Water Chemistry in Forests of Southern Chile

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Synopsis

The inputs, redistribution and outputs of nutrients were studied in a *Fitzroya cupressoides* forest, located in the Cordillera de la Costa, and in *Nothofagus pumilio* forest located in Cordillera de los Andes in southern Chile. Water samples were collected to determine the concentrations of organic-N, NO_3-N, total-P, K^+, Na^+, Ca^{++}, and Mg^{++} in bulk precipitation, throughfall, stemflow, effective precipitation, soil infiltration and streamflow. In relation to the bulk precipitation there was a significant enrichment of N-organic, NO_3-N, total-P and K^+ in throughfall, stemflow, effective precipitation and soil infiltration in the coniferous forest of *F. cupressoides*. An enrichment was also observed for Ca^{++} and Mg^{++} but only in effective precipitation, soil infiltration and streamflow. Constrasting to these results, the concentration of organic-N in precipitation was higher than the of NO_3-N and both values were much higher than those of the streamflow in the summergreen forest of *N. pumilio*.

Water chemistry, nutrients, temperate rainforest, Fitzroya cupressoides, Nothofagus pumilio, southern Chile

Introduction

The majority of the studies on biogeochemical fluxes in temperate forests have been carried out in very inhabited regions of the Northern Hemisphere, where biogeochemical cycles often reflect the anthropogenic influence (PARKER 1983, VAN BREEMEN & al. 1989; TIETAMA & VERSTRATEN 1991). Very few studies have been carried out in the Southern Hemisphere, especially in regions with little pollution (LIKENS & al. 1987, HEDIN & al. 1995, GALLOWAY & al. 1996). The chemistry of precipitation in southern Chile reflects one of the closest approximations of pre-industrial atmospheric conditions in the world (WEATHERS & LIKENS 1997). The objective of this work is to study the water chemistry within a *Fitzroya cupressoides* forest, located in the Cordillera de la Costa, and – in comparison – with a temperate rainforest of *Nothofagus pumilio* located in the Cordillera de los Andes, in southern Chile.

Study area

The study sites were located in the Monumento Natural Alerce Costero, in the Cordillera de la Costa (40°S, 73°W, 820 m a.m.s.l.) and in the Puyehue National Park of the Cordillera de los Andes, Chile (40°S, 72° W, 1200 m a. m.s.l) (Fig. 1). The study area in Cordillera de la Costa has a rainy temperate climate with mean annual rainfall about 4000 mm and the mean annual temperature is 8°C. The soil in *F. cupressoides* forest had a sandy loam texture, with acid and hydromorphic characteristics (PERALTA & al. 1982). The Ah horizon is 20 cm and the B horizon 40–50 cm. These soils are Haplumbrept according to the USDA Soil Taxonomy classification and have developed on a Paleozoic geological substratum composed generally by mica schist rocks. In the lake District's, Puyehue National Park in the Cordillera de los Andes the climate is classified as humid temperate, near to the to treeline. The mean annual precipitation is about 5600 mm, with snow cover lasting normally from May until early December and the mean annual temperature is 5° C aproximately. The soil is volcanic in origin, classified as Andisol at treeline in *N. pumilio* forest, more recently affected by vulcanism (HILDEBRAND-VOGEL & al. 1990). These soils have developed on a geological substratum composed by volcanic rocks and fluvioglacial sediments.

Material and methods

Experimental measurements

Microcatchments were selected in the two forest types. Streamwater discharge was measured by water level recorder installed in the microcatchments. Within the catchments, a representative plot of 20x20 m of the main forest type was delimited, where 12 rain gauges were installed to collect throughfall along three transects at 5 m intervals. Stemflow was collected by placing plastic rings around 12 trees, using the methods of HUBER & OYARZUN (1992). The effective precipitation (defined as net precipitation minus litter interception) was collected using 12 small collectors (625 cm^2) with litter, deposited on the floor of the forest. Soil water infiltration, from 20 cm depth, was collected

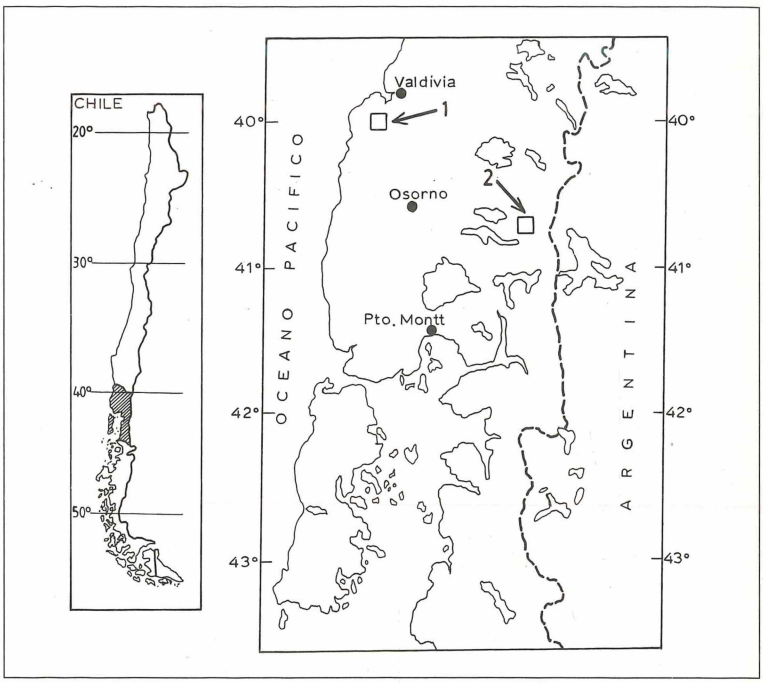

Fig. 1
Location of the study sites. 1: *Fitzroya cuppressoides* forest (Monumento Natural Alerce Costero, Cordillera de la Costa, Chile); 2: *Nothofagus pumilio* forest (Puyehue National Park, Cordillera de los Andes, Chile).

using 12 small lysimeters (625 cm^2) in the floor of the forest, according the methods of STEUBING & FANGMEIER (1992). Precipitation was collected by 3 rain gauges installed in a clearing adjacent to the forest, designed with a plastic ring in order to exclude bird droppings. The precipitation and throughfall collectors were provided with filters to exclude contamination of leaves and biological material.

Chemical analysis of water

The water samples were collected during the last rainfall event of each monthly sampling period, respectively, preserved and transported to the laboratory in 1000 ml plastic bottles. The collectors were carefully cleaned with deionized water after each collection. The samples were filtered on 0.45 µm membrane filters, and chemical analyses were performed usually within 24 hr after sampling. The NO_3-N was determined colorimetrically using the sodium salicylate and Seignette salt method. Organic-N was determined by Kjeldahl digestions. The total-P was measured by antimonic tartrate method after a digestion with sulfuric acid and perhidrol at 30%. Potassium, Ca^{++}, Na^{+} and Mg^{++} were measured by atomic emission spectrometry.

Results and discussion

During April 1995–March 1996, the precipitation in the *F. cupressoides* forest was 4097 mm. Throughfall was 3184 mm and the stemflow was only 8 mm. The effective precipitation was 3076 mm, soil water infiltration 2704 mm and streamflow 2249 mm. In the *F. cupressoides* forest the annual average concentrations of nitrogen (org-N and NO_3-N) differed sharply between at different samples of the forest, with the greatest concentrations of NO_3-N in the stemflow (1606 µg L^{-1}), and organic-N in the effective precipitation (90.9 µg L^{-1}) (Table 1). The concentrations of organic-N (22.5 µg L^{-1}) and NO_3-N (43 µg L^{-1}) in the precipitation were smaller than in the other forest samples. In *F. cupressoides* nitrogen showed an enrichment, especially NO_3-N, in the stemflow, effective precipitation and soil infiltration levels. Concentrations of NO_3-N and organic-N in the streamflow were characterized by greater concentrations of NO_3-N (141 µg L^{-1}) than organic-N (35.6 µg L^{-1}), wich is in contrast with the values reported by HEDIN & al. (1995) and HEDIN & HETHERINGTON (1996).

During the period May–August 1997, the precipitation in the *N. pumilio* forest was 3158 mm, 1333 as rain water and 1825 mm as snowfall. Throughfall was 2486 mm and the stemflow was 183 mm. In the *N. pumilio* forest showed a nitrate enrichment, especially in the stemflow (1060 µg L^{-1}) and soil infiltra-

Table 1
Nutrients concentration (μg/L) for *Fitzroya cupressoides* forest (samples from April 1995–March 1996) (mean of monthly sampling).

Sample	NO3-N	Org-N	Tot-P	K^+	Na^+	Ca^{++}	Mg^{++}
Precipitation	43	22.5	8.1	233	1440	532	255
Throughfall	359	59.6	18.4	982	1120	525	221
Stemflow	1606	77.6	21.9	820	2320	505	254
Efective precipitation	1054	90.9	31.8	1050	1750	977	533
Soil infiltration	818	72.1	16.5	916	1220	596	354
Streamflow	141	35.6	4.6	132	1820	999	630

Table 2
Nutrients concentration (μg/L) for *Nothofagus pumilio* forest (samples from May 1997–August 1997) (mean of monthly sampling).

Sample	NO3-N	Org-N	Tot-P	K^+	Na^+	Ca^{++}	Mg^{++}
Precipitation	126	144.6	21.3	428	1100	304	506
Throughfall	120	63.6	33.0	165	840	230	605
Stemflow	1060	79.7	24.6	445	875	315	690
Efective precipitation	298	75.0	101.2	300	635	800	985
Soil infiltration	341	105.0	71.3	435	590	300	555
Streamflow	52	40.9	77.8	807	1670	1390	753

tion (341 μg L^{-1}) levels, with respect to precipitation (126 μg L^{-1}) (Table 2).

The chemistry of precipitation at our study site is characterized by moderate or low concentrations of practically all the elements, except Na^+. They are especially low for nitrate, which principally is of anthropogenic origin (BELILLAS & RODA 1991). The concentrations of Na^+ will be probably influenced by the distance to the ocean, since sea spray is the main source. In the *F. cupressoides* forest, located nearer to the ocean higher values of Na^+ could be found (Table 1). Precipitation chemistry, particulary for nitrogen in native forests of southern Chile reflects one of the closest approximations of pre-industrial atmospheric conditions in the world. The input has been calculated as 1.7 kg N/ha yr (0.97 kg as NO_3-N) (OYARZUN & al., 1998).

Phosphorus shows an enrichment at the level of the effective precipitation in both *F. cupressoides* (31.8 μg L^{-1}) and *N. pumilio* (101.2 μg L^{-1}) forests, and streamflow (77.8 μg L^{-1}) in *N. pumilio* (Tables 1 and 2). The base cations (Na^+, Ca^{++}, Mg^{++}) concentrations varied: Na^+ was highest in stemflow (2320 μg L^{-1}), and Ca^{++} (977 μg L^{-1}) and Mg^{++} (630 μg L^{-1}) in streamflow for *Fitzroya. cupressoides* forest. In *Nothofagus pumilio* forest, Ca^{++} and Mg^{++} enrichment was greatest in the effective precipitation and streamflow. For Na^+, there was no enrichment pattern in the differents samples of the two forests.

The output concentrations of the cations in the streamflow was higher than the input in both *N. pumilio* and *F. cupressoides*, with the exception of K^+ in the conifer forest. The same result was obtained for total-P in *N. pumilio* forest, but not for *F.cupressoides* (Table 2). The K^+ enrichment in the water that flows through the forest cover could be a result of leaching. According to PARKER (1983) generally until a 90% of the potassium could origined from leaching. Ca^{++} generally also shows appreciable values of leaching (PARKER 1983). A significant enrichment in concentration was observed only in the effective precipitation, possibly as a result of the washing of the litter deposited onto soil or as contribution of the decomposition.

Conclusions

- The annual average concentrations of nitrogen in both *F. cupressoides* and *N. pumilio* forests differed sharply at different level of the forest, with the greatest concentrations of NO_3-N in the stemflow (1606 and 1060 μg L^{-1} , respectively) and organic-N in the effective precipitation (90.9 μg L^{-1}) and precipitation (145 μg/L).
- Precipitation nitrogen concentrations in *F. cupressoides* was smaller than the streamflow.

Contrasting to the results, the concentration of organic-N and NO_3-N were higher than of the stream in the summergreen forest of *N. pumilio.*

- The precipitation concentrations of all elements, except Na^+, are greater in the *N. pumilio* forest located at the Cordillera de los Andes, probably due to anthropogenic contribution from the agricultural activities and cities located in the Central Valley of the southern Chile.

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