Biomass and element pools of selected spruce trees in the catchments of Plešné and Čertovo Lakes in the Šumava Mts.

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ABSTRACT: This paper presents detailed data on the biomass and element pools of six sample trees in the catchments of Plešné and Čertovo Lakes. Diameters and heights of the sample trees ranged from 28.0 to 63.7 cm and from 14.1 to 38.7 m. The age of the sample trees ranged from 84 to 177 years. Total biomass of the sample trees was in the range of 239.4 kg to 2,932.3 kg. Variation of total biomass between the sample trees was a consequence of the tree biometric data (height and dbh) and age differences. The proportion of stem wood and bark ranged from 63.5 to 69.5%, and from 4.6 to 7.2%, respectively. The proportion of foliage and fine branches ranged from 4.3 to 8.4%, and from 0.7 to 1.9%, respectively. The proportion of branch wood and bark ranged from 2.2 to 6.5%, and from 0.8 to 2.2%, respectively. Mean concentrations of C in different tree components were quite similar. Except C and compared to the other elements, N had the highest mean concentrations in tree components in all cases. Concentrations of P, Ca, Mg, and K showed similar patterns. Generally the highest concentrations of these elements were found in foliage, fine branches, fine roots and bark of stem and branches. Fe, Na, Al and Mn showed the lowest mean concentrations in tree components for all the analyzed elements. The total element pools per tree were highly variable because of the differences in total biomass between the individual trees. Generally, stem wood and bark, foliage, and roots contained the highest proportion of the elements. But there were differences between individual elements. Concerning the important nutrients, while the highest proportion of Ca and Mg was contained in stem wood and bark, the highest proportion of P was contained in foliage. The foliage contained a relatively high proportion of P and K, but a relatively low proportion of Ca and Mg.

Keywords: Norway spruce; biomass; element pools; Bohemian Forest Mts.; Čertovo Lake; Plešné Lake

The majority of the latest studies on element cycles are a result of current interest in C fixation (Dieter, Elsasser 2002; Joosten, Schulte 2002; Finér et al. 2003). But in forests the biogeochemical cycles of elements are closely related because the foliage nutrient content strongly controls carbon assimilation and therefore their productivity (Scarascia-Mugnozza et al. 2000). Forest production is controlled by ecological gradients of nutrient availability, soil properties and climatic conditions. In a recent study on tree biomass and nutrient pools of spruce forests along the European ecological transect, significant differences in production and element concentrations were found (Scarascia-Mugnozza et al. 2000). Therefore, none of the particular ecosystem studies dealing with biogeochemical cycles should simply relay on the available published data. Instead of that, at least partial studies on the production and element concentrations of the particular forest stand clarifying the available data should be carried out.

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Fig. 1. Position of both studied localities in the Czech Republic: CT – Čertovo Lake, PL – Plešné Lake

The aim of this paper is to report the results of investigations on the biomass and nutrient pools of selected trees in the catchments of unique glacier lake ecosystems in the Bohemian Forest Mts. The chemistry and element fluxes of these lakes have been studied intensively for a long time. Many interesting results have already been published, but there are still some questions that have not been fully answered. Significant differences in the element concentrations and fluxes between the Plešné and Čertovo Lake were found in spite of similarities between these two lakes (Kopáček et al. 2001a). Both lakes differ in trends of biological recovery after long-term acidification in the last century caused by air pollution (Kopáček et al. 2002a; Majer et al. 2003). To understand and explain these processes, detailed studies on lake and stream chemistry, atmospheric deposition, soil pools and biochemistry have been carried out in recent years. However, important components of the biogeochemical cycle such as nutrient pools stored in the forest stands have not been studied yet. This study should fill a gap in the present knowledge of nutrient pools and flows within the ecosystems of these glacier lakes.

This investigation is a part of the integrated study on the Šumava Mts. (Bohemian Forest Mts.) watershed-lake ecosystems *Nutrient cycling in the nitrogen-saturated mountain forest ecosystem: History, present, and future of water, soil, and Norway spruce forest status*. In this study we provide data on: (1) total aboveground and belowground biomass of selected trees in the catchments of Plešné and Čertovo Lakes, (2) element pools in aboveground and belowground biomass of these trees.

METHODS

Study sites

The research was carried out in the catchments of Plešné Lake (abbreviated as PL; 48°46´35´´N, 13°52´0´´E; elevation of 1,090–1,375 m; total forested area of 59.48 ha) and Čertovo Lake (CT; 49°9´55´´N, 13°11´50´´E; elevation of 1,027–1,343 m; total forested area of 81.19 ha) in the Šumava Mts. (Bohemian Forest Mts.). The position of both localities is drawn in Fig. 1. More information on the lakes, soils in the catchments, and the forest stands are provided by Kopáček et al. (2002b,c).

Sampling procedure

Tree selection and basic biometric data

Both lakes and their catchments with forest stands are located in strictly protected areas. Therefore we were not allowed to cut down or dig any trees. We used only naturally uprooted trees for our sampling procedure. During the spring 2003 we searched the forest stands in the catchments of both lakes and chose three suitable recently uprooted trees in each watershed. The sampling procedure followed standard methods described for example by Černý (1990). For each tree, the following parameters were measured: girth at breast height, total height, and length of live crown. The basic biometrical data of individual trees are shown in Table 1.

Table 1. Basic characteristics and biometric data of sample trees

Catchment	Tree No.	Height (m)	dbh (cm)	Crown length (m)	Age* (years)
	1	20.5	35.3	12.8	138
CT	2	30.9	53.2	18.7	177
	3	38.7	63.7	27.7	171
	4	25.5	50.9	11.3	134
PL	5	20.5	36.9	6.0	129
	6	14.1	28.0	6.8	84

*According to tree rings at 1.3 m height

Stem analysis

The stems of the trees were regularly divided into 10 sections (the 1st section was adjacent to the tree stump). For each section, girth was measured at the beginning, in the middle and at the end of the section. From the middle part of each section, and in the case of the first section also from dbh height, stem disks were taken and brought to the laboratory. The measurements of each stem section were used to calculate the stem volume of each tree.

In the laboratory, bark was separated from the stem disks. The thickness of bark samples was measured at four random points and average bark thickness in each stem section was calculated. The volume and dry matter (dried at 105°C) of the bark samples and stem disks were determined. The measurements were used to calculate the bulk density of the stem bark and wood sample in each stem section. The bulk density for bark and wood samples and bark and wood section volume were used to compute dry matter for wood and bark in each section and then for the whole tree.

Tree crown analysis

The live crown of each tree was divided into 5 sections of the length corresponding to 1/5 of the total live crown length. The section numbering was done from crown bottom to tree top. Branches of each section were separated from the stem and weighed together with needles in the field. The number of branches in each section was counted. A representative subsample from each crown section was taken, weighed in the field and brought to the laboratory.

For the crown subsamples, foliage was separated from live branches in the laboratory and oven dried at 105°C. The branch subsamples in each crown section were divided into five diameter categories (0.0–0.5, 0.5–1.0, 1.0–2.0, 2.0–3.0, and > 3.0 cm). Dry matter (dried at 105°C) for each category of the crown section was analyzed. For each diameter category of branches (except the finest category 0.0–0.5 cm) across all trees and crown sections, ten samples were randomly taken and the proportion of branch wood and bark was analyzed. The ratio between field fresh weights and dry matter of the section crown subsample was used to calculate dry matter of the branches of tree crown sections. The fine branches (0.0–0.5 cm) were analyzed separately.

The proportions of foliage, fine branches, branch wood and bark of the crown sections of the trees were used to calculate these proportions for each crown section and for the whole tree. The data on foliage biomass were later verified using biometric equations to take into account data on samples from the neighbouring living trees with similar biometric parameters to the sample trees. The branch samples from these neighbouring trees were taken and analyzed in a similar manner like for the trees that were sampled on the ground.

Root system analysis

The bare root system of the trees was cleaned from the soil and approximately one quarter of the subsample was taken to the laboratory. The data on root biomass were later verified using a biometric equation.

Root subsamples were sprayed with water to remove soil remnants. Subsamples of each tree were divided into five diameter categories (0.0–1.0, 1.0–3.0, 3.0–7.0, > 7.0 cm, and stump). The volume and dry matter (oven dried at 105°C) of each category were determined. These values were used to calculate the dry matter of the root system for each tree according to diameter classes.

The following abbreviations of the tree components are further used in the text: foliage – F, fine branches – FB, branch bark – BB, branch wood – BW, stem bark – SB, stem wood – SW, and roots – R. All mass and chemical results further reported in this paper are given on a dry weight biomass basis. Dry matter is abbreviated as DM.

Chemical analysis

Stem wood, stem bark, foliage, branch wood, branch bark and roots were analyzed for the total content of the following elements: C, N, P, Ca, Mg, Na, K, Al, Fe and Mn. For the stem wood, 5 samples taken across the whole length (section 1, 3, 5, 7, 9) of tree stem were analyzed. For the stem bark, the sampling procedure was the same. Because of using uprooted trees for sampling, the foliage samples for chemical analyses were taken from surrounding live trees during autumn of the same year (see the chapter *Sampling procedure*). Needle samples were taken from the lower, middle and upper part of the crown of these trees and first-year needles and mixture of the remaining needles were analyzed. Similarly, fine branches (0.0–0.5 cm), branch wood and bark samples (categories 1.0–2.0 and > 3 cm) were taken from the lower, middle and upper part of the crown, but from six sample trees. Root samples were taken for each tree for the following diameter classes (0.0–1.0, 1.0–3.0, 3.0–7.0, > 7.0 cm).

The dry biomass samples were analyzed for the total content of the following elements. Total P was determined from an HNO_3 and $HClO_4$ acid extract using a phosphomolybdate blue method (Kopáček et al. 2001b). Carbon (C) and nitrogen (N) were determined with a CN analyzer (NC 2100, ThermoQuest, Italy). The total concentration of metals (Ca, Mg, Na, K, Al, Fe, and Mn) was analyzed from an H_2SO_4, HNO_3, and HF mixed acid extract (200°C, 2 h) by flame atomic absorption spectrometry.

Data processing

The biometrical data of individual trees collected in the field and the measurements of the samples collected in the laboratory were used to calculate stem (wood and bark), branch (fine branch, wood and bark), foliage and root dry matter. To verify data on foliage biomass, the following biometric equations (Table 3) (Burger 1953; Malkonen 1973; Del Favero 1983; Černý 1990) were used:

$DMF = 0.11057 \times (dbh^2 \times dH/H)^{0.88344}$
(Burger 1953)

$DMF = -0.46 + 0.045 \times (dbh^2 \times dH/H)$
(Malkonen 1973)

$DMF = 0.012333 \times (dbh^2 \times dH/H)^{1.2340}$
(Del Favero 1983)

$DMF = 0.119566 \times (dbh^2 \times dH/H)^{0.81887}$
(Černý 1990)

where: DMF – dry matter of foliage per tree (kg),
dbh – diameter at breast height (cm),
dH – crown length (m),
H – tree height (m).

The data on foliage biomass were also verified using samples of branches from standing trees (see the chapter *Sampling procedure*). To verify data on root biomass, the following aboveground biomass and root ratios (Table 4) (Dieter, Elsasser 2002; Matějka unpubl., this equation is based on data of Vyskot 1981) were used:

$DMR = 0.1731 \times (DMBR + DMS)$
(Matějka unpubl.)

$DMR = 0.18 \times DMAGB$
(Dieter, Elsasser 2002)

where: DMR – dry matter of roots per tree (kg),
DMBR – dry matter of branches per tree (kg),
DMS – dry matter of stem per tree (kg),
DMAGB – dry matter of aboveground biomass (kg).

The total element concentrations in the tree components were calculated as weighted means of element concentrations. The simple *t*-test and principal component analysis (PCA) were used to analyze the differences in the element concentration between the individual trees and catchments.

Table 2. Total tree biomass (dry mass) and its components in sample trees

Tree component dry matter (kg)	Tree No./catchment					
	1/CT	2/CT	3/CT	4/PL	5/PL	6/PL
Dry matter of stem wood	411.6	1,180.3	1,906.6	967.6	414.9	154.4
Dry matter of stem bark	35.3	113.3	134.0	88.4	34.5	17.3
Dry matter of foliage	14.9	49.3	77.7	15.3	16.2	7.4
Verified dry matter of foliage*	40.9	90.1	154.2	60.2	21.2	20.1
Dry matter of branch wood	41.9	119.8	189.8	43.9	23.2	5.3
Dry matter of branch bark	12.7	40.3	50.8	13.1	7.3	2.0
Dry matter of fine branches	8.6	30.7	57.0	9.6	8.2	4.4
Total branch biomass (wood and bark)	63.2	190.8	297.5	66.6	38.7	11.7
Dry matter of roots	176.0	391.7	984.7	296.1	216.6	62.8
Verified dry matter of roots*	97.3	278.0	440.0	208.8	89.9	35.9
Total stem biomass	446.9	1,293.6	2,040.6	1,056.0	449.4	171.7
Total branch and foliage biomass**	104.1	280.9	451.7	126.8	59.9	31.8
Total root system biomass**	97.3	278.0	440.0	208.8	89.9	35.9
Total aboveground biomass**	551.0	1,574.5	2,492.3	1,182.8	509.3	203.5
Total belowground biomass**	97.3	278.0	440.0	208.8	89.9	35.9
Total tree biomass**	648.3	1,852.4	2,932.3	1,391.6	599.2	239.4

*Verified values of foliage and root biomass were calculated using biometric equations (foliage), neighbouring trees (foliage), and biomass to root ratio (roots) (see Tables 3 and 4)
**Verified values of foliage and root dry matter were used to calculate final values of tree component dry matter and tree biomass

RESULTS AND DISCUSSION

Tree biomass

Diameters and heights of the sample trees ranged from 28.0 to 63.7 cm and from 14.1 to 38.7 m. The age of the sample trees ranged from 84 to 177 years. For detailed characteristics of sample trees and sites see Table 1. Total tree biomass, aboveground and belowground biomass, and tree component dry matter (DM) are shown in Table 2. Because of some restrictions during the sampling procedure, foliage biomass and root biomass were verified using allometric equations (Tables 3 and 4). This approach was also used in the paper of Kovářová and Vacek (2003). The measurements of foliage biomass were underestimated probably due to the time period between the fall of trees and the sampling procedure. The verified average values of foliage biomass (Table 2) were therefore used while calculating total tree biomass. All trees in both catchments are defoliated. The estimation of average defoliation is 25–37% in the CT catchment and 35–47% in the PL catchment with the range of 10 to 100% in individual trees in both localities, according to the estimation in 2005. It is accepted as an explanation of large differences between the observed and calculated values.

The measurements of root biomass were overestimated probably due to difficulties during the sampling procedure. The root plate of the windfallen tree was only partially uncovered and the sampling of the one-quarter root system was rather difficult. The verified average values of root biomass (Table 2) were therefore used while calculating total tree biomass.

Total biomass of the sample trees ranged from 239.4 kg (tree No. 6) to 2,932.3 kg (tree No. 3) (Table 2). Variation of total biomass between the sample trees was the consequence of the tree biometric data (height and dbh) and age differences. The proportion of tree DM components in total tree biomass is shown in Table 5. Our results confirm the well-known fact that stem DM accounts for the biggest portion of the whole tree biomass, while the root biomass and branch – foliage biomass account for a relatively similar portion of the tree biomass (Wirth et al. 2004). The proportion of stem wood and bark ranges from 63.5 to 69.5%, and from 4.6 to 7.2%, respectively. The proportion of foliage and fine branches ranges from 4.3 to 8.4%, and from 0.7 to 1.9%, respectively. The proportion of branch wood and bark ranges from 2.2 to 6.5%, and from 0.8 to 2.2%, respectively (Table 5).

While for some values of the tree DM components the coefficient of variation (CV) is low, for other components is rather high (Table 5). The CV for stem wood DM is 4.2%, for stem bark 15.1%, and for the whole stem it is 4.1% (Table 5). Higher values of CV for stem bark are probably due to age differences between sample trees. Younger trees have a higher ratio of stem bark to stem wood compared to older trees (Wirth et al. 2004). Tree No. 6 has the highest portion of stem bark. The mean value of CV for total branch DM is 34.3%, for branch wood 40.4%, for branch bark 37.6, and for fine branches it is 30.7% (Table 5). There is no clear explanation for rather high CV values for branch biomass. The CV mean value for foliage DM is 31.5%. The highest foliage portion was found for tree No. 6. The higher value of CV for foliage is probably due to age differences between the individual trees. Younger trees have a higher ratio of foliage DM to tree biomass compared to older trees (Wirth et al. 2004).

Element concentration

Results on the mean element concentrations in different components of sample trees from CT and PL catchments are given in Table 6. Mean concentrations of C in different tree components were quite

Table 3. Measurements of foliage biomass, equations applied to verify the measurements, and mean values used for further analysis

Tree No./catchment	Foliage biomass (kg/tree) – our measurements, equations and mean value						
	measurements	Burger (1953)	Malkonen (1973)	Del Favero (1983)	Černý (1990)	samples of the neighbouring trees	mean
1/CT	14.9	37.9	34.6	45.6	45.6	43.3	40.9
2/CT	49.3	76.0	76.6	120.6	87.0	117.3	90.1
3/CT	77.7	121.2	130.2	231.5	134.1	181.8	154.2
4/PL	15.3	53.4	51.2	73.6	62.7	31.1	60.2
5/PL	16.2	21.0	17.5	20.0	26.4	16.3	21.2
6/PL	7.4	20.0	16.6	18.7	25.2	5.4	20.1

Table 4. Measurements of root biomass, allometric ratios applied to verify the measurements, and mean values used for further analysis

Tree No./ catchment	Root biomass (kg/tree) – our measurements, allometric ratios and mean values			
	measurements	Matějka (unpubl.)	Dieter and Elsasser (2002)	mean
1/CT	176.0	99.2	95.4	97.3
2/CT	391.7	283.4	272.5	278.0
3/CT	984.7	448.6	431.4	440.0
4/PL	296.1	212.9	204.7	208.8
5/PL	216.6	91.7	88.2	89.9
6/PL	62.8	36.6	35.2	35.9

similar and ranged from 41.4 to 45.3 mol/kg. The highest mean concentrations of C were generally found in fine branches and fine roots. Except C and compared to the other elements, N had the highest mean concentrations in tree components in all cases. Mean concentrations of N in tree components ranged from 0.09 to 1.15 mol/kg. The highest concentrations of N were found in foliage (1.15 mol/kg), fine branches (1.15 mol/kg), fine roots (1.03 mol/kg), while the lowest concentrations were found in stem wood (0.09 mol/kg) and coarse roots (0.10 mol/kg). All N foliage concentrations are higher than the deficiency limit (0.86 mol/kg; e.g. MZE-VÚLHM 2004). Concentrations of P, Ca, Mg, and K showed similar patterns. Generally, the highest concentrations of these elements were found in foliage, fine branches, fine roots and bark of stem and branches. But there were some differences between individual elements. The highest concentrations of P and K were found in foliage (58.5 and 179.3 mmol/kg) and fine branches (43.7 and 111.8 mmol/kg). On the other hand, the highest concentration of Ca was found in the bark of stem (216.0 mmol/kg) and branches (300.5 mmol/kg). In the case of Mg, the highest concentrations were found in branch bark (42.0 mmol/kg), one-year-old needles (44.1 mmol/kg), and stem bark (46.1 mmol/kg) from the upper part of the tree. The lowest concentrations of Ca and Mg were found in branch wood (20.4 and 6.6 mmol/kg) and stem wood (18.0 and 3.9 mmol/kg). It is possible to compare nutrient concentrations with deficiency limits for spruce needles of the 1st and 2nd

Table 5. Proportions of tree component dry matter in total tree biomass (%) and basic statistics (mean value, standard deviation – STD, and coefficient of variation – CV)

Proportion of tree component dry matter in total tree biomass (%)	Tree No./lake						Mean	STD	CV (%)
	1	2	3	4	5	6			
Dry matter of stem wood	63.5	63.7	65.0	69.5	69.2	64.5	65.9	2.7	4.2
Dry matter of stem bark	5.4	6.1	4.6	6.4	5.8	7.2	5.9	0.9	15.1
Dry matter of foliage*	6.3	4.9	5.3	4.3	3.5	8.4	5.4	1.7	31.5
Dry matter of branch wood	6.5	6.5	6.5	3.2	3.9	2.2	4.8	1.9	40.4
Dry matter of branch bark	2.0	2.2	1.7	0.9	1.2	0.8	1.5	0.6	37.6
Dry matter of fine branches	1.3	1.7	1.9	0.7	1.4	1.8	1.5	0.5	30.7
Total branch biomass	9.7	10.3	10.1	4.8	6.5	4.9	7.7	2.6	34.3
Dry matter of roots*	15.0	15.0	15.0	15.0	15.0	15.0	15.0		
Total stem biomass	68.9	69.8	69.6	75.9	75.0	71.7	71.8	3.0	4.1
Total branch and foliage biomass**	16.1	15.2	15.4	9.1	10.0	13.3	13.2	3.0	22.5
Total root system biomass**	15.0	15.0	15.0	15.0	15.0	15.0	15.0		
Total aboveground biomass**	85.0	85.0	85.0	85.0	85.0	85.0	85.0		
Total belowground biomass**	15.0	15.0	15.0	15.0	15.0	15.0	15.0		
Total tree biomass[2]	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

*Verified values of foliage and root biomass were calculated using biometric equation (foliage), neighbouring trees (foliage), and biomass to root ratio (roots) (see Table 3 and 4)

**Verified values of foliage and root dry matter were used to calculate final values of tree component dry matter and tree biomass

Table 6. Mean element concentrations in the components of sample trees from the catchment of CL (first number) and PL (second number). For definition of tree components, crown and stem sections, diameter categories and needle year class see the chapter *Sampling procedure*

Tree component	Section	Needle year/ diameter category (cm)	C	N	P	Ca	Mg	Na	K	Al	Fe	Mn
			(mol/kg)		(mmol/kg)							
Foliage	1	1 year old	42.7|42.9	1.08|1.16	50.8|58.1	56.3|58.9	33.9|35.6	1.66|2.09	189.7|168.2	2.76|2.34	0.90|0.94	7.92|6.01
	1	older than 1 year	43.1|43.1	1.07|1.00	35.3|34.6	109.8|95.0	24.3|21.3	2.98|2.55	131.8|94.0	8.67|5.59	2.19|1.89	12.22|8.12
	3	1 year old	42.6|42.4	1.09|1.25	54.5|64.5	56.2|55.4	36.6|41.5	2.65|0.99	185.3|170.2	3.02|2.31	0.95|0.96	6.98|6.99
	3	older than 1 year	43.3|43.1	1.01|1.02	38.9|39.7	95.8|115.2	23.7|26.7	4.55|3.11	132.9|99.2	10.12|6.28	2.92|2.02	11.31|10.19
	5	1 year old	42.9|43.0	1.12|1.18	57.1|56.5	77.8|77.2	40.5|43.5	2.86|2.31	209.2|134.7	4.08|1.94	1.28|0.85	10.18|8.94
	5	2 years old	43.1|43.1	1.17|1.11	56.1|50.4	97.3|97.0	47.2|41.0	3.11|2.11	176.4|125.3	5.53|2.77	1.47|1.07	11.67|11.00
	5	older than 2 years	43.1|43.3	1.03|1.00	37.4|37.7	95.8|114.7	26.8|23.4	3.44|3.09	140.4|98.1	8.42|5.44	2.11|1.93	10.68|10.61
Fine branches	1	0.0–0.5	44.1|43.8	1.00|0.98	40.4|45.4	64.7|76.4	30.3|33.4	5.22|4.31	108.7|104.2	9.93|11.68	2.93|3.64	4.71|5.50
	3	0.0–0.5	44.1|44.3	0.94|1.02	42.8|44.5	67.4|75.7	29.4|31.1	3.90|5.68	131.7|91.9	10.83|17.69	3.24|5.49	4.52|5.92
	5	0.0–0.5	44.9|44.5	1.02|1.03	45.3|45.9	69.1|77.7	27.7|33.8	4.12|5.13	106.6|93.9	12.44|15.65	3.75|5.14	3.84|5.63
Branch bark	1	1.0–2.0	42.6|41.5	0.58|0.56	22.2|23.6	168.7|215.5	40.4|38.0	1.35|2.99	64.6|66.7	7.56|5.18	1.91|1.63	10.40|8.97
	1	> 3.0	41.2|40.5	0.54|0.49	18.5|19.4	284.9|316.1	38.7|38.8	2.02|3.00	56.5|54.9	8.71|4.94	2.26|1.29	10.92|9.73
	3	1.0–2.0	42.4|42.6	0.59|0.61	22.9|28.6	156.0|159.1	39.7|39.6	3.14|4.80	63.7|77.3	8.65|10.19	2.04|3.03	9.45|8.58
	3	> 3.0	41.5|41.2	0.50|0.52	18.8|22.9	232.5|321.1	36.5|41.7	3.48|4.91	57.3|59.8	6.75|6.65	1.52|1.99	10.04|10.81
	5	1.0–2.0	44.0|43.4	0.67|0.68	31.8|32.4	103.7|128.8	37.6|45.2	5.16|6.03	87.2|87.4	11.73|14.74	3.26|4.76	7.50|7.51
	5	> 3.0	43.0|42.9	0.57|0.62	24.2|29.6	161.8|176.3	39.0|45.0	4.47|5.14	60.2|80.8	7.14|7.53	1.69|2.34	8.41|8.77
Branch wood	1	1.0–2.0	42.6|42.1	0.18|0.19	3.3|3.3	23.1|24.3	8.0|7.3	2.20|2.08	15.5|12.6	0.47|0.47	0.34|0.47	2.11|1.63
	1	> 3.0	42.7|42.7	0.15|0.16	1.5|1.6	25.1|22.9	6.9|6.4	2.20|1.31	13.0|12.5	0.33|0.27	0.26|0.42	1.88|1.43
	3	1.0–2.0	42.4|42.0	0.18|0.21	3.8|3.9	22.7|20.5	7.8|8.1	2.21|1.99	14.3|15.1	0.33|0.40	0.38|0.43	1.88|1.74
	3	> 3.0	47.7|42.9	0.17|0.16	1.9|1.9	29.1|20.0	9.2|6.3	2.60|3.31	17.0|13.0	0.38|0.20	0.39|0.34	2.07|1.35
	5	1.0–2.0	42.2|41.9	0.20|0.22	6.8|7.4	21.8|20.4	8.7|9.9	1.99|2.77	20.6|21.6	0.47|0.40	0.43|0.47	2.03|1.74
	5	> 3.0	42.6|41.9	0.16|0.19	2.9|4.9	21.2|19.5	7.0|7.6	1.66|3.30	15.6|17.3	0.40|0.34	0.35|0.73	1.69|1.64
Stem bark	1		43.4|43.1	0.33|0.36	14.1|13.6	181.3|213.7	33.8|27.5	4.58|3.33	60.4|49.4	3.06|1.82	0.53|0.58	8.73|7.43
	3		42.5|42.6	0.35|0.36	15.8|14.4	220.4|211.6	31.5|29.1	3.53|3.58	58.8|58.9	2.84|1.61	0.75|0.63	10.84|8.56
	5		42.2|42.9	0.38|0.39	17.9|16.1	201.3|197.2	36.0|37.1	3.42|3.91	69.3|64.3	2.42|1.19	0.71|0.49	10.76|8.62
	7		43.4|42.8	0.42|0.45	19.9|20.4	184.3|195.6	41.3|37.8	4.56|3.58	74.5|76.5	2.91|1.96	0.71|0.72	12.35|9.44
	9		43.4|42.8	0.66|0.60	30.7|27.9	150.7|175.1	46.5|45.8	3.98|4.15	113.3|93.0	4.50|3.08	1.01|0.85	13.73|10.80

Table 6 to be continued

<table>
<tr><th>Tree component</th><th>Section</th><th>Needle year/ diameter category (cm)</th><th>C</th><th>N</th><th>P</th><th>Ca</th><th>Mg</th><th>Na</th><th>K</th><th>Al</th><th>Fe</th><th>Mn</th></tr>
<tr><th></th><th></th><th></th><th colspan="2">(mol/kg)</th><th colspan="8">(mmol/kg)</th></tr>
<tr><td rowspan="5">Stem wood</td><td>1</td><td></td><td>41.5|42.5</td><td>0.06|0.13</td><td>0.4|0.6</td><td>17.9|20.2</td><td>5.8|4.9</td><td>2.58|2.93</td><td>13.6|13.1</td><td>0.48|0.28</td><td>0.30|0.13</td><td>1.34|1.66</td></tr>
<tr><td>3</td><td></td><td>41.5|42.2</td><td>0.07|0.12</td><td>0.9|0.5</td><td>17.0|18.8</td><td>4.1|4.7</td><td>3.03|2.25</td><td>12.5|12.7</td><td>0.41|0.21</td><td>0.26|0.13</td><td>1.44|1.74</td></tr>
<tr><td>5</td><td></td><td>41.5|42.2</td><td>0.06|0.12</td><td>0.7|0.6</td><td>17.4|17.9</td><td>3.7|4.2</td><td>2.91|2.60</td><td>11.0|13.2</td><td>0.41|0.34</td><td>0.26|0.13</td><td>1.53|1.62</td></tr>
<tr><td>7</td><td></td><td>41.8|42.4</td><td>0.07|0.12</td><td>1.0|1.0</td><td>18.3|17.7</td><td>4.1|4.1</td><td>2.58|2.93</td><td>12.0|13.0</td><td>0.41|0.28</td><td>0.48|0.13</td><td>1.59|1.37</td></tr>
<tr><td>9</td><td></td><td>41.8|42.4</td><td>0.09|0.14</td><td>2.6|1.7</td><td>18.1|18.4</td><td>5.0|4.8</td><td>2.13|2.82</td><td>17.3|14.4</td><td>0.34|0.21</td><td>0.30|0.17</td><td>1.63|1.30</td></tr>
<tr><td rowspan="4">Roots</td><td></td><td>0.0–1.0</td><td>44.3|43.9</td><td>0.69|0.88</td><td>20.9|27.8</td><td>84.8|82.5</td><td>18.4|20.7</td><td>6.77|7.57</td><td>24.6|55.0</td><td>42.16|28.70</td><td>5.64|4.27</td><td>3.82|3.37</td></tr>
<tr><td></td><td>1.0–3.0</td><td>42.3|43.5</td><td>0.28|0.36</td><td>13.8|12.7</td><td>44.4|63.0</td><td>11.4|13.0</td><td>2.60|3.52</td><td>62.2|70.1</td><td>1.44|1.18</td><td>0.44|0.35</td><td>2.56|2.30</td></tr>
<tr><td></td><td>3.0–3.7</td><td>42.3|42.8</td><td>0.13|0.15</td><td>3.9|3.6</td><td>23.3|22.7</td><td>5.7|6.4</td><td>2.49|2.60</td><td>25.2|32.6</td><td>0.48|0.55</td><td>0.17|0.35</td><td>1.26|1.16</td></tr>
<tr><td></td><td>> 7.0</td><td>41.7|42.9</td><td>0.09|0.13</td><td>1.9|2.1</td><td>20.3|21.5</td><td>6.7|5.0</td><td>3.27|2.48</td><td>30.2|22.2</td><td>0.55|0.34</td><td>0.30|0.17</td><td>1.26|1.14</td></tr>
</table>

year class (MZE–VÚLHM 2004): P 32 mmol/kg, Ca 37 mmol/kg, Mg 25 mmol/kg, and K 90 mmol/kg. All measured concentrations in needles up to the 2nd year class were higher. Fe, Na, Al and Mn showed the lowest mean concentrations in tree components for all the analyzed elements.

Some differences were found in the element concentrations of different parts of the trees from the CT and PL catchments (Table 7). Because of the relatively low number of all analyzed samples, the results have only a preliminary character. Generally, the samples from the PL catchment had lower concentrations of N, P, Ca and Mg. On the other hand, the samples from the CT catchment had higher concentrations of Al in foliage and stems but lower concentrations in branches and roots. Differences in average element concentrations obtained for sample trees from both catchments were statistically tested using *t*-test. The prevailing part of differences is not significant. The following ones are noteworthy: lower carbon content in CT stem wood (test error probability $p = 4.3\%$), lower nitrogen concentration in CT biomass for the 1st year class foliage ($p = 12\%$; higher error probability is accepted regarding the small number of measured values in this case and in the following cases), stem wood ($p = 12.6\%$) and roots ($p = 10.4\%$), lower phosphorus concentration in CT root biomass. All other significant differences show lower element concentrations within the CT catchment: Ca in branch wood ($p = 7.2\%$), Na in the 1st year class foliage ($p = 12.7\%$), K in the 1st year class foliage ($p = 11.5\%$) and in older classes ($p = 5.4\%$). A number of these significant results were determined for aluminium (1st year class foliage, $p = 1.5\%$; 2nd year class foliage, $p = 3.6\%$; older class foliage, $p = 10.8\%$; stem wood, $p = 6.2\%$; stem bark, $p = 5.8\%$) and iron (1st year class foliage, $p = 7.7\%$; 2nd year class foliage, $p = 3.7\%$; stem wood, $p = 0.1$).

Relationships between the element concentrations in selected parts of biomass and their differences within all sample trees are visible from the principal component analysis (PCA) result (Fig. 2). The first and the second axis represent 49% and 20% of total data variability, respectively. There are two element pencils. The first one is represented by Na, Fe and Al. These elements are important from the acidification point of view. The most origin-distant points lying in the direction of this pencil represent fine branch biomass and branch bark. All analyzed nutrients (N, Mg, P, K, Mn and Ca partly) create the second element pencil. Comparing equivalent points associated with both catchments within the ordination space, it is possible to find outlying values for the CT catchment (higher variability of point position, pre-

Table 7. Relative differences in average element concentrations in main tree parts between both catchments. Higher element concentrations in sample trees of CT catchment are given by positive values. Negative values show higher concentrations in the tree material from PL catchment. All differences in percent as ratios of the average element concentration in all 6 sample trees

	C	N	P	Ca	Mg	Na	K	Al	Fe	Mn
Foliage – 1st year	–0.1	–9.1	–9.7	–0.7	–8.3	28.4	21.0	39.9	12.7	13.4
Foliage – 2nd year	–0.1	5.0	10.8	0.2	14.0	38.3	33.8	66.8	30.5	5.9
Branch	2.5	–2.4	–7.0	–14.4	–6.7	–9.4	9.1	–12.0	–22.5	–1.5
Stem	–0.9	–16.9	5.2	–4.2	6.7	6.8	5.2	50.3	28.3	16.4
Root	–2.6	–56.8	–41.8	–24.0	–4.0	0.8	–7.1	–20.7	–13.7	–8.2

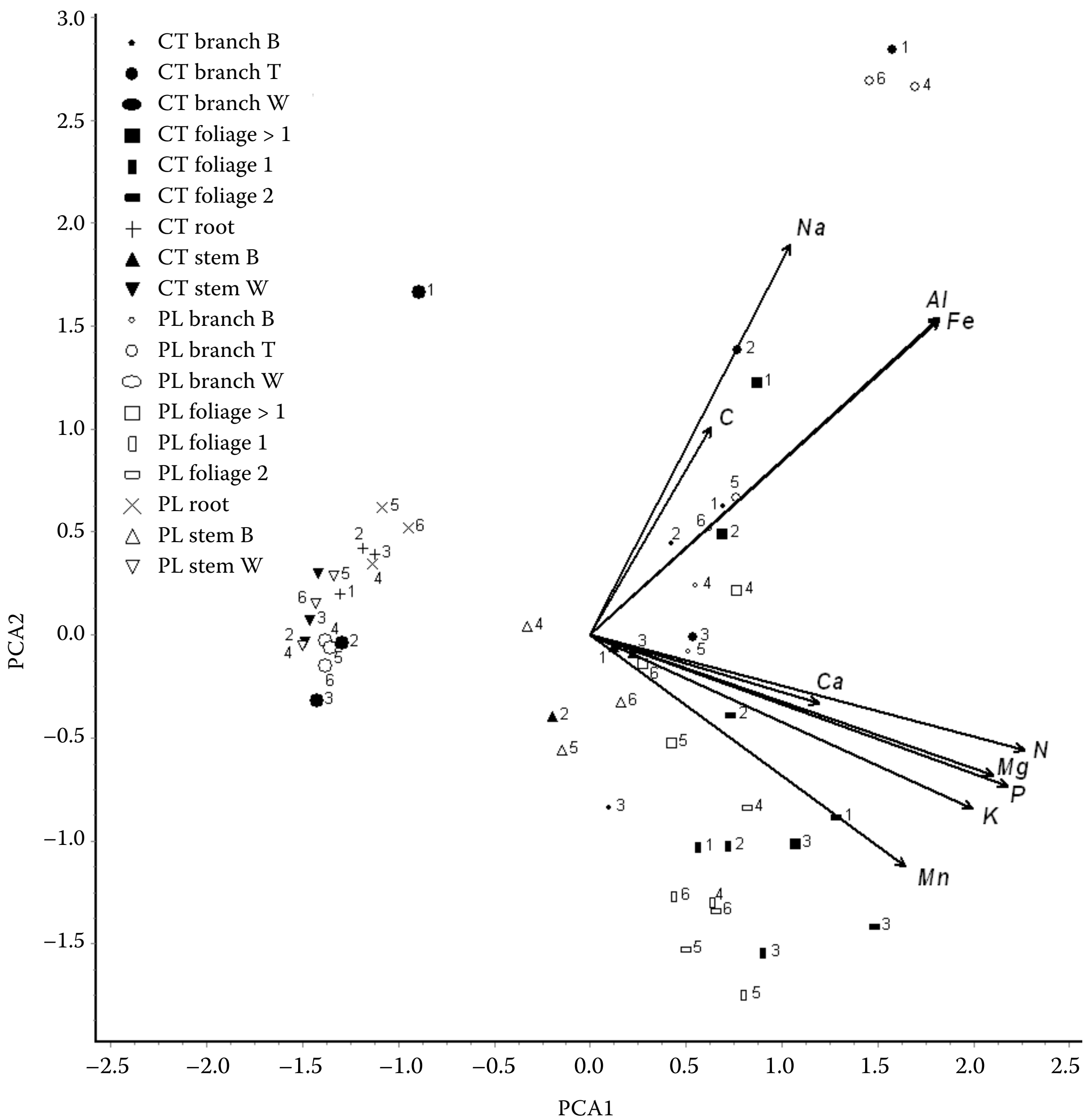

Fig. 2. Principal component analysis (PCA) of average element concentrations in different parts of sampling trees from Čertovo Lake (CT, trees 1–3) and Plešné Lake (PL, trees 4–6): ordination biplot in the first two axes for data on bark of branches (branch B), wood of branches (branch W), whole small branches (branch T), foliage of 1st, 2nd year class and 2nd or higher year class (foliage 1, foliage 2 and foliage > 1, respectively), stem bark (stem B), stem wood (stem W) and root mass were analyzed. Arrows are 2.5-times oversized in the figure

Table 8. Element pools in different tree components in the CT catchment (foliage – F, fine branches – FB, branch bark – BB, branch wood – BW, stem bark – SB, stem wood – SW, and roots – R)

Tree	Tree component	Element pools									
		C	N	P	Ca	Mg	Na	K	Al	Fe	Mn
		(kg)	(g)								
1	F	24.1	710.3	75.6	98.7	32.5	4.3	276.0	8.4	5.9	9.8
1	FB	4.7	130.4	12.7	22.8	7.3	1.1	35.4	4.1	2.6	1.3
1	BB	6.4	107.1	9.8	97.5	16.3	1.2	32.2	3.1	1.8	4.3
1	BW	25.0	118.0	4.4	38.7	9.5	3.5	25.8	0.5	1.0	2.5
1	SB	18.3	214.4	23.9	269.6	37.4	3.0	94.6	3.3	1.6	12.4
1	SW	206.1	398.4	12.1	259.7	56.2	30.5	205.2	6.0	6.0	21.9
1	R	89.0	329.2	22.1	136.2	26.9	10.3	150.1	6.2	5.8	7.4
1	Total	373.6	2,008.0	160.6	923.2	186.1	53.9	819.2	31.7	24.7	59.6
2	F	63.9	1,767.5	137.1	358.4	87.5	9.5	911.4	23.1	11.7	52.7
2	FB	16.3	415.8	37.8	83.1	17.4	2.8	116.0	9.6	5.6	7.5
2	BB	20.7	327.6	26.7	305.9	30.3	3.1	106.0	10.8	4.6	19.6
2	BW	61.8	268.8	9.7	130.7	27.0	5.5	105.4	1.3	2.4	12.6
2	SB	57.9	497.4	54.7	964.4	94.9	8.5	267.8	6.3	3.1	45.8
2	SW	587.5	1,184.4	24.7	882.7	129.7	64.8	638.0	10.9	22.0	86.6
2	R	200.6	617.9	40.1	409.1	69.6	28.4	558.6	18.4	9.0	24.3
2	Total	1,008.7	5,079.5	330.8	3,134.3	456.3	122.7	2,703.3	80.6	58.3	249.1
3	F	95.1	2,762.8	281.0	892.3	158.9	10.0	1,087.7	26.0	14.1	178.0
3	FB	30.0	697.2	73.5	163.3	40.8	4.7	350.4	7.1	4.8	19.1
3	BB	25.3	344.5	29.2	433.2	37.8	2.5	106.2	6.8	4.0	38.9
3	BW	96.2	388.4	11.2	216.0	28.6	6.8	67.7	1.3	2.9	30.7
3	SB	68.9	692.7	55.4	1,069.2	88.9	15.1	360.6	11.2	5.4	130.4
3	SW	951.5	1,465.9	37.1	1,473.0	176.0	118.2	862.5	21.1	32.9	212.5
3	R	483.8	1,735.5	98.9	1,160.2	192.2	84.3	1,107.2	88.8	23.0	135.8
3	Total	1,750.7	8,086.8	586.3	5,407.3	723.4	241.7	3,942.2	162.3	87.1	745.4

vailing in the direction of the 1st element pencil) as a locality of the most important acidification changes in the 20th century.

Element pools

The element pools in the trees and their components, together with the proportions of element pools in the tree components are given in Tables 8 and 9. The total element pools per tree were highly variable because of the differences in total biomass between the individual trees.

There were differences in the proportions of element pools in the tree components between the individual elements (Table 10). The highest proportion of C was contained in stem wood and bark (58.6 and 5.4%) followed by roots (24.5%). The highest proportion of N was contained in stem wood and bark (28.4 and 10.7%), followed by foliage (24.6%) and roots (21.7%). The highest proportion of P was contained in foliage (33.7%), followed by stem wood and bark (9.8 and 16.8%), and roots (21.8%). The highest proportion of Ca was contained in stem wood and bark (28.2 and 27.4%), followed by roots (18.7%) and foliage (12.2%). The highest proportion of Mg was contained in stem wood and bark (30.9 and 20.2%), followed by roots (20.4%) and foliage (14.7%). The highest proportion of Na was contained in stem wood and bark (55.3 and 7.0%), followed by roots (26.4%). The highest proportion of Al was contained in roots (41.8%), followed by a similar proportion in branches (20.1%) and stem wood and bark (14.1 and 8.2%). The highest proportion of Fe was contained in stem wood and bark (27.7 and 7.8%), followed by roots (29.0%) and branches (20.7%). The highest proportion of Mn was contained in stem wood and bark (38.5 and 20.3%), followed by a similar proportion in roots (15.3%) and foliage (14.8%).

Generally, stem wood and bark, foliage, and roots contained the highest proportions of the elements. But there were differences between individual elements. Concerning the important nutrients, while the highest proportion of Ca and Mg was contained in stem wood and bark, the highest proportion of P was contained in foliage. The foliage contained a relatively high proportion of P and K, but a relatively

Table 9. Element pools in different tree components in the PL catchment. For abbreviations of tree components see Table 8

Tree	Tree component	Element pools									
		C	N	P	Ca	Mg	Na	K	Al	Fe	Mn
		(kg)	(g)								
4	F	16.6	488.3	44.4	138.0	23.2	2.0	175.4	4.6	3.0	15.8
4	FB	5.2	144.5	13.7	35.4	8.0	1.2	42.5	4.6	3.0	2.8
4	BB	6.6	104.6	11.2	130.9	11.6	1.1	39.2	2.8	1.6	5.4
4	BW	22.5	102.9	3.4	41.5	6.6	2.1	25.8	0.3	0.8	3.4
4	SB	46.1	430.5	40.6	635.2	49.1	7.7	176.2	3.4	2.6	35.0
4	SW	487.0	883.0	17.2	810.4	99.8	51.4	449.7	6.0	7.3	90.6
4	R	150.5	711.4	43.6	355.5	47.3	18.0	330.6	26.4	10.5	23.3
4	Total	734.4	2,865.1	174.1	2,147.0	245.7	83.5	1,239.3	48.2	28.8	176.2
5	F	10.5	334.4	39.1	69.6	18.8	0.9	100.7	1.6	1.4	9.7
5	FB	4.3	114.8	11.8	24.0	5.9	0.6	31.2	2.1	1.4	2.6
5	BB	3.6	56.8	5.1	81.5	6.9	0.7	16.8	1.3	0.8	4.4
5	BW	11.8	59.9	2.0	19.3	4.2	1.1	12.6	0.2	0.6	1.9
5	SB	17.6	203.8	17.3	355.2	23.9	2.3	91.0	1.8	1.2	14.2
5	SW	213.2	971.1	9.0	335.4	52.7	28.8	273.8	3.6	3.0	38.9
5	R	113.6	547.4	28.8	321.1	36.4	15.1	218.1	16.8	5.6	16.2
5	Total	374.5	2,288.3	113.1	1,206.2	148.7	49.5	744.2	27.3	14.0	88.0
6	F	3.5	100.0	8.3	17.8	4.7	0.4	33.3	0.7	0.5	2.6
6	FB	2.3	57.0	5.7	12.0	3.7	0.6	14.6	1.9	1.3	1.4
6	BB	1.0	15.6	1.5	15.1	2.3	0.2	5.2	0.4	0.3	1.0
6	BW	2.7	12.8	0.4	4.4	1.0	0.2	2.6	0.1	0.1	0.5
6	SB	8.9	98.8	9.4	131.9	19.6	1.7	45.2	0.8	0.7	10.2
6	SW	78.5	314.1	3.3	104.4	16.1	9.7	60.6	1.0	1.1	12.6
6	R	32.4	277.2	13.9	71.1	13.8	5.3	96.1	2.9	1.8	6.9
6	Total	129.2	875.5	42.5	356.7	61.2	18.0	257.6	7.8	5.8	35.2

low proportion of Ca and Mg. Surprisingly not only roots contained a high proportion of Al, but also fine branches. Even though the relative proportion of fine branches in total tree biomass was only 1.5%, it contained 11.9% of total Al pool. Similarly, the relative proportion of foliage in total tree biomass was only 5.4%, but it contained 33.7, 24.6, 24.3, 14.7, and 12.2% of P, N, K, Mg, and Ca, respectively.

CONCLUSION

The presented data are the first information on chemical element concentrations in the biomass of trees growing in catchments of two glacial lakes. This most extensive study is a part of the running project with the goal to describe element dynamics in local ecosystems. We use these data to calculate element pools within the whole tree layer in the catchments.

Both catchments have different environmental conditions (e.g. prevailing 7th forest altitudinal zone in the CT catchment compared with 8th zone in the PL catchment, different management history, higher previous pollution level in the CT catchment, present spruce decline in the PL catchment caused by bark-beetle) resulting in element dynamics.

Concentration variability is an important factor which should be taken into account. The following study should investigate the situation from this aspect.

There are some common recommendations. The state of nutrition is traditionally analyzed on the basis of foliar element concentration (e.g. Stefan et al. 1997). On the other hand, the state of pollution and disturbance of element dynamics as a result of acidification are appropriately quantified by analyzing such parts of biomass as fine branches and branch bark.

Acknowledgement

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Table 10. Values of the mean proportions and their standard deviations (STD) and maximum and minimum proportions of the element pools contained in tree components. All values in percent

Element	Function	Proportion of the elements in tree components						
		F	FB	BB	BW	SB	SW	R
C	Mean	4.3	1.4	1.3	4.4	5.4	58.6	24.5
	STD	1.9	0.4	0.5	1.9	1.1	4.4	4.0
	Max	6.4	1.8	2.1	6.7	6.9	66.3	30.3
	Min	2.3	0.7	0.8	2.1	3.9	54.3	19.9
N	Mean	24.6	6.6	4.0	3.9	10.7	28.4	21.7
	STD	11.3	1.5	1.7	1.7	2.4	9.6	6.8
	Max	35.4	8.6	6.4	5.9	15.0	42.4	31.7
	Min	11.4	5.0	1.8	1.5	8.6	18.1	12.2
P	Mean	33.7	9.9	5.5	2.5	16.8	9.8	21.8
	STD	10.1	2.2	1.7	1.3	5.4	4.2	7.8
	Max	47.1	13.3	8.1	4.8	23.3	18.1	32.8
	Min	19.6	7.9	3.4	1.0	8.6	7.5	12.1
Ca	Mean	12.2	3.5	6.9	3.0	27.4	28.2	18.7
	STD	11.1	2.6	2.7	1.6	9.7	6.2	5.0
	Max	34.2	8.6	10.6	4.8	37.0	37.7	26.6
	Min	5.0	1.7	4.2	1.2	8.6	18.1	13.1
Mg	Mean	14.7	4.4	5.6	3.7	20.2	30.9	20.4
	STD	5.7	1.1	1.8	1.6	6.6	6.1	4.9
	Max	22.0	6.1	8.8	5.9	32.0	40.6	26.6
	Min	7.7	3.2	3.8	1.6	12.3	24.3	14.5
Na	Mean	4.4	2.1	1.6	3.3	7.0	55.3	26.4
	STD	2.8	0.8	0.6	1.9	1.9	4.5	6.1
	Max	7.9	3.5	2.6	6.5	9.2	61.6	34.9
	Min	1.9	1.3	1.0	1.2	4.6	48.9	19.0
K	Mean	24.3	5.1	3.0	2.3	12.4	27.9	26.7
	STD	10.4	2.0	0.8	1.1	3.1	6.8	6.7
	Max	33.7	8.9	3.9	3.9	17.5	36.8	37.3
	Min	12.9	3.4	2.0	1.0	9.1	21.9	18.3
Al	Mean	15.8	11.9	7.2	1.0	8.2	14.1	41.8
	STD	9.7	7.1	3.7	0.5	1.8	2.4	17.9
	Max	28.7	24.9	13.5	1.7	10.5	19.0	61.6
	Min	5.8	4.4	4.2	0.6	6.6	12.5	19.7
Fe	Mean	14.8	11.2	5.9	3.6	7.8	27.7	29.0
	STD	6.2	5.5	1.4	0.9	2.2	8.0	9.0
	Max	23.8	21.8	7.9	4.6	11.4	37.7	40.2
	Min	8.6	5.5	4.5	2.4	5.3	19.4	15.5
Mn	Mean	14.8	2.7	5.2	3.1	20.3	38.5	15.3
	STD	6.7	0.9	2.1	1.5	4.6	8.1	4.0
	Max	23.9	4.1	7.9	5.0	29.1	51.4	19.5
	Min	7.5	1.6	2.8	1.3	16.2	28.5	9.8

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Biomasa a zásoba prvků vybraných stromů smrku v povodí Plešného a Čertova jezera na Šumavě

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ABSTRAKT: Příspěvek uvádí podrobná data o biomase a zásobě chemických prvků v šesti vzornících z povodí Plešného a Čertova jezera na Šumavě. Průměr stromů ve výčetní výšce kolísal mezi 28,0 a 63,7 cm, výška byla v rozmezí

14,1 a 38,7 m, věk kolísal mezi 84 a 177 lety. Celková biomasa vzorníků byla od 239 do 2 932 kg v sušině. Podíl hmoty dřeva kmene na celkové biomase byl mezi 63,5 a 69,5 %. Podíl hmoty kůry činil 4,6 až 7,2 %. Jehličí představovalo 4,3 až 8,4 %, jemné větve 0,7 až 1,9 %, dřevo větví 2,2 až 6,5 %, kůra větví 0,8 až 2,2 %. Průměrná koncentrace uhlíku v různých částech stromů byla podobná. Navzájem obdobné rozdělení v biomase vykazovaly P, Ca, Mg a K, přičemž nejvyšší hodnoty byly nalézány v jehličí, jemných větvích, jemných kořenech a v kůře. Nejnižší průměrné koncentrace vykazovaly Fe, Na, Al a Mn. Celková zásoba prvků je závislá na velikosti jednotlivých stromů, jejich rozdělení mezi jednotlivými částmi stromů se mírně liší při srovnání různě velkých stromů. Ca a Mg měly nejvyšší podíl v dřevě a kůře, zatímco P byl nejvíce zastoupen v jehličí obdobně jako K.

Klíčová slova: smrk; biomasa; zásoba prvků; Šumava; Čertovo jezero; Plešné jezero

Cílem studie bylo získat údaje o biomase a obsahu živin ve vybraných stromech smrku v povodí Plešného a Čertova jezera na Šumavě. Cykly živin a chemismus těchto jezer se intenzivně studují již dlouhou dobu. Obě jezera se liší v trendech biologického zotavování po dlouhodobé acidifikaci v minulém století (Kopáček et al. 2002a). Pro pochopení těchto procesů bylo v posledních letech provedeno několik detailních studií, zabývajících se chemismem těchto jezer, atmosférickou depozicí v povodí a biochemickými procesy v půdě. Přesto stále ještě chybějí údaje o zásobě živin v lesních porostech a jejich úloze v geochemických cyklech na úrovni povodí. Studie je součástí komplexního výzkumu ledovcových jezer na Šumavě. V článku jsou prezentovány údaje (1) o nadzemní a podzemní biomase vybraných stromů v povodí Plešného a Čertova jezera, (2) o zásobě živin v biomase těchto stromů.

V povodí Plešného a Čertova jezera bylo vybráno šest vzorníkových stromů, u kterých byl proveden detailní rozbor podzemní a nadzemní biomasy. Byla stanovena sušina jednotlivých částí biomasy: jehličí, jemné větve, kůra větví, dřevo větví, kůra kmene, dřevo kmene a kořeny. Následně byly odebrány vzorky jednotlivých částí biomasy a byla stanovena koncentrace těchto prvků: C, N, P, Ca, Mg, Na, K, Al, Fe a Mn.

Výčetní tloušťka a výška jednotlivých stromů se pohybovala v rozmezí 28,0–63,7 cm a 14,1–38,7 m (tab. 1). Věk vzorníkových stromů se pohyboval v rozmezí 84–177 let (tab. 1). Celková sušina biomasy stromů se pohybovala v rozmezí 239,4 až 2 932,3 kg (tab. 5). Rozdíl v celkové biomase stromů byl důsledkem rozdílů v taxačních charakteristikách stromů. Podíl jednotlivých částí biomasy stromů byl následující: jehličí 4,3–8,4 %, jemné větve 0,7 až 1,9 %, kůra větví 0,8–2,2 %, dřevo větví 2,2–6,5 %, kůra kmene 4,6–7,2 % a dřevo kmene 63,5–69,5 % (tab. 5).

Průměrné koncentrace prvků v různých částech stromů z Čertova a Plešného jezera jsou uvedeny v tab. 6. Uhlík měl ze všech analyzovaných prvků nejvyšší koncentrace. Průměrné koncentrace uhlíku v různých částech stromů byly podobné. Kromě uhlíku měl dusík v porovnání s ostatními prvky nejvyšší koncentrace v biomase. Koncentrace fosforu, vápníku, hořčíku a draslíku měly podobný charakter. Nejvyšší koncentrace těchto prvků byly nalezeny v jehličí, jemných větvích, v kůře větví a kůře kmene. Železo, sodík, hliník a mangan měly nejnižší koncentrace v biomase ze všech analyzovaných prvků.

Celková zásoba prvků ve stromech a jejich částech byla podkladem pro výpočet podílu prvků v jednotlivých částech stromů (tab. 8 a 9). Celková zásoba prvků v jednotlivých stromech byla variabilní v důsledku rozdílů v celkové biomase jednotlivých stromů. Obecně je možné konstatovat, že největší podíl z celkové zásoby prvků ve stromech byl obsažen ve dřevě a v kůře kmene, jehličí a kořenech (tab. 10), přesto však byly nalezeny rozdíly mezi jednotlivými prvky. Pokud se týká důležitých živin, vápník a hořčík měl největší podíl v kůře a dřevě kmene, zatímco největší podíl fosforu byl zjištěn v jehličí.

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