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Below-ground organic carbon and decomposition potential in a field-forest glacial-outwash landscape

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Abstract Relationships of soil properties to land use and topography may vary among locales because of differences in other controlling factors. We evaluated relationships of below-ground C, defined as soil organic C plus fine-root C, and decomposition potential to site characteristics at Cedar Creek Natural History Area in east-central Minnesota, USA. The landscape, formed in glacial outwash sand, has a complex spatial pattern of grasslands and forests resulting from interactions among cultivation, agricultural abandonment, topography, and fire. Below-ground C was higher in mature forests than in either adjacent abandoned agricultural fields or uncultivated prairie for both the O Horizon (0.57 vs. 0.13 kg m⁻²) and the underlying 0–10 cm of soil (2.1 vs. 1.0 kg m⁻²) but was similar at 10–30 cm (2.0 vs. 2.0 kg m⁻²) and 30–50 cm (1.4 vs. 1.5 kg m⁻²). The higher C in surface soil under forests contrasted with published observations for finer textured substrates. Below-ground C was constant across forest summit, shoulder, and back-slope positions, and increased at the toeslope position. Average fine-root (<2 mm diameter) C at the depth of 0–50 cm was 0.2 kg m⁻² and represented 4% of below-ground C. In contrast to an expected trend of monotonically increasing decomposition with increased temperature, cellulose decomposition during a 60-day field incubation increased with temperature on cool forest slopes but decreased with temperature in warm fields. Nutrient availability, water availability, and microbial biomass may confound this relationship. The results indicate diverse controls on decomposition in this field-forest landscape.

Key words Abandoned agricultural fields · Decomposition potential · Grassland · Old fields · Prairie · Roots · Soil organic C · Tree transect

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Introduction

Vegetation and disturbance are two of the many soil-forming factors (Jenny 1980) that influence belowground C, defined as soil organic C plus fine-root C. In the Great Plains of the USA and Canada, prairie soils contain more soil organic C than forest soils (Smith et al. 1950; White and Riecken 1955; St. Arnaud and Whiteside 1964; Dorrmar and Lutwick 1966; Geis et al. 1970; Severson and Arneman 1973; Zhang et al. 1988; Almendinger 1990). Cultivation of prairie generally decreases root C (Richter et al. 1990) and soil organic C (Mann 1986; Schimel et al. 1985a), although this effect may be limited to the surface soil (Angers et al. 1992). Studying a herbaceous succession in abandoned agricultural fields on a Minnesota sand plain, Zak et al. (1990) found that organic C was increased in the surface (0–10 cm), mineral soil. In contrast, in a postagriculture forest succession in New Hampshire, Hamburg (1984) found an increase in O-horizon C, a decrease in C in the surface (0–19 cm) mineral soil, and no discernible pattern of change in subsurface soil.

Soil organic C and related soil characteristics are also influenced by topography. In an Iowa prairie, total soil N increased from the shoulder to the toeslope position, while the summit had either higher or lower amounts than the shoulder (Aandahl 1948). In a Colorado shortgrass steppe, soil organic C increased from the backslope to the toeslope, while the summit had either higher or lower amounts than the backslope, depending on the depth considered (Schimel et al. 1985b). In contrast, no effect of slope position on surface-soil organic C was found on cultivated and uncultivated rangeland in North Dakota (Schimel et al. 1985a). Similarly, in forest soils, slope position and slope gradient have lesser or inconsistent effects on soil organic C (Franzmeier et al. 1969) and other soil properties (Frolking 1989). Other factors that affect soil organic C include climate, texture, parent material, and time of soil formation (Jenny 1980; Homann et al. 1995).

Soil organic C exists because of the long-term inequality between detrital production and microbial decomposition. These processes provide the mechanistic link be-

tween soil organic C and environmental and site characteristics, but measurements of processes are difficult to carry out, particularly in complex landscapes. Decomposition potential, using standardized substrates such as cotton strips and cellulose filter paper, has therefore been used to assess the relationship of decomposition to environmental and site characteristics. Although Howard (1988) concluded that this approach does not provide an index of litter decomposition or general biological activity, its correlation to a variety of soil properties and processes may reflect ecosystem functioning (Smith et al. 1993).

Cellulose decomposition has been correlated with and influenced by a variety of environmental conditions. It varied between microsites in Minnesota forested bog soil (Farrish and Grigal 1988) but not in Alaskan upland forest soils (McClellan et al. 1990). It correlated with foliar-litter decomposition across a range of taiga forest stands, and both were positively related to soil temperature and O-horizon N concentrations (Fox and van Cleve 1983). It was greater in fallowed field than in a forest soil in interior Alaska; the field had higher temperatures and possibly greater nutrient availability (Sparrow et al. 1992). Cellulose decomposition in the subsurface soil was increased by draining a peatland (Liefers 1988). It was increased by clearcutting plus soil-mixing in a western hemlock and Pacific silver fir forest, but was decreased in a western red cedar forest (Keenan et al. 1994). It increased in the O horizon following forest harvesting (Binkley 1984) and thinning (Piene and van Cleve 1978), suggesting that higher soil temperatures increased decomposition.

In the present study we examined controls on below-ground C and decomposition potential in the Cedar Creek Natural History Area (CCNHA), Minnesota, USA. This landscape formed in glacial outwash sand. It has a complex pattern of forest and grassland vegetation that has been influenced by cultivation, topography, and fire (Inouye et al. 1987b; Tester 1989). Our first objective was to determine the relationship between below-ground C and current vegetation to test the concept that vegetation and disturbance history are important soil-forming factors in this landscape. We hypothesized that forests would have similar amounts of below-ground C to those in recently abandoned agricultural fields but lower than that in older abandoned fields and uncultivated prairie. We evaluated the O horizon and the mineral soil layer at 10–50 cm, in addition to the upper 0–10 cm of mineral soil previously studied by Zak et al. (1990) at CCNHA. Our second objective was to determine the relationship between below-ground C and position on forest slopes. We hypothesized that there would be no difference in below-ground C among upland positions on forested slopes. Our third objective was to determine the relationship between decomposition potential and site characteristics. We hypothesized that the decomposition potential would be higher on warmer sites.

Materials and methods

Study area

The CCNHA is a long-term ecological research site located 60 km north of Minneapolis, Minnesota. This 2300 ha site on the Anoka Sand Plain is characterized by rolling topography, a high water table, organic soils on wetlands, and sandy (>90% sand) mineral soils on uplands (Grigal et al. 1974). Soil distribution and general characteristics have been described by Grigal et al. (1974).

Wetlands occupy approximately a third of the area. The remainder is upland, extending to a maximum of 6 m above the water table. Approximately half of the upland has been cultivated, but most agricultural tracts have been abandoned over the last 60 years and are undergoing herbaceous succession (Inouye et al. 1987b) with very slow encroachment of forest (Engstrom 1992). The remaining area is currently closed-canopy forests dominated by northern red oak (*Quercus rubra* L.), northern pin oak (*Quercus ellipsoidalis* E.J. Hill), and bur oak (*Quercus macrocarpa* Michx.), but other species are also present, including red pine (*Pinus resinosa* Ait.), white pine (*Pinus strobus* L.), basswood (*Tilia americana* L.), sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.) and paper birch (*Betula papyrifera* Marsh.). Stands of cedar (*Thuja occidentalis* L.) occupy part of the wetlands.

Eight transects, 30–50 m in length, were established from fields into adjacent mature forests (Table 1). Along each transect, five sampling positions were chosen. Typically, positions 1 and 2 were in herbaceous vegetation of abandoned agricultural tracts or uncultivated prairie, position 3 was at the field-forest boundary, position 4 in young forest (mean age across all transects, 20 years, based on coring selected trees), and position 5 in mature forest (mean age across all transects, 67 years). Transects were located on relatively level sites to minimize the influence of topography on soil properties. Each transect was identified by a number equivalent to the number of years since the field was abandoned from cultivation (Table 1).

Three transects were established from the top to bottom of forested slopes (Table 2). They were sited on slopes that had relatively constant vegetation, except in the toeslope positions, which were wetland cedar stands. Slopes were approximately 15% and aspect varied among the transects (Table 2). Five sampling positions were identified along each transect: summit, shoulder, backslope, foot-slope, and toeslope (nomenclature follows Ruhe and Walker 1968).

Below-ground organic C

Forest-slope transects were sampled in August 1989 and field-forest transects in June 1990. At each sampling position, five sampling points were established along a perpendicular to and within 5 m of the transect. At each point, non-rooted Oi/Oe horizon (hereafter called O horizon) material was collected from within a 15.5×15.5 cm

Table 1 Characteristics of field-forest transects at Cedar Creek Natural History Area, Minnesota. Transect number is the number of years since abandonment of the field from cultivation. Field number is that designated in the archives of the Cedar Creek Long-term Ecological Research project. UN, uncultivated, no record of cultivation; NA, not applicable, no field number assigned

Transect number	Cedar Creek field number	Direction of transect from field to forest (degrees)	Mature forest type
3	46-1	270	Oak
13	46-10	270	Oak
22	29	160	Oak
33	25	150	Pine
38	76	90	Oak
63	72	250	Oak
>65	36	50	Oak
UN	NA	180	Oak

Table 2 Characteristics of forest-slope transects at Cedar Creek Natural History Area, Minnesota

Cedar Creek forest	Direction of transect from summit to toeslope (degrees)	Forest type at		
		Summit	Shoulder, backslope, and footslope	Toeslope
Crone's Knoll	210	Basswood, maple, birch, oak	Basswood, maple, birch, oak	Cedar
Lindeman	310	Oak, maple, pine, birch	Oak, maple, pine birch	Cedar
West of Lindeman	130	Pine	Oak, maple, pine	Cedar

square, and the underlying rooted mineral soil was collected with a 3.75 cm diameter corer. The cores were separated into genetic horizons or into depths of 0–10, 10–30, and 30–50 cm when genetic horizons were difficult to identify. There were two exceptions to this procedure: (1) on one transect (UN), the O horizon had been consumed by prescribed burning several weeks before sampling and any residual O horizon was sampled with the mineral soil, (2) a rooted organic layer of ca. 7 cm thickness that occurred at the Lindeman toeslope and 15 cm thickness at the West toeslope was collected from within the 15.5×15.5 cm square.

O horizon and toeslope organic layer samples were dried at 70°C and weighed. Loss on ignition was determined by heating at 450°C for at least 12 h. Mineral soil samples were air-dried and weighed. Fine roots less than 2 mm in diameter were removed with forceps and saved for further processing; however, root fragments that were both smaller than ca 0.5 mm in diameter and shorter than ca. 5 mm could not be effectively removed and were left in the soil. Pieces of root and decomposing wood greater than 2 mm in diameter were rare and were discarded; one entire core was discarded because it contained large amounts of decomposing wood. The moisture content of the root-free mineral soil was determined by heating the soil at 105°C for at least 12 h, and loss on ignition by heating it at 450°C for at least 12 h. Fine roots were dried at 70°C and weighed; for one sampling point for each sampling position, fine roots from all layers were combined to provide sufficient material to determine loss on ignition by heating it at 450°C for at least 12 h.

To facilitate comparisons within and between transects, sample area, depth, mass, loss on ignition, and the ratio of loss on ignition to C were used to calculate below-ground C and root C (in kg C m⁻²) for the O horizon and three successive layers of rooted substrate (0–10, 10–30, and 30–50 cm) by the Jenkinson (1970) method. This method standardizes layers to specified mineral masses to account for expansion in soil volume, such as that caused by changes in organic matter. The mineral mass values were 106 kg m⁻² for 0–10 cm, 282 kg m⁻² for 10–30, and 308 kg m⁻² for 30–50 cm in depth. The loss on ignition to C ratio was 1.96; based on loss on ignition and total C (Carlo Erba CNS Analyzer) in the surface 10 cm of rooted soil (one composite for each sampling position). Total N was measured simultaneously with total C.

Table 3 Partitioning of below-ground C variability in Cedar Creek Natural History Area. Values represent % of total sum of squares from nested analysis of variance

Layer	Variability (%) among		
	Five sampling points at each sampling position	Five sampling positions on each transect	Transects
Eight field-forest transects			
O horizon	13	64	23
0–10 cm	16	68	16
10–30 cm	18	55	27
30–50 cm	13	27	59
Total	12	54	34
Three forest-slope transects			
O horizon	30	61	9
0–10 cm	18	82	<1
10–30 cm	46	54	<1
30–50 cm	56	43	<1
Total	27	72	<1

Decomposition potential

On May 29–30, 1990, at seven points at each sampling position on each transect, an 11-cm diameter Whatman no. 1 cellulose filter paper enclosed in a 1-mm mesh plastic fabric was inserted into the surface 10 cm of rooted soil. After 60 days, the cellulose papers were collected, dried at 105°C, and the ash-free mass was measured by heating at 450°C for at least 12 h. The ash-free mass loss during field incubation was calculated as the percentage of ash-free mass of non-incubated cellulose paper. On July 9, 1990, between 12.40 and 6.40 p.m., the temperature of the top 0–10 cm of rooted soil was measured with a dial thermometer at two points at each sampling position; the two measurements were typically within 1°C of each other.

Results and discussion

Field-forest transect

As indicated by the terminal transect positions (Fig. 1), the mature forests consistently had more C in O horizons and in the top 0–10 cm of soil than did the adjacent fields, irrespective of the time since field abandonment. The O-horizon C of the young forests (data not shown) was similar to that of the mature forests, while the trend at 0–10 cm was field ≤ young forest ≤ mature forest. In contrast, at 10–30 and 30–50 cm, there were few differences between positions on individual transects (Fig. 1), indicating no consistent effect of disturbance and vegetation history on below-ground C at these depths.

In the O horizon and the top 0–10 cm of soil, spatial variability was largely caused by differences between sampling positions within transects, with additional variability

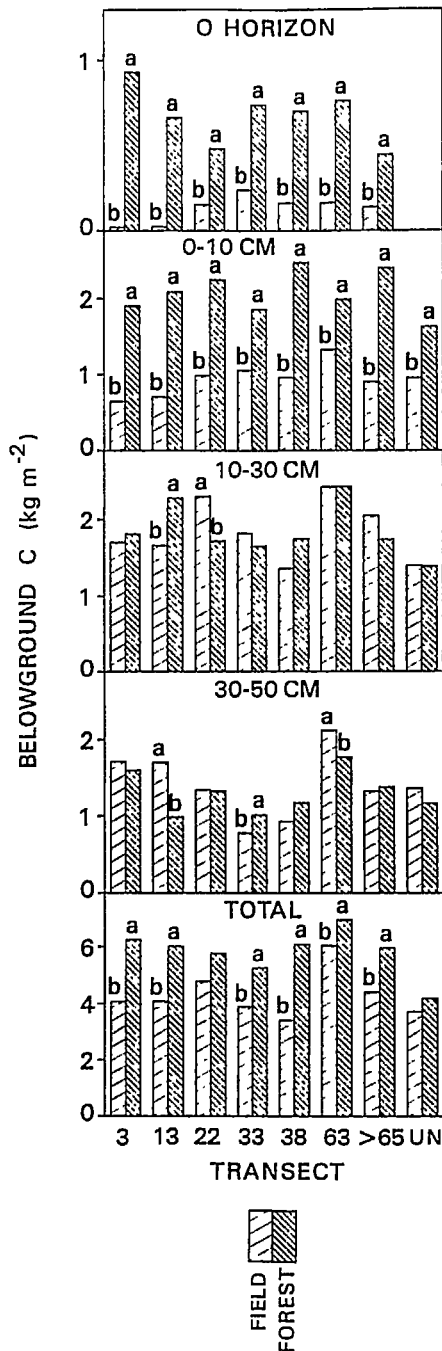


Fig. 1 Below-ground organic C at the terminal field and mature-forest positions of field-forest transects at Cedar Creek Natural History Area, Minnesota. The transect number is the number of years since abandonment of the field position from cultivation. Within each transect, positions identified by different letters are significantly different at $P < 0.01$, by Duncan's multiple-range test applied to all five sampling positions on the transect

occurring between transects (Table 3). At greater depth, between-position variability decreased in importance as between-transect variability increased. The between-transect variability at 10–30 and 30–50 cm (Table 3, Fig. 1) occurred in spite of the relatively homogeneous sandy parent

material in this landscape (Grigal et al. 1974). Differences in water and nutrient availability caused by depth to water table or the presence of thin fine-textured layers in the soil (Hannah and Zahner 1970) might create differences in long-term productivity, and hence detrital production and organic matter accumulation.

Zak et al. (1990) used a chronosequence approach to examine the changes in soil organic C (0–10 cm depth) over a herbaceous succession in abandoned agricultural fields at CCNHA. An increase in C over the herbaceous succession was indicated by higher organic C levels in fields abandoned long ago compared to more recently abandoned fields. Our data for 0–10 cm (Fig. 1), some of which were collected from the same fields studied by Zak et al. (1990), showed a similar trend. Our data also showed that accumulation of the O horizon during the first few decades of herbaceous succession contributed to the increase in below-ground C.

Forest encroachment may cause a more rapid build-up of below-ground C than a herbaceous succession. Compared with fields that had undergone herbaceous succession for 22 to >65 years, the adjacent young forests had 0.2–0.6 kg m⁻² more C in O horizons and up to 0.3 kg m⁻² more C in the top 0–10 cm of mineral soil. Although we do not have precise histories of forest encroachment for the individual transects, the presence of young forests along field edges is consistent with the concept of a slow encroachment of woody vegetation into abandoned agricultural fields in this landscape (Engstrom 1992). In a New England landscape, organic matter in the O horizon increased substantially during 70 years of forest succession following the abandonment of agricultural fields, but did not increase in surface mineral soil (Hamburg 1984).

The lower concentration of surface-soil organic C in uncultivated prairie compared with adjacent forest is consistent with the lower or equal surface-soil organic C under oak savanna compared with pin oak and northern hardwood forest observed by Zak et al. (1990). The observations for CCNHA are in contrast to results from other studies in the Great Plains, where prairies contained more soil organic C than forests (Smith et al. 1950; White and Riecken 1955; St. Arnaud and Whiteside 1964; Dormarr and Lutwick 1966; Geis et al. 1970; Severson and Arne-man 1973; Zhang et al. 1988; Almendinger 1990). The opposite trend at CCNHA may be related to the high sand content (>90%) of the soils (Grigal et al. 1974) and the extensive bioturbation caused by gophers in CCNHA fields (Inouye et al. 1987a).

Varying patterns of soil organic C under prairie and forest have been observed in other regions. The higher soil organic C levels found in ponderosa pine groves than in interspersed grasslands in California (Jenny 1980) are similar to our observations for CCNHA. In contrast, Pope-noe et al. (1992) found that in the upper 10 cm of mineral soil, organic C was similar under Californian prairie, oak woodland, and conifer forest, but organic C was higher deeper in the prairie profile.

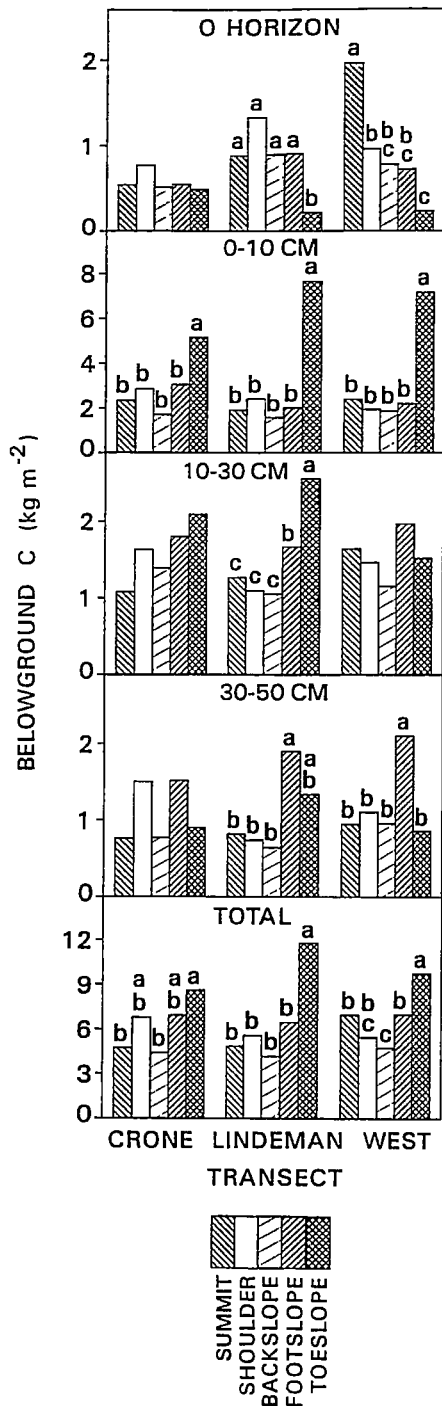


Fig. 2 Below-ground organic C on forest-slope transects at Cedar Creek Natural History Area, Minnesota. Within each transect, positions identified by different letters are significantly different at $P < 0.01$, by Duncan's multiple-range test

Forest-slope transects

Spatial patterns of C in the non-rooted O horizon varied among the slopes (Fig. 2), including similar values in all positions (Crone's Knoll), lower amounts on the toeslope (Lindeman), and higher amounts on the summit (West of

Lindeman). This latter observation is coincident with pine dominating that summit (Table 2). In contrast, at 0–10 cm, the pattern was consistent on the three transects: the C content was the same on the summit, shoulder, backslope and footslope, and higher on the toeslope, a trend similar to that observed in oak stands at CCNHA (Hairston and Grigal 1991). At 10–30 and 30–50 cm in depth, the summit, shoulder, and backslope had similar amounts of C, while the footslope and toeslope occasionally had higher levels (Fig. 2).

Roots

Root C at 0–50 cm averaged 0.18 kg m^{-2} for all sampling positions of the field-forest transects. Recently abandoned fields had substantially lower root C while one older field had higher amounts than the adjacent mature forest (Fig. 3). Compared to adjacent forests, there was a trend for root C to be a lower proportion of below-ground C in recently abandoned fields and a higher proportion in older fields. Root C was a higher proportion of below-ground C at the soil surface than at depth. In the young and mature forest positions, root C averaged 4.1% at 0–10, 3.3% at 10–30, and 3.0% at 30–50 cm in soil depth. The value for 0–10 cm is similar to the 5% found at 5–10 cm of mineral soil depth in a *Pinus taeda* L. stand in South Carolina (Ruark and Zarnoch 1992). In the two most recently aban-

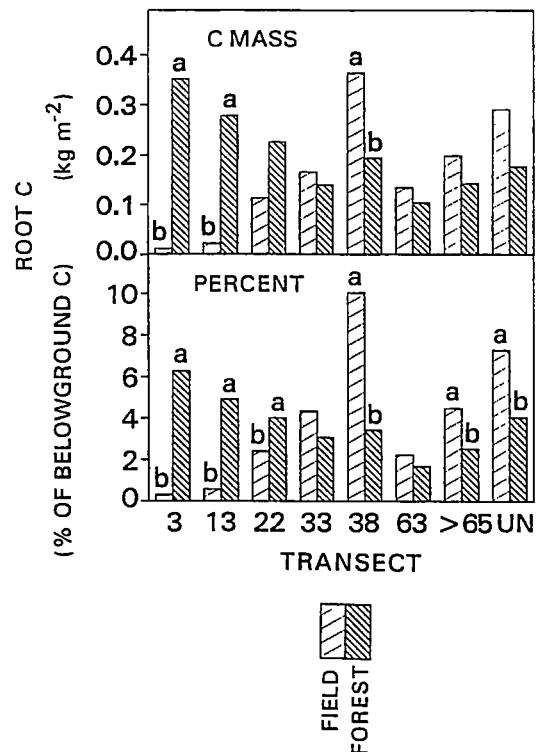


Fig. 3 Fine-root (<2 mm diameter) C at 0–50 cm depth of soil at the terminal field and mature-forest positions of field-forest transects at Cedar Creek Natural History Area, Minnesota. For further explanations, see Fig. 1

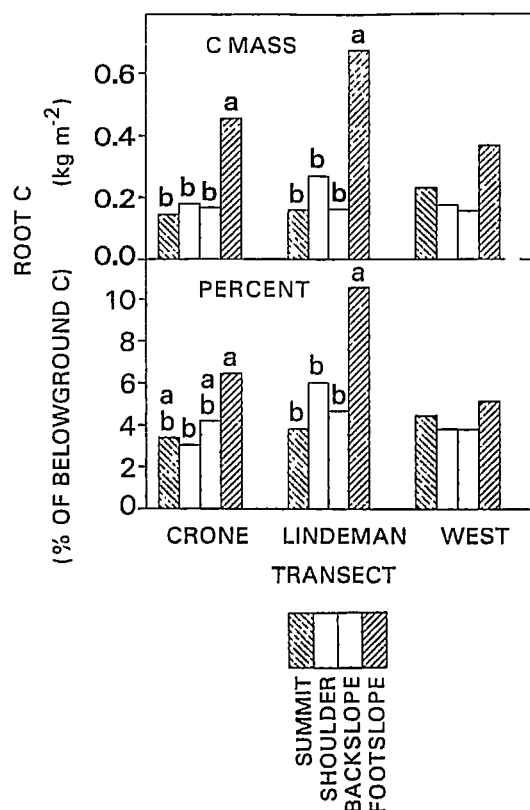


Fig. 4 Fine-root (<2 m diameter) C at 0–50 cm depth of soil in three forest-slope transects at Cedar Creek Natural History Area, Minnesota. Fine roots were not determined for the toeslope position because some fine roots could not be separated from samples. For further explanations, see Fig. 2

doned fields, root C averaged 2.4% of below-ground C at 0–10, 0.9% at 10–30, and 0.4% at 30–50 cm. In other fields it averaged 7.5%, 4.4%, and 1.8% for the three layers. These values are much lower than the 10% found in the top 0–15 cm of mineral soil in annually tilled and 25% in untilled clay-loam grassland soils in Michigan (Richter et al. 1990).

Table 4 Coefficients of determination (R^2) for regressions of cellulose paper decomposition (% mass loss in 60 days) vs. soil characteristics (0–10 cm) for forest-slope and field-forest transects. Signs in parentheses indicate signs of regression coefficients; for the temperature plus temperature² regression and the below-ground C plus C²

Soil characteristic	Transect positions				
	Forest slope (all)	Field-forest			All
		Field	Forest	All	
Temperature (°C)	0.51 (+)	0.66 (–)	NS	NS	NS
Temperature and temperature ²	NS [†]	0.89 (+, –)	NS	0.48 (+, –)	0.48 (+, –)
Below-ground C (kg C m ⁻²)	0.31 (–)	0.36 (+)	NS	NS	NS
Below-ground C and C ²	NS	0.75 (+, –)	NS	NS	NS
Root C (kg C m ⁻²)	NS	0.31 (+)	NS	NS	NS ^{††}
Below-ground C:N	0.43 (–)	NS	NS	NS	NS
n	15	15	19	40	55

On the forest slopes, root C did not differ among the upslope positions (Fig. 4). It was higher in the footslope than upslope positions on two of the three slopes. As a proportion of below-ground C, root C in the footslope was greater than or equal to upslope root C (Fig. 4).

Decomposition potential

Decomposition potential varied considerably over the landscape, with mass loss during the 60-day incubation ranging from 25 to 100%. Over all sampling positions, decomposition potential was curvilinearly related to temperature, with decomposition increasing with temperature at low temperatures but decreasing at high temperatures (Table 4, Fig. 5).

Decomposition potential increased with temperature on the forest slopes (Table 4); it was higher in the warmer upslope positions than in the cooler footslope and toeslope positions (Fig. 5). This is consistent with our expectation of increased decomposition with higher temperature and consistent with previous studies in which decomposition was related to temperature (Fox and van Cleve 1983; Sparrow et al. 1992) or enhanced by treatments that increased temperature (Piene and van Cleve 1978; Binkley 1984). However, other factors that influence microbial activity might also have been involved. The negative relationship between decomposition potential and the below-ground C:N ratio (Table 4) is similar to observations in taiga forest stands (Fox and van Cleve 1983) and may indicate a nutrient limitation on decomposition in the footslope and toeslope positions (mean C:N 22) compared with upslope positions (mean C:N 18). Further, although they were not waterlogged during this study, the footslope and toeslope positions are periodically saturated, which might influence microbial processes during subsequent unsaturated periods.

In the field-forest transects, there were no consistent spatial patterns of decomposition. For example, decomposition in the fields was greater than in adjacent mature for-

est, signs are given for the two terms. NS, regression not significant at $P < 0.05$; NS*, additional temperature² or below-ground C² term not significant at $P < 0.05$; NS^{††}, excludes the three toeslope positions because roots were not quantified separately for some toeslope samples

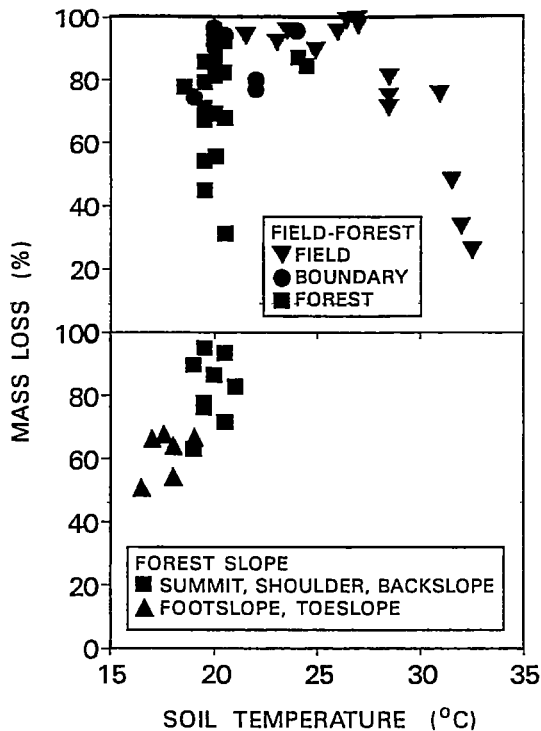


Fig. 5 Sixty-day mass loss of cellulose paper in relation to soil temperature on field-forest and forest-slope transects

ests in some transects, but lower in others. Decomposition potential was not related to temperature in the forest positions, which had a relatively narrow range of temperature.

Decomposition potential decreased with increased temperature in the fields, which had a broad range of mineral soil temperature due to differing amounts of above-ground vegetation (Gleeson and Tilman 1990) and organic layer (Fig. 1) creating different degrees of shading. The decrease in decomposition at high temperatures was contrary to our expectation and occurred at temperatures much lower than those normally thought to reduce microbial decomposition (Alexander 1977). Several factors may contribute to this pattern. First, our temperature measurements were made at a single point in time and may not reflect extreme temperatures experienced by microbes during the full incubation. Second, the high soil temperatures may reflect a low soil moisture content, as Knapp and Seastadt (1986) observed in burned and unburned tall-grass prairie, which may limit microbial activity. Third, soil temperature was inversely related to below-ground C for the field positions ($r = -0.51$), and microbial biomass has been highly positively correlated with below-ground C in CCNHA fields (Zak et al. 1990). Therefore, fields with the highest soil temperatures would have had the lowest microbial biomass content. Although higher temperatures might stimulate microbial activity, the lower decomposition potential observed in warmer fields indicates that such potential stimulation did not compensate for a lower microbial biomass content.

In conclusion, we expected forests to have similar contents of below-ground C to those of recently abandoned

agricultural fields but lower than in older abandoned fields and uncultivated prairie. However, in the very sandy substrate of CCNHA, we found that mature forests had higher below-ground C contents than all adjacent fields and uncultivated prairie in both the O horizon and the surface 10 cm of mineral soil. This contrasts with other studies in the Great Plains on less sandy substrates. At greater depths, fields and adjacent forests had similar below-ground C contents, indicating that landscape evaluations of changes in below-ground C as a result of changes in land use probably do not have to take deeper soil layers into account.

Consistent with our expectations, we found no difference in below-ground C among upland positions of forested slopes. However, these positions had less below-ground C than the toeslope position, which was close to or at the water table. Therefore, landscape evaluations of below-ground C stores in this landscape do not have to differentiate between upland positions but must distinguish between upland and lowland.

We hypothesized that the decomposition potential would be higher on warmer sites. However, this parameter was curvilinearly related to temperature, with decomposition increasing with temperature at low temperatures on forest slopes, but decreasing at high temperatures in fields. Nutrient availability, soil moisture, and microbial biomass may be confounding factors in this unexpected finding.

Overall, our results indicate multiple controls on below-ground C and on decomposition processes in this field-forest landscape. The differences in our results compared to those reported in the literature reiterate the unique nature of extremely sandy soils and lend support to the use of caution in extrapolating observations to untested situations.

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