Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 242 (2007) 133–141
Forest Ecology and Management
www.elsevier.com/locate/foreco

Soil fluxes of mineral elements and dissolved organic matter following manipulation of leaf litter input in a Taiwan *Chamaecyparis* forest

Shih-Chieh Chang [a], Chiao-Ping Wang [b], Che-Ming Feng [a], Rainer Rees [c], Uwe Hell [c], Egbert Matzner [c,*]

[a] *Institute of Natural Resources, National Dong Hwa University, 974 Hualien, Taiwan*
[b] *Division of Silviculture, Taiwan Forestry Research Institute (TFRI), 100 Taipei, Taiwan*
[c] *Lehrstuhl für Bodenökologie, Universität Bayreuth, D-95440 Bayreuth, Germany*

Received 12 May 2006; received in revised form 18 October 2006; accepted 11 January 2007

Abstract

Forest ecosystems in Taiwan are frequently influenced by typhoons that cause large amounts of litter input to the soil. The rapid decomposition of such litter under the high precipitation and temperature conditions may trigger nutrient losses via seepage. Our goal was to investigate the effects of exceptionally high inputs of *Chamaecyparis obtusa* var. *formosana* leaves to the soil on the solute fluxes and concentrations of mineral elements, dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in a Lithic Leptosol. We simulated the effect of a typhoon by adding the annual aboveground litterfall (4600 kg ha^{-1}) and about 3 times the annual litterfall (13,900 kg ha^{-1}) as fresh leaves in a single event to small manipulation plots. All plots were also subjected to the natural litterfall. Soil solution was collected 4 months before and 15 months following the litter manipulation in 14 days intervals underneath the forest floor with free draining lysimeters and by ceramic suction cups at 60 cm depth. The 3-fold litter addition caused increased fluxes of K, Mg, Ca, and NH_4 in forest floor percolates as compared to the 1-fold litter treatment. DOC and DON fluxes also increased, but this was only statistically significant for DON. DON was the dominant form of N both in forest floor percolates and in seepage. The 3-fold litter manipulation increased the seepage fluxes of K, DON, and DOC relative to the 1-fold treatment with largest differences recorded for K, reaching 12.4 kg ha^{-1} 15 $month^{-1}$. The fluxes of DOC with forest floor percolates and with seepage in both treatments exceeded published values by far. Our results suggest that the decomposition of large amounts of fresh leaf litter may trigger K losses from the ecosystem via seepage, whereas the probability for additional N and DOC losses is moderate. For Ca and Mg, additional losses seem to be rather unlikely.

Keywords: *Chamaecyparis obtusa* var. *formosana*; Dissolved organic matter; Fluxes; Mineral elements; Soil solution; Taiwan

1. Introduction

Forest ecosystems of Taiwan are subjected to high precipitation rates, with large annual variations depending on the number and strength of typhoons. On average typhoons hit Taiwan 3.7 times a year (Wu and Kuo, 1999). In those ecosystems that are affected by high wind speeds, drastically increased litter inputs to the soil were reported for Taiwan forests (Horng et al., 1995; Lin et al., 2003) and elsewhere (Ostertag et al., 2003). The litter derived from typhoon events represents to a large extent fresh leaves with relatively high nutrient concentrations in comparison to regular litter (Xu et al., 2004). The expected high rates of nutrient release from the decomposition of fresh leaves might exceed the capacity of the vegetation, microorganisms, and the soil to retain the nutrients in the ecosystem. As a result, nutrient losses by seepage are likely, especially under high precipitation conditions. The losses of mineral elements with runoff from a forested catchment in Puerto Rico, influenced by a hurricane, were increased for K and to a minor extend also for NH_4 and NO_3 (Schaefer et al., 2000). Increased gaseous N losses from the soil were also reported as a consequence of a hurricane (Erickson and Ayala, 2004).

The release of nutrient cations from decomposing litter is often dramatically faster than mass loss, especially in case of K, and to lesser degree also for Mg (Xu et al., 2004; Hirobe et al., 2004; Laskowski et al., 1995). In a decomposition study with *Chamaecyparis obtusa* var. *formosana* leaves, about 80% of the K in the leaves was released by leaching during the first 2 months of field exposure (Rees et al., 2006). The release of Mg

* Corresponding author. Tel.: +49 921 55 5610; fax: +49 921 55 5799.
E-mail address: egbert.matzner@uni-bayreuth.de (E. Matzner).

0378-1127/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2007.01.025

was also much faster than the mass loss of the decomposing litter. On the other hand, the N content of the decomposing litter increased, suggesting a low risk of mineral N losses by seepage.

The leaching of dissolved organic carbon (DOC) and nitrogen (DON) from decomposing litter might be an important contribution to mass loss, especially under high precipitation conditions, since positive relations between DOC and DON fluxes with forest floor leachates and the amount of precipitation were reported for temperate forest ecosystems (Michalzik et al., 2001). Under low N inputs by atmospheric deposition, the fluxes of DON represent important contributions to the N cycle. Some studies found DON as the dominating form of N in soil solution (Van Breemen, 2002; Qualls et al., 2002) and also the dominating loss of N from the ecosystem via seepage and runoff (Perakis and Hedin, 2002). The fluxes of DOC and DON in soils depend largely on tree species and other environmental conditions, but still it is very difficult to predict those from boundary conditions alone (Qualls, 2000; Kalbitz et al., 2000).

While there are numerous field studies available dealing with solute organic matter fluxes in soils of the temperate climate zone, only few studies were conducted in subtropical and tropical systems under high precipitation and temperature regimes. The relevance of DOC in the C cycle under these conditions was already emphasized (e.g.: Liu and Sheu, 2003; Neff et al., 2000; McDowell, 1998), but only very few studies have focussed on DON: Wilcke et al. (2001) found DON as the dominant form of N in litter leachates in a mountain forest in Ecuador, while – on the contrary – the dominance of mineral N was reported in solute fluxes in a wet tropical forest ecosystem in Costa Rica (Schwendenmann and Veldkamp, 2005). However, the flux of DON in litter percolates at the Costa Rica site was considerable (13 kg N ha^{-1} $year^{-1}$).

The goal of our study was to investigate the effects of exceptionally high litter inputs on the fluxes of mineral elements, DOC, and DON in soil solution in order to improve our understanding of potential typhoon effects on forest ecosystems. Given high precipitation rates and temperatures at the study site, our hypothesis was that exceptionally high leaf litter inputs cause losses of nutrients with seepage. The study is based on the experimental manipulation of litter input, on measurements of decomposition rates in litter bags and on soil solution analysis. Here, we report on concentrations and solute fluxes in forest floor percolates and soil solutions at 60 cm depth.

2. Methods

Yuanyang Lake (YYL) forest ecosystem is located in northern Taiwan (24°35′N, 121°24′E) at an altitude of 1400–1800 m a.s.l. The mean annual air temperature is 13 °C and the annual precipitation varies between 2000 mm and more than 5000 mm, depending on the number and intensity of typhoons. Fog is very frequent and adds substantially to the water and nutrient input (Chang et al., 2006). The average relative humidity of the atmosphere is 90%. The field experiment was conducted in a stand of a 40-year old *Chamaecyparis obtusa* var. *formosana* plantation. The old-growth trees at the study site were clear-cut in 1960s. The stand is dominated by *C. obtusa* var. *formosana* with a density of 1820 trees ha^{-1} and 82% of the total basal area. The aboveground biomass of *C. obtusa* var. *formosana* is 140 t dry mass ha^{-1}, of which leaves, twigs, and stems represent 12, 12, and 76%, respectively (Chang, unpublished data).

The soil is a Lithic Leptosol (WRB, 1998) of loamy texture developed from metamorphic slate and quartzite of a former landslide. The mineral soil has a very high content (80–90 vol%) of coarse (>2 mm) material. Because of the high precipitation rates and continuous precipitation over the year, the soil is permanently moist, without any impermeable layer. The soil is very acidic with pH in 0.02 M $CaCl_2$ of less than 3.2 throughout the whole soil profile (Table 1). The pools of exchangeable nutrient cations (Ca, Mg, K) are largely restricted to the forest floor and the 0–5 cm layer. The exchange capacity of the deeper mineral soil horizons is almost completely represented by exchangeable Al.

The forest floor is well developed and has a thickness of 7–10 cm. Because of intensive rooting, the stratification of the forest floor into different layers is poor and properties of the forest floor were determined in a mixed sample. The C/N ratio of the forest floor is 17 and the pH in water is 3.5 (Table 1). The total annual natural aboveground litterfall at the site was measured at 5722 kg dry mass ha^{-1} $year^{-1}$ (Table 2).

The field experiment is based on manipulation of litter inputs. In four subplots of each 1.5 m × 1.5 m, the leaf litter input was increased artificially about 3-fold the annual flux to 13,900 kg dry mass ha^{-1} in September 2003 in order to simulate the effect of a sudden litter input by a typhoon. Furthermore, about 1-fold the annual amount of litter (4600 kg dry mass ha^{-1}) was added to four other subplots. The 1-fold treatment was thought to represent an average typhoon caused litter input, while the 3-fold treatment

Table 1
Chemical soil properties at the YYL site

Horizon	Depth [cm]	pH (H_2O)	pH ($CaCl_2$)	%C	%N	C/N	Exchangeable cations[a] [$mmol_c$ kg^{-1}]						
							Na	K	Ca	Mg	Mn	Al	CEC
O	10–0	3.54	2.83	34	2.00	17.0	n.d.	19.9	35.6	12.2	2.8	11.5	83.6
A	0–5	3.51	2.78	8.8	0.67	13.1	n.d.	2.7	5.6	1.8	0.3	6.8	19.9
Cw	5–25	3.85	3.03	1.1	0.08	13.3	n.d.	n.d.	0.6	0.4	n.d.	9.9	12.0
Cw	25–40	4.01	3.17	0.7	0.06	11.2	n.d.	n.d.	0.2	0.03	n.d.	12.4	13.7

[a] Determined by ICP-OES in 1N NH_4Cl extracts; n.d. = not detectable.