Chapter (non-refereed)

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Effects of tree species on forest soils in northern France, detected by cotton strip assay

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1 *Summary*
The aim of the study was to determine whether or not the cotton strip assay is sufficiently sensitive to act as an indicator of changes in soil properties induced by forest trees.

Three forest sites were used for these studies: one in the Ardennes, with sessile oak (*Quercus petraea*) or Norway spruce (*Picea abies*), on an acid brown earth overlying shale; the second in Normandy with oak, beech (*Fagus sylvatica*) or spruce, on a leached brown earth formed from loess overlying clay with flints; and the third in the Vosges, with Scots pine (*Pinus sylvestris*), on a podzolic soil over grit. After a pilot study, cotton strips were inserted in soil profiles in the winter (December–February) for 8 weeks and in summer (July) for 3 weeks during 1983–84.

The results show that the cotton strip assay is sensitive and is able to reflect changes in some organic and physical properties. Between-forest site, between-species, between-soil depth and seasonal effects on cotton strip decomposition were detected. The between-species effects were detected in the surface soil layer only in the summer period, and were of the same order for the 2 sites where comparisons were possible. It was concluded that the seasonal factor should be taken into account in studying tree species effects on soils, and that the study should be extended to other sites.

2 *Introduction*
Trees and associated forest management practices are known to cause changes in soil properties and fertility: some changes induced are of low intensity and are often detectable only after a long period (Duchaufour & Bonneau 1961; Bollen 1974; Page 1974; Bonneau *et al.* 1976; Nys 1981). At CNRF, we are currently studying changes in the quality of organic matter, microbial activity and chemical and physical properties of soils brought about by different tree species (Nys 1981; Bonnaud *et al.* 1985; Nys & Ranger 1985; Nys *et al.* 1987).

The rate at which cellulose decays in soil differs in various forest sites and at the same site under different tree species (Lahde 1974; Berg *et al.* 1975). Change in tensile strength of cotton strips after insertion in soil has been proposed as an index of the rate of cellulose decomposition (Latter & Howson 1977), and the rate of decomposition of these strips has been found to vary in soil under different tree species. The rates have also been shown to correlate well with the improvement in tree growth in species mixtures (Brown & Harrison 1983; Brown & Howson 1988).

The aim of the present study was to test whether or not the cotton strip assay could be a sensitive indicator of changes in potential decomposition, within the framework of our studies on the effect of forest trees on soil fertility in northern France.

3 *Site description*
The 3 sites are situated in Normandy, the Ardennes and the Vosges, in France. The first 2 sites have sessile oak as climax species and a similar range of other species. The third site, in the Vosges, is under Scots pine.

3.1 Normandy site
The Normandy site is situated at Eu forest, 150 km west of Paris, at an elevation of 200 m. The soil (Nys *et al.* 1987) is an eluviated brown earth (sol brun lessive); some properties are given in Table 1. The

Table 1. Characteristics of organic matter in surface litter and A_1 horizon (organo mineral horizon)

	Normandy			Ardennes		Vosges
	Oak	Beech	Spruce	Oak	Spruce	Pine
Litter (t ha^{-1})	14.0	26.8	54.2	17.3	37.3	
A_1 horizon						
Carbon (t ha^{-1})	23.1	18.3	33.0	56.6	81.5	33.1
Nitrogen (t ha^{-1})	1.8	1.3	1.5	3.9	4.8	1.1
C/N	12.8	14.1	22.0	10.5	16.4	32.7
Organic matter (% C total)						
Fresh	4.7	6.9	12.7			
Bound	41.0	24.5	8.2			
Residual humin	1.9	6.0	6.7			
pH	4.4	4.5	4.0	4.2	3.7	3.4
Humus	Acid mull	Acid mull	Moder	Acid mull	Moder	Dysmoder

soils are formed from a loess deposit, one to several metres thick, overlying a layer of clay-with-flints on cretaceous chalk. The climate is oceanic, with a mean annual rainfall of 777 mm evenly distributed throughout the year and a mean annual temperature of 9.5°C.

Oak: A sessile oak stand about 100 years old, with a mean tree diameter at breast height (dbh) of 35 cm, this site was used as the initial forest control plot. The ground flora consists of grasses, cow-wheat (*Melampyrum* spp.), bracken (*Pteridium aquilinum*) and bramble (*Rubus* spp.).

Beech: A stand of beech (*Fagus sylvatica*), 150–200 years old, now about 35 m high, with a dbh of 55 cm, and virtually no ground flora.

Spruce: Norway spruce, about 80 years old, with a density of 150 trees ha^{-1}, 35–40 m high, and a dbh of 60 cm. The ground flora is mainly bracken.

3.2 Ardennes site

The Ardennes site is situated at Montherme, 200 km east of Paris, at an elevation of 400 m. The soil is a brown earth (sol brun acide) (Table 1), formed from a silt deposit overlying a revinien shale (Nys 1981). The mountain climate has a mean annual rainfall of 1300 mm, distributed throughout the year, and a mean annual temperature of 8.5°C.

Oak: A coppice with sessile oak standards, with 70 trees ha^{-1}, 150–200 years old, and 17 m high. The stand consists of 30-year-old oak (35%), birch (*Betula verrucosa*) (40%) and rowan (*Sorbus aucuparia*) (20%). The ground flora consists of grasses, bracken and bilberry (*Vaccinium myrtillus*).

Beech: Isolated trees of beech, 10 ha^{-1}, 150–200 years old, 17–20 m high covering 100 m^2 each. There is no ground flora.

Spruce: The Norway spruce were planted 50 years ago after clearfelling of part of the oak stand. The trees are 20–22 m high, with a dbh of 25 cm and 900 trees ha^{-1}. There is no ground flora.

3.3 Vosges site

The Vosges site is situated at Grandviller, 350 km east of Paris, at an elevation of 400 m, and the soil is a podzolic soil on grit. The climate is semi-continental, with a mean annual rainfall of 900 mm. Scots pine trees were planted 30 years ago and, after thinning, there are now 700 trees ha^{-1}, 15 m high.

4 *Method*

After a pilot study in the summer of 1983, 10 cotton strips were inserted in areas between trees adjacent to the litter traps, which were already on the plots.

Methods for assessing the organic matter properties of the forest soils (Table 1) are given in Bonneau and

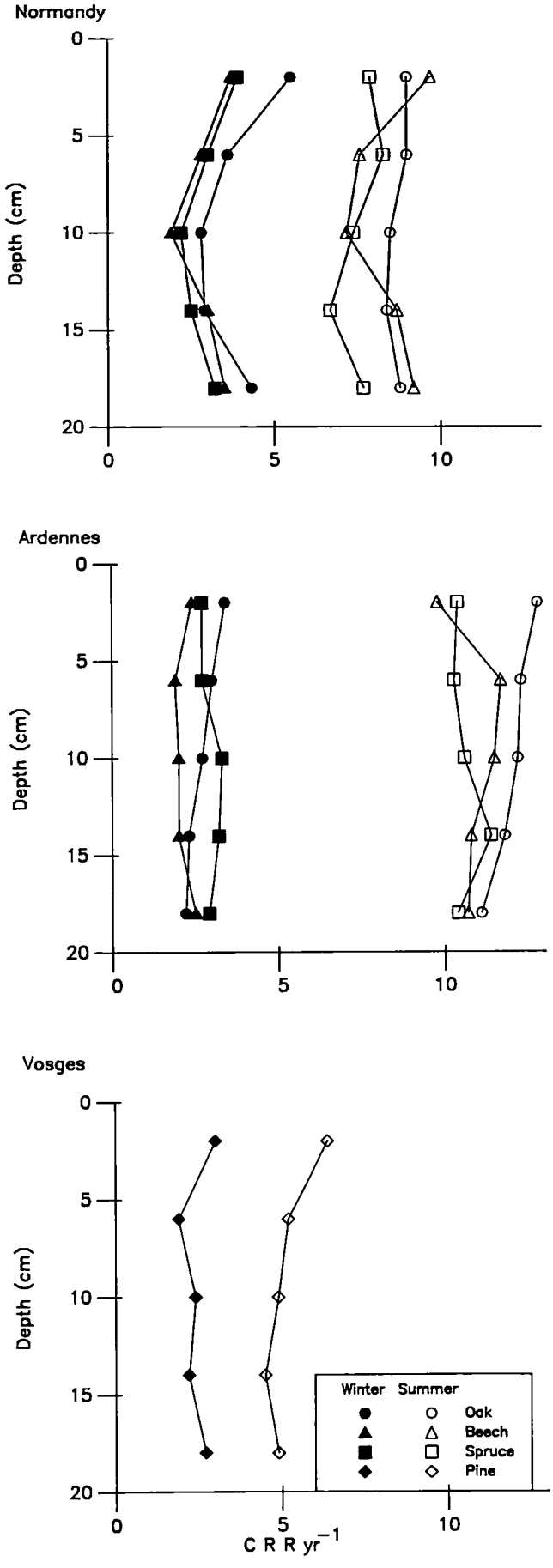

Figure 1. Rotting rates (CRR) of cotton strips. The variation between tree species and season in 3 sites in France

Table 2. Analysis of variance of cotton strip rotting rates (CRR yr^{-1}); F values for site and species effects

	Depth (cm) 0–4	4–8	8–12	12–16	16–20
Winter 1983					
n = 89					
Site	5.5 **	1.5 NS	0.25 NS	0.4 NS	4.5 *
Species	1.5 NS	0.6 NS	1.2 NS	0.6 NS	1.5 NS
Site x species	0.9 NS	0.5 NS	2.1 NS	3.4 NS	2.6 NS
Summer 1984					
n = 107					
Site	5.8 **	9.1 **	15.7 **	12.7 **	4.8 **
Species	2.4 *	0.9 NS	0.9 NS	0.9 NS	1.0 NS
Site x species	5.5 *	1.4 NS	0.3 NS	2.0 NS	0.3 NS

NS, not significant; * $P<0.05$; ** $P<0.01$

Table 3. Analysis of variance of cotton strip rotting rates (CRR yr^{-1}); mean ± SD; F values for site effect for means of all species

	Depth (cm) 0–4	4–8	8–12	12–16	16–20
Winter 1983					
Normandy	4.60 ± 1.68	3.10 ± 1.46	2.56 ± 1.29	2.67 ± 1.21	3.29 ± 1.39
Ardennes	2.70 ± 1.24	2.48 ± 1.24	2.45 ± 1.21	2.37 ± 0.88	2.56 ± 0.91
Vosges	2.92 ± 0.69	1.79 ± 0.73	2.30 ± 1.02	2.15 ± 0.77	2.30 ± 0.69
F ratio	14.65**	4.7*	0.2 NS	1.3 NS	4.3*
Summer 1984					
Normandy	9.02 ± 2.7	7.99 ± 2.9	7.64 ± 2.7	7.65 ± 2.7	8.11 ± 3.2
Ardennes	11.12 ± 2.7	11.50 ± 2.6	11.15 ± 2.2	11.07 ± 2.5	11.11 ± 2.1
Vosges	6.35 ± 1.8	5.20 ± 1.7	4.92 ± 2.1	4.50 ± 1.7	4.91 ± 2.5
F ratio	13.6**	28.1**	33.6**	32.6**	22.9**

NS, not significant; * $P<0.05$; ** $P<0.01$

Souchier (1982). The winter series were inserted for 8 weeks and the summer series for 3 weeks, from December 1983–February 1984 and in July 1984, respectively. Cotton strips were inserted and processed according to the method of Latter and Howson (1977), and the data expressed as cotton rotting rate (CRR) according to Hill *et al.* (1988).

5 *Results*

The rates of decomposition of cotton strips (CRR) decreased in the order oak>beech>spruce at both sites (Figure 1), but the species effect is only significant in the humus layer of the soil (Table 2). Figure 1 also shows that season, under the French climate, had the greatest effect on cellulose decomposition, significant at 1% (F ratio = 275, df 1, 194). The site effect shows different decomposition rates ($P<0.01$) in the summer (Table 3), despite the dry summer of 1984.

A good relationship is apparent between the order of the CRR and the classification of humus type and some soil properties over the 6 plots examined, the CRR values increasing with increasing pH, decreasing carbon/nitrogen (C/N) and decreasing quantity of litter across the sites. Thus, beech or oak sites with lower quantity of litter and C/N ratio and higher pH showed higher cellulose decomposition rates than the spruce plots. Figure 2 shows, for the Normandy site, that the physical properties of soils are also highly related with the CRR. The better the soil porosity, clay stability and soil aggregation, the faster is the decomposition of the cotton strips.

6 *Conclusion*

The experiment indicates that the assay was sufficiently sensitive to differentiate between the effects on soils of different tree species, despite the dry summer of 1984. The relationships between cotton strip decomposition rates and humus form and soil physical and chemical properties show that this method could be used as a test of soil biological activity in the same way that the mineral bag method is used as an indicator of decline in soil fertility (Bonnaud *et al.* 1985).

It is concluded that the experiment should be repeated at more sites with a similar range of tree species or silvicultural treatments, because of the very significant interaction between sites and species. Cotton strips should also be inserted for different periods of the year to examine the seasonal variation patterns (cf Brown & Howson 1988) for different sites.

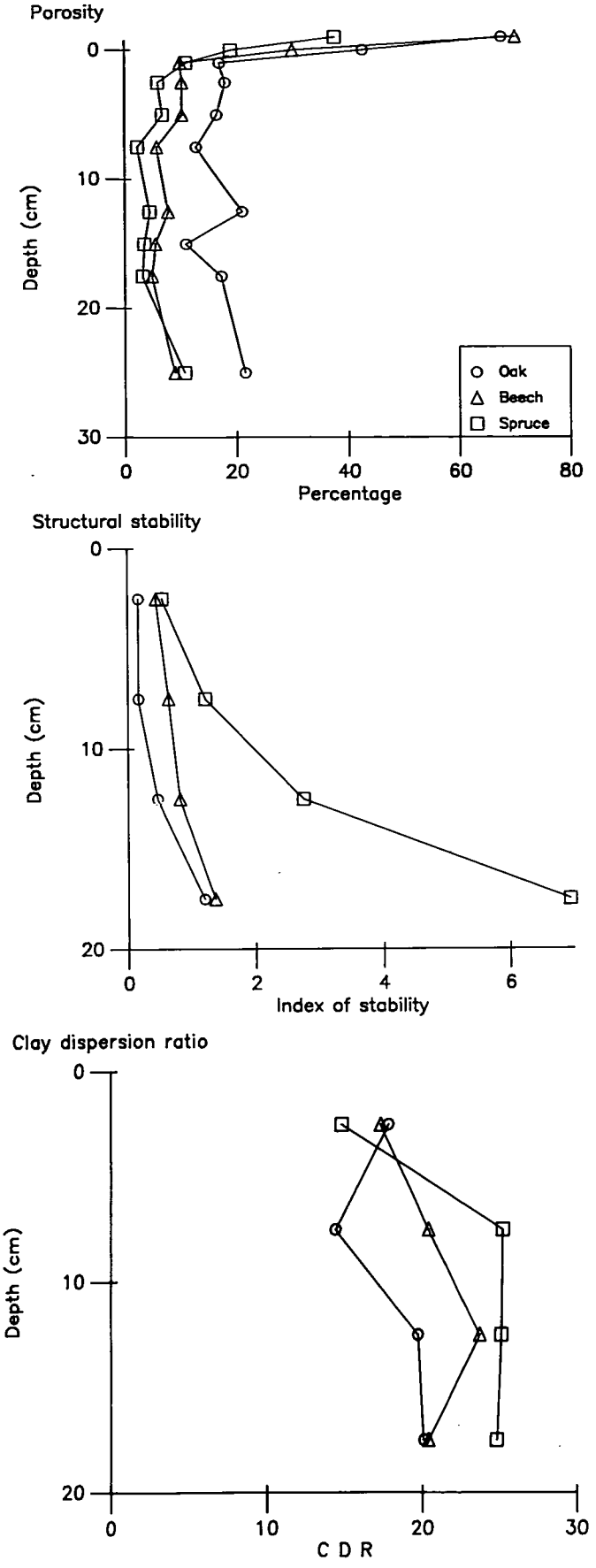

Figure 2. Physical characteristics of the soil profile at the Normandy site

i. Porosity is the area of pores/total analysed area, expressed as a percentage

ii. Structural stability (method: Henin et al. *1969)*

iii. Clay dispersion ratio (method: MAFF 1982)

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