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Regular research paper

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RATE OF CHANGE OF PINE LITTER FALL AND DECAY IN RESPONSE TO CHANGING CLIMATE ALONG N-S TRANSECT

ABSTRACT: The response of pine ecosystems to changing latitude and thermoclimate in Central/Northern Europe was investigated through the measurements of rates of two ecosystem processes: organic matter (litter) production and decomposition. Studies were carried out at nine sites of pine and mixed pine forests placed along the N-S transect of about 2000 km crossing Finland, Estonia, Latvia, Lithuania and Poland. Warmer climates were observed with movement to southern sites; the coefficient of determination (R^2) between annual long-term temperature and latitude was at the level of 0.99. The rates of change of both processes were compared in terms of relative increment per 1°C of long-term temperature and per –1° of latitude, and expressed in %. Litter production responds stronger to the southward change of climate: the fall of litter is 18–19% greater per +1°C of average annual temperature and by 8% greater per each –1° of latitude, compared to the decomposition process, which was accelerated at the rate of 9–12% per 1°C and 4–5% per –1° of latitude. These results are summarized by the statement that in pine ecosystems the OM Production Sub-system is more sensitive to change of climate than the Sub-system of OM Decay, which is more conservative.

KEY WORDS: pine ecosystem transect study, litter fall/decay, decomposition, climate change.

The purpose of the present paper is to compare two essential ecosystem processes and their reaction to climate change along a N-S transect. The studies were conducted in the pine forests, i.e., ecosystems that are widely present in Central and Northern Europe. A major change is expected to take place in this type of forests in case of global warming. The processes selected for the study were litter production measured as the annual fall of the dead plant fragments and annual decomposition of this litter. The study was conducted over the years 1997–2000. The rates of both processes per 1° of latitude and 1°C of temperature were calculated for sites comparison.

The N-S transect extends from Northern Finland to Southern Poland (about 2000 km and 20 degrees of latitude) and presents a regular, distinct temperature increase southward . The difference in average annual temperature between two extreme sites exceeds 9°C (ranging from –1.9°C to +7.4°C) (Fig. 1). Precipitation does not show any distinct pattern of change with latitude (more detailed climatic data can be found in Breymeyer 2003a, this volume). At its northernmost end, the transect reaches the limits of occurrence of forest with Scots pine, while at the southern end we encounter the last lowland examples of such forests.

The nine study sites considered are located in Finland (3: FN1, FN2, FN3), Estonia (1: ES1), Latvia (1: LT1), Lithuania (1: LI1), and Poland (3: PL1, PL2 , PL3). Sites selection was based on overall similarity with respect to species composition, stand age, elevation, and soil type and morphology. All stands are dominated by the overstory of Scots pine. Although the relative abundance of ground cover plant species varies from site to site, *Vaccinium spp*., *Cladonia spp*., and *Pleurozium schreberi* are common at all sites (Solon 2003, this volume). Average tree-stand age was 110 years (range: 66–178), see Nagel *et al.* (2003, this volume). All soils are sandy with a similar origin (i.e. glacial outwash and fluvial accumulation) and are classified as either podzolic or rusty podzolic (Degórski 2003, this volume).

The measurements of the rate of decomposition and production of litter were carried out at all the nine study sites during four expeditions to the transect in the years 1997–2000. The rate of litter decomposition was evaluated on the basis of the loss of the litter mass during year long incubation in the forest. The portions of litter dried down to constant weight were closed in nylon net bags (net cells of 1x1 mm) and laid out at the study sites on the surface of the soil, then collected after a year, dried and weighted again. The difference of weights constituted the measure of decomposition of the litter. Litter production, on the other hand, was measured by gathering of the dead plant fragments falling down on the forest bottom, which were collected on the sand-covered surfaces with the help of the circular frame of 0.1 m^2. The litter was dried and weighted. A detailed description of the methodology applied can be found in Breymeyer (2003b, this volume).

In order to calculate the correlation between the rate of decomposition, on the one hand, and latitude, as well as long-term temperature, on the other, 1040 measurements of litter mass losses on each of the study sites were used. In case of correlation between litter fall and the same environmental factors 855 measurements were used. The data were transferred into the % change per 1°C and 1° N latitude.

A very high determination coefficient ($R^2 = 0.9895$) was observed between the long-term annual temperatures, and the geographical location of the sites, and a very well fitted polynomial trend was obtained for this dependence (Fig. 1A). The regularly increasing temperature along transect is very distinctly associated with the latitude change. Then, the correlation values were calculated, and the interdependence between the two processes LITF & DECO and latitude were presented on the diagrams (Fig. 1B,C). These determination coefficients are also high, the higher one corresponding to the litter decomposition process. The rates of the two ecological processes increase along with the southward movement conform to the exponential curve.

The rates of change for decomposition (DECO) and litterfall (LITF) processes per unit of temperature and unit of latitude were calculated (Table1). The rate of change is expressed in % corresponding to the relative in-

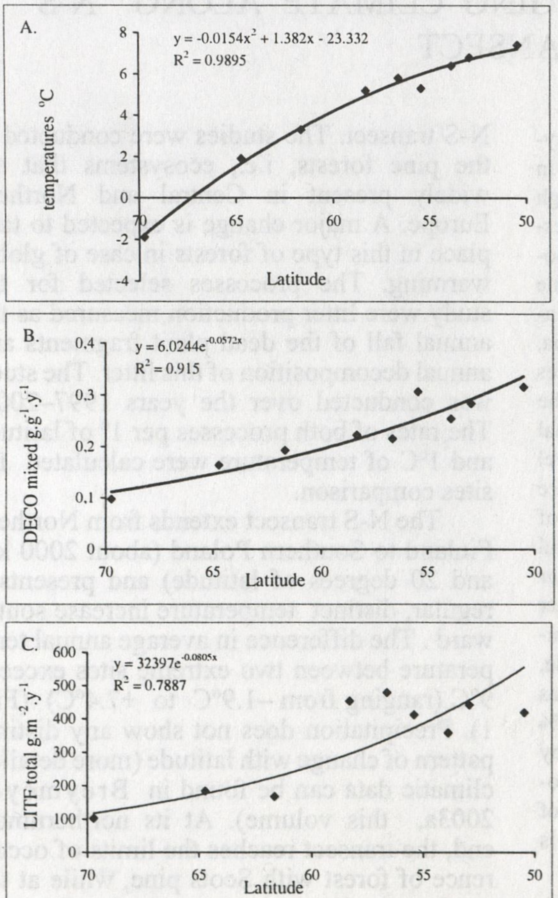
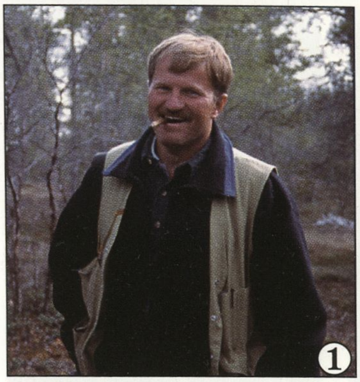


Fig. 1. Conditioning of the thermoclimate and of both LITF & DECO ecosystem processes by the geographic position of sites. A. Latitude *versus* long-term average temperatures. B. Latitude *versus* DECO process. C. Latitude *versus* LITF process.



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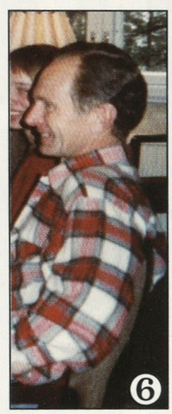

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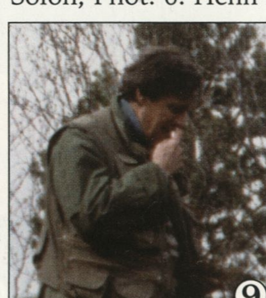
Project participants on the road and in the forests

Phot. 1. Glenn Mroz; Phot. 2. David Reed; Phot. 3. Alicja Breymayer and Ewa Roo-Zielińska; Phot. 4. Jerzy Solon; Phot. 5. Glenn Mroz (from left), Reginald Noble, Jerzy Solon, Alicja Breymeyer, Marek Degórski, Marek Nowak (our driver) and Jerzy Solon; Phot. 6. Henn Pärn; Phot. 7. Alicja Breymeyer (from left), Marek Degórski, Marek Nowak (our driver) and Jerzy Solon; Phot. 8. Reginald Noble, Marek Degórski, Rauni Ohtonen (our Finnish advisor); Phot. 9. Jurij Martin.



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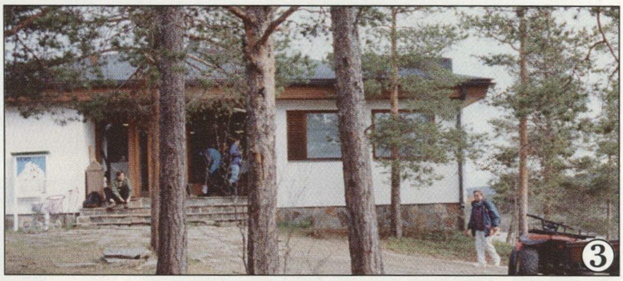

Phot. 1. Our guest-raindeer in FN1 site;
Phot. 2. Looking for the most northern point in the Continent we traveled to Nordkapp (72°N), but there was not Scots pine (yet?);
Phot. 3. Kevo Field Station;
Phot. 4. Mini-excursion to Savolinna castle FN3;
Phot. 5. 1996 scientific seminar of the project in Riverside, CA, USA;
Phot. 6. Collecting litterfall or praying for good weather and money for next expedition?

Table 1. Rate of change of litterfall (LITF) and decomposition (DECO) processes with southward increase of temperature and latitude change. Rate expressed in % as relative increment per 1°C of long term T and –1°N of latitude. Data from years 1997–1998 (LITF) and 1997–1999 (DECO). LITF measured in $g.m^{-2}.y^{-1}$, DECO measured in $g.g^{-1}.y^{-1}$.

Process	Rate of change in %	
	per 1°C	**per -1°latitude**
Litter fall (LITF)		
needles	18.09	8.02
wood	19.42	8.48
total (mixed)	**19.04**	**8.38**
Decomposition (DECO)		
needles	12.90	5.77
cones	11.62	5.58
twigs	9.45	4.51
mixed (total)	**12.96**	**5.89**

crement per 1°C of long-term temperature and, in the case of latitude, per –1°N.

The rates of change for LITF and DECO processes are different. The rate of litterfall changes faster with the southward movement along the transect: by 18–19% per each 1°C, compared to 9–12% of change in the decomposition rate. A similar difference in behaviour of the two processes is found in the case of latitude change: increase by 8% for litterfall and by 4–5% for decomposition per each degree of latitude.

Two essential processes were analysed, which constitute the "little budget" of carbon cycle in forest ecosystem , i.e. the litter fall and its decomposition. The pine forest study sites were situated in various climates, as defined by the varying air temperatures. Both of the processes analysed underwent acceleration along with the increase of temperature. However, the acceleration is clearly bigger in case of litter production than in case of its decomposition. Hence, the process of litter production is stimulated more strongly than the process of litter decomposition. Is the litter decomposition in fact a more conservative process? It certainly takes place in conditions better isolated from the changing air temperature: the decomposition processes, which take place in the layers of litter and humus, are protected by the vegetation of the forest bottom, while the tree crowns, where production of leaves occurs, are more exposed to climatic influences.

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