and unthinned plots is shown by the F ratio obtained from a one-way analysis of variance
ii. The difference between 'tree' and 'stump' areas is shown by a paired T test

Period	Mean tensile strength loss (kg) Jul–Oct 1979	Oct–Jan	Jan–Apr 1980	Apr–Jul
i.				
Unthinned	14.1	15.5	31.4	21.7
Thinned	11.0	14.5	26.1	23.2
F ratio, df 1, 97	4.6*	0.7	9.8**	0.9
ii.				
Intermediate thinned				
Tree	41.4	39.8	29.9	24.4
Stump	41.2	37.6	23.7	20.3
T test	−0.1	−1.5	−2.6*	−2.2*
High thinned				
Tree	39.2	38.0	25.5	20.2
Stump	44.3	36.6	26.1	20.6
T test, df 19	2.8*	−1.1	0.08	0.2

*P<0.05; **P<0.01

Nevertheless, the intermediate thinned plots appear to provide the best conditions for decomposition, because this treatment showed a higher CTSL over the year as a whole than either the high thinned or unthinned treatments.

4.2 Litterfall

The annual litterfall (Table 2 & Figure 3) was appreciably greater in the unthinned plots than in either of the thinned treatments. The 2 thinned plots had similar litterfall values, despite the different levels of thinning

Table 2. Litterfall and forest floor accumulation for thinned and unthinned areas. Litter weight ha^{-1} with SE for treatment differences

	Thinning treatment Un-thinned	Inter-mediate	High	SE
July 1979–June 1980[1]				
Litterfall (t ha^{-1} yr^{-1})	4.86	2.81	3.01	0.24*
July 1978[2]				
Litter accumulated on the forest floor (t ha^{-1})				
L horizon	14.39	11.20	13.19	1.32 NS
F + H	122.06	92.07	117.34	112.90 NS

* P<0.05
[1] Data supplied by D Evans, ITE, Bangor
[2] Data supplied by Forestry Commission

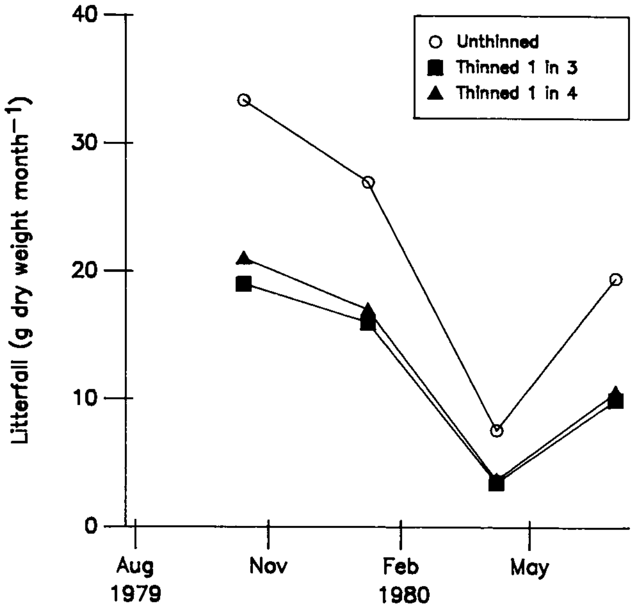

Figure 3. Seasonal changes in litterfall, July 1979–June 1980. Points are mean litterfall per month over 4 3-monthly periods for 2 blocks combined

intensity. A one-way analysis of variance was carried out on the annual litterfall data, combining the 2 blocks but with no data transformation, as Bartlett's test again showed that variances were homogeneous. Tukey's Honestly Significant Difference test then showed that the annual litterfall under the unthinned plot was significantly higher (P<0.05) than under either of the 2 thinned plots.

4.3 Litter accumulation

The quantity of litter (L) and fermentation and humus (F + H) material accumulated on the forest floor (Table 2 & Figure 4) tended to be highest in the unthinned plot, with slightly less material on the high thinned plot and least on the intermediate thinned plot. However, as these data were very limited in replication, the differences were not found to be statistically significant.

4.4 Decay rate

The data for annual litterfall (AL) and for the accumulated litter in the L layer (x) were used to calculate k

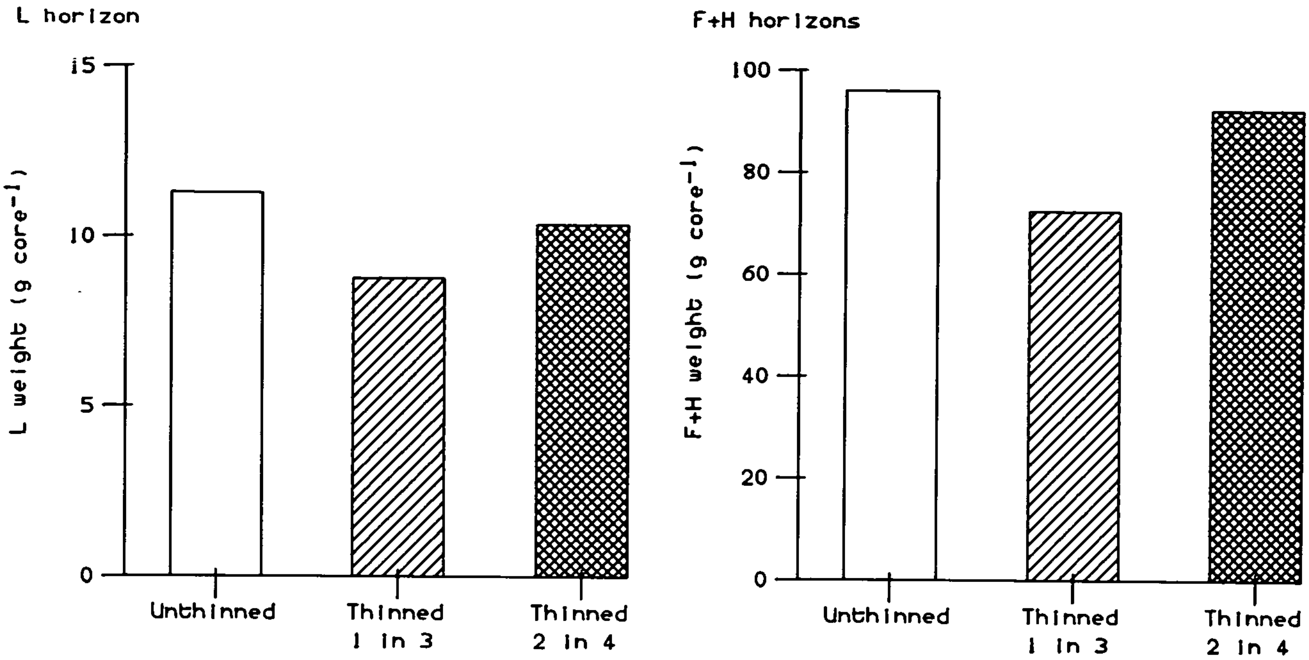

Figure 4. Forest floor accumulation, July 1978, calculated from 25 samples per plot

values and 95% turnover times (ie 3/k years), according to Olsen (1963) and Whittaker (1975), where k = AL/x, and a steady state is assumed (Table 3). The k values were in the order: unthinned>intermediate >high thinned, and the same relative order between treatments was obtained if the F+H and L data were added together.

Table 3. k values and 95% turnover rates for the L layer

Thinning treatment	k	95% time
Unthinned	0.34	9
Intermediate	0.25	12
High	0.23	13

5 *Discussion*

The results show that the cotton strip assay is able to detect significant differences in the potential rate of organic matter decomposition induced in the forest soils by the forest thinning treatments. Furthermore, the assay results indicate that quite complex interactions occur between organic matter decomposition processes and the environmental conditions related to the thinning pattern, soil depth and seasonal factors. These interactions appear to be biologically significant, as the same type of effects have been found in other forest stands (Brown & Howson 1988; Nys & Howson 1988; Brown 1988). Also, the rates of decomposition of the cotton strips directly relate to the soil organic matter decay rates calculated as k (Table 3). Using filter paper, Fox and Van Cleve (1983) have similarly demonstrated that differences in annual rates of cellulose decomposition among stands in an Alaskan taiga forest were correlated with the k values. The changes in the environmental conditions which follow the removal of trees during thinning are complex. Unthinned plots tend to be cooler and drier than thinned plots. Any thinning treatment results in less interception of the rain so that more rainfall reaches the ground, and line thinning may allow more rainfall to reach the ground than selective thinning. Further, the increased throughfall after line thinning tends to exceed any water loss by evaporation (Hamilton 1980), particularly if brash is left on the soil surface, and this, together with lower rates of water uptake by roots and transpiration by fewer trees, results in moister soil conditions. We did observe that cotton strips retrieved from 'stump' areas were wetter than those from the 'tree' areas throughout the year. Everett and Sharrow (1985) also found that soil water content was relatively greater in areas around cut stems of pinyon pine (*Pinus cembroides*) trees than on unthinned plots, and the difference could be detected for up to 4 years. In an experiment on 70-year-old white spruce (*Picea glauca*), near Fairbanks, Alaska, Piene and Van Cleve (1978), using litter and cellulose bags, found that there were differences in decomposition and weight loss influenced by the changes in a number of factors following thinning of plots. Similarly, light intensity also increases following thinning, so temperature changes, too, are likely to be greater in thinned stands, and the 'stump'areas in particular, than in unthinned stands. It is, therefore, realistic to expect that the microbially mediated organic matter decomposition processes would be increased under the improved moisture and temperature conditions provided in the thinned stands, as has been indicated by the cotton strip assay; the synthesis of the collated data (Ineson *et al.* 1988) has shown that the factors with the greatest influence on decomposition rates in cotton strips are temperature and moisture. Though the study has been carried out in only one forest experiment, it appears that the tendency for greater litter accumulation under unthinned stands is not just a result of higher litterfall, but also due to generally slower decomposition rates. The cotton strip assay not only detected this general trend for slower decomposition in the unthinned stands, but has also produced evidence for quite subtle interactions between organic matter decomposition processes in forest soils and environmental factors. In view of the direct links between organic matter turnover, nutrient cycling and tree productivity on the poor afforested upland soils (Miller *et al.* 1979), these interactions and the potential effects of management practices on them warrant further study.

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