Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Litterfall production and quality at Level II sites

By Liisa Ukonmaanaho

Summary

Litterfall production was monitored in eight Norway spruce, seven Scots pine and two birch stands between 1996–2007. The annual litterfall production varied considerably over the years and from one site to another. The mean annual litterfall sum of spruce stands ranged from 61 to 462 g m^{-2}, for pine stands from 79 to 359 g m^{-2} and for birch stands 146 to 346 g m^{-2}. Average foliar litter production varied from 60% to 78% of the total litterfall flux in the Norway spruce stands and from 32% to 6% in the Scots pine stands. In birch stands, the share of foliar litter was nearly 80% of the total litterfall. In addition to birch stands, the highest litterfall production was observed in Scots pine stands in the autumn, while in Norway spruce stands litterfall production was more evenly distributed throughout the year. The studied nutrient concentrations increased in the following order: birch > Norway spruce > Scots pine, the concentrations usually being higher in foliar than in miscellaneous fraction. The concentration of all other nutrients except Mn and Fe were higher in birch litter than in spruce and pine litter. A slight latitude-related trend was found in S and Mn concentrations; S concentration decreased the further north the stands were located, while Mn concentration showed a corresponding increase. For more information about previous results, see Ukonmaanaho et al. 2008.

Background

In forested ecosystems, litterfall is the largest source of organic material and nutrients in the soil humus layer. It represents a major pathway through which soils, depleted of nutrient uptake and leaching, are replenished. In addition, litterfall represents one of the primary links between producer and decomposer organisms. Therefore, litterfall has a key role in understanding the dynamics of nutrient cycling within the forest ecosystem.

Foliar litter is the major component of aboveground litterfall in boreal forest ecosystems. Litterfall production is found to be strongly correlated with site, stand and climate factors. Annual litterfall can vary considerably, and is related to weather conditions that differ from year to year. In addition, there is a variation between the seasons, e.g. deciduous trees shed most of their foliar biomass in the autumn. The element concentrations in foliar litter are affected by several factors such as tree species, soil properties, climatic factors and tree growth intensity. This report presents the results of litterfall production and quality on Level II sites between 1996 and 2007.

Results and discussion

Litterfall production

The annual litterfall production varied considerably over the years and between stands (Fig. 1, interactive map, below). The mean annual litterfall sum of spruce stands ranged from 61 to 462 g m^{-2}, whereas for pine stands it ranged from 79 to 359 g m^{-2} (Fig. 1, interactive map, below). In the birch stands, the average litterfall production at the northern site of Kivalo (nr. 32) was 146 g m^{-2} and at the southern site of Punkaharju (nr. 33) it was 346 g m^{-2}. The lowest litterfall production in both pine and spruce stands was in the northernmost sites, in the case of spruce at Kivalo (nr. 5) and Pallasjärvi (nr. 3), and at Kivalo (nr. 6) and Sevettijärvi (nr. 1) in pine sites. The general decrease from south to north in litterfall production was apparent, which is obviously related to the species-specific characteristics of these tree species, as well as climate and latitude. For example the height of trees is the lowest in the northern sites (Table 4 in Intensive and continous monitoring of...), indicating the impact of tree height in litterfall production. On average, litterfall production was at its greatest in spruce stands (274 g m^{-2}), at birch stands it was 245 g m^{-2}, and at pine stands 210 g m^{-2}. It can be estimated that roughly half of the litterfall mass is carbon, therefore within litterfall, there is an average carbon return to the forest floor of 137 g m^{-2} in spruce stands, 123 g m^{-2} in birch stands and 105 g m^{-2} in pine stands.

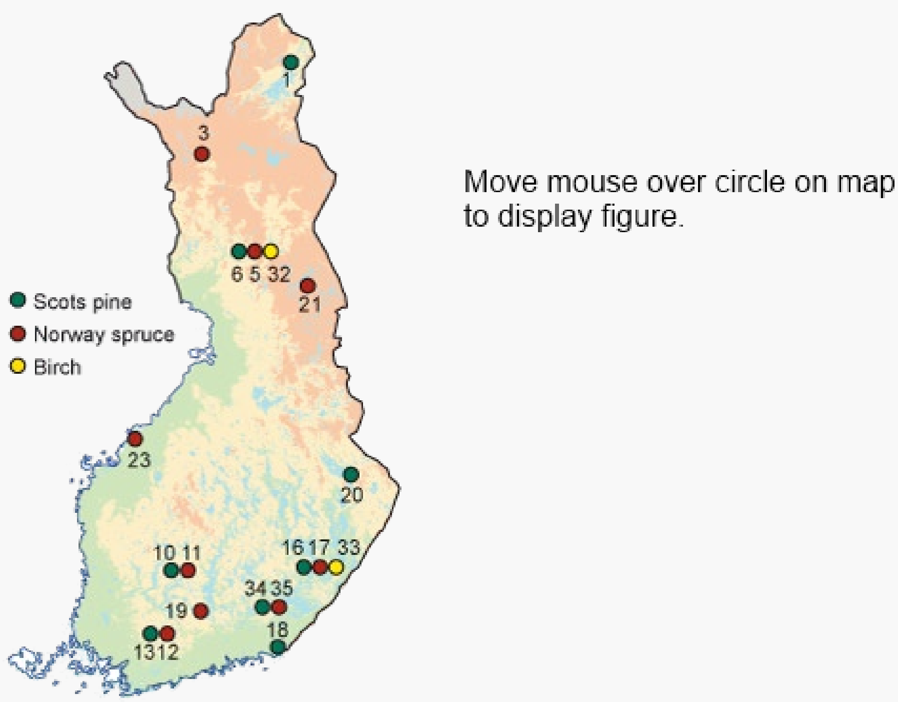

Figure 1. Location of the study sites. Please move mouse over circle on map to display figure.

The variation in foliar litter (needles and leaves) production was also considerable between the plots and years (Fig. 1). A similar decrease from south to north was observed in foliar litterfall production as with total litterfall production. The average foliar litterfall production varied from 60% (Oulanka nr. 21) to 78% (Pallasjärvi nr. 3) of the total litterfall flux in the Norway spruce stands and from 32% (Lieksa nr. 20) to 69% (Kivalo nr. 6) in the Scots pine stands. On average, there was a slightly greater foliar litterfall production in spruce stands (69%) than in pine stands (55%). It is known that in boreal coniferous forests, needle litter constitutes the main part of the litterfall flux on the forest floor. The rest of the litterfall (miscellaneous) was composed of reproductive structures of trees such as seeds, cones, flower parts and branches, bark and smaller amounts of dead insects and animal faeces. In birch stands, the share of foliar litter was nearly 80% of the total litterfall.

Birch has a clear seasonal pattern in litterfall production due to the abscission of leaves in the autumn (Fig. 2a), however, there was also a clear seasonal pattern in the litterfall production in Scots pine stands (Fig 2b). The highest litter production was observed during the autumn, which is connected with needle senescence. The oldest needle age-class of Scots pine are usually shed between August and October. Litter production was lowest during the winter and early summer. A similar seasonal pattern in Scots pine has been observed in many other previous studies (e.g. Viro 1955, Mälkönen 1974). Norway spruce litterfall production was more evenly distributed throughout the year than that of Scots pine, only a small peak was observed in early summer and autumn (Fig. 2c), which is typical for Norway spruce.

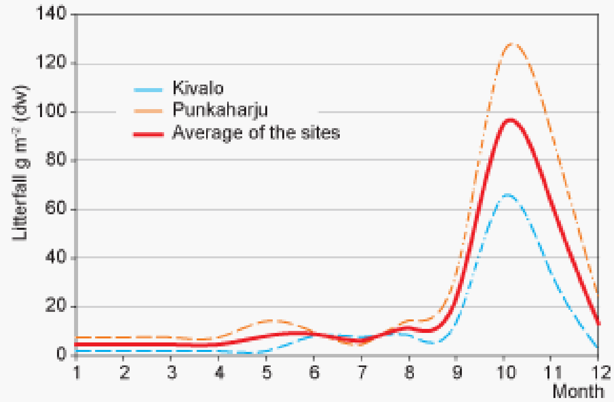

Figure 2a. Monthly litterfall sum during 2005–2007 at birch stands.

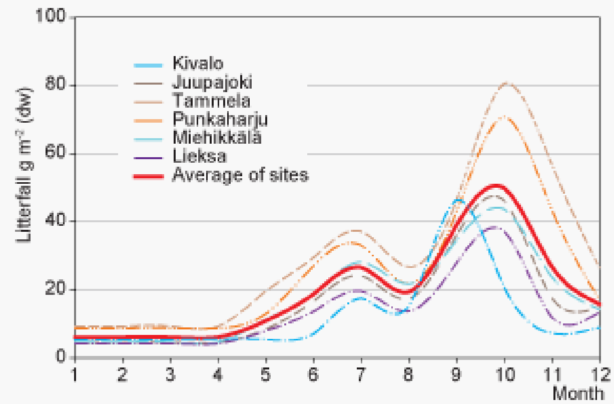

Figure 2b. Monthly litterfall sum during 1996–2007 at pine stands.

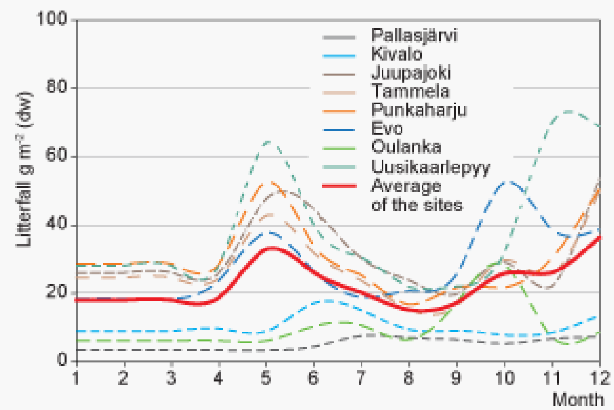

Figure 2c. Monthly litterfall sum during 1996–2007 at spruce stands.

Nutrient concentrations in litterfall

The mean nutrient concentrations in foliar and miscellaneous litter from Norway spruce, Scots pine and birch dominated stands are shown in Tables 1a and 1b. In general, the nutrient concentrations in the spruce litter tended to be higher than those in pine, which is consistent with earlier studies (e.g. Johansson 1984, 1995), but the highest concentrations were usually in birch litter. In fact, the concentrations of all other nutrients except Mn and Fe were higher in birch litter than in spruce and pine litter (Tables 1a and 1b). Nutrient concentrations varied between the fractions, the highest concentrations frequently occurring in the leaf fraction. Iron was the only nutrient with the highest concentration in the miscellaneous fraction in the birch, spruce and pine stands.

The difference in nutrient concentrations of Norway spruce, Scots pine and birch litter is due to many factors. It is generally agreed that tree species differ greatly in their ability to take up elements from the soil, but it is more obvious that other processes such as resorption, retranslocation and leaching together with the age of the needles and leaves greatly affect the chemical composition of litter. For example, spruce needles are normally older at the time of abscission than pine needles, and thus more immobile nutrients such as Ca and Mn are accumulated in senescent tissues over the years. On the other hand, high concentrations in birch leaves might be due to the fact that the resorption of nutrients into woody organs before leaf abscission is greater in coniferous trees than in hardwoods.

Slight latitude-related trends were found in the nutrient concentrations of the two most abundant fractions (needles, leaves and miscellaneous). The most obvious trend was for the Mn and S concentrations in both the spruce and pine stands. The Mn concentration increased the further north the stand was located, while the S concentration showed a corresponding decrease. The northwards-decreasing S trend in the needle and miscellaneous litter fractions followed the general S deposition trend reported in Finland (e.g. Lindroos et al. 2006). If litterfall in a birch stand is ignored, the highest nutrient concentration in litterfall frequently occurred on the Uusikaarlepyy plot (nr. 23). This plot is located on acid sulphate soil and receives an input of $MgSO_4$ from the sea (Gulf of Bothnia) and, in addition, there is a fur farm near the plot. Therefore, the tree canopy on the plot is also exposed to ammonia (NH_3) emissions from the fur farm. All these factors undoubtedly contribute to the relatively high S, N and Mg concentrations in litterfall on the Uusikaarlepyy plot.

Material and methods

Figure 3. The top of the funnel-shaped trapsstood at a height of 1.5 m above the forest floor.

The study was carried out in eight Norway spruce (*Picea abies* L. Karst.), seven Scots pine (*Pinus sylvestris* L.) and two birch (*Betula* sp.) stands between 1996 and 2007; at some of the stands sampling started later than 1996. Litterfall was collected using twelve traps located systematically on a 10 x 10 m grid on one plot (30 x 30 m) in each stand. The top of the funnel-shaped traps, with a collecting area of 0.5 m^2, stood at a height of 1.5 m above the forest floor (Fig. 3). The litterfall was collected in a replaceable cotton bag attached to the bottom of the litterfall trap. Litterfall was sampled bi-weekly during the snow-free period (May to November, depending of the latitude of the plot), and once at the end of winter. After collection, all the litter samples were air-dried and sorted into at least four fractions: Scots pine needles, Norway spruce needles, birch leaves and the remaining material (=miscellaneous). The mass of each fraction was weighed and chemical analyses were performed on the most abundant fractions. Litterfall production (dry mass per unit area) was calculated by dividing the total and needle litterfall masses by surface area of the traps.

Chemical analyses

Litterfall samples were dried at a temperature of 60ºC. The dried samples were milled and wet digested using microwave-assisted digestion in a mixture of $HNO_3 + H_2O_2$. The concentrations of Ca, K, Mg, Mn, P, S, Fe and Zn were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES). The total N concentration was determined with a CHN analyser (LECO).

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Table 1a. Annual nutrient concentrations in foliar litterfall on the Scots pine (pine needles), Norway spruce (spruce needles) and birch (birch leaves) stands during 1996-2007. Plots are arranged from north to south. Standard deviations (sd) are also indicated.

Plot	n		N	Ca	K	Mg	P	S	Mn	Zn	Fe
					$mg\ g^{-1}$					$\mu g\ g^{-1}$	
PINE NEEDLES											
1 Sevettijärvi	3	mean	5.6	3.57	1.25	0.77	0.74	0.59	533	40.4	110.1
		sd	± 1.53	± 0.600	± 0.593	± 0.103	± 0.247	± 0.098	± 90.2	± 8.06	± 68.22
6 Kivalo	12	mean	5.1	4.82	1.08	0.52	0.55	0.46	849	48.8	71.6
		sd	± 1.48	± 0.606	± 0.580	± 0.138	± 0.208	± 0.067	± 131.9	± 3.13	± 46.64
20 Lieksa	9	mean	6.1	3.73	1.26	0.62	0.51	0.51	931	54.3	59.9
		sd	± 1.94	± 0.478	± 0.598	± 0.097	± 0.175	± 0.080	± 168.6	± 6.35	± 18.96
10 Juupajoki	12	mean	6.6	3.32	1.22	0.56	0.58	0.55	624	41.4	104.2
		sd	± 1.86	± 0.426	± 0.593	± 0.139	± 0.204	± 0.096	± 132.1	± 5.50	± 46.27
16 Punkaharju	9	mean	6.6	5.04	1.51	0.51	0.59	0.58	1207	51.6	61.2
		sd	± 2.16	± 0.835	± 0.685	± 0.093	± 0.241	± 0.107	± 275.4	± 5.12	± 33.68
13 Tammela	12	mean	7.7	4.62	1.45	0.48	0.61	0.60	743	48.9	91.4
		sd	± 2.42	± 0.619	± 0.780	± 0.108	± 0.258	± 0.136	± 175.6	± 3.46	± 53.11
18 Miehikkälä	6	mean	7.5	4.05	1.74	0.49	0.61	0.59	490	56.4	99.4
		sd	± 2.35	± 0.698	± 0.940	± 0.113	± 0.260	± 0.127	± 130.9	± 6.77	± 43.70
SPRUCE NEEDLES											
3 Pallasjärvi	6	mean	6.9	12.86	1.65	0.81	0.94	0.61	1397	97.4	42.9
		sd	± 0.88	± 2.011	± 0.727	± 0.102	± 0.185	± 0.058	± 219.0	± 10.66	± 25.84
5 Kivalo	12	mean	7.7	10.88	1.78	0.58	0.79	0.67	1895	79.3	39.8
		sd	± 1.07	± 1.805	± 0.718	± 0.088	± 0.156	± 0.053	± 310.3	± 8.86	± 20.65
21 Oulanka	9	mean	6.5	10.06	1.70	0.73	0.91	0.65	1619	66.3	50.1
		sd	± 1.23	± 1.389	± 0.757	± 0.100	± 0.216	± 0.083	± 188.0	± 5.00	± 80.34
23 Uusikaarlepyy	9	mean	10.2	5.61	3.41	1.13	0.97	0.85	558	27.4	42.4
		sd	± 1.30	± 0.767	± 0.896	± 0.071	± 0.146	± 0.066	± 66.0	± 3.43	± 13.48
11 Juupajoki	12	mean	8.7	9.38	2.30	0.75	1.03	0.69	1781	40.0	39.2
		sd	± 0.83	± 1.294	± 0.769	± 0.073	± 0.185	± 0.047	± 266.7	± 5.19	± 15.63
17 Punkaharju	9	mean	8.4	7.18	2.05	1.06	0.64	0.71	1167	15.4	39.7
		sd	± 1.37	± 0.999	± 0.636	± 0.092	± 0.137	± 0.070	± 200.5	± 10.39	± 9.33
19 Evo	9	mean	8.5	11.48	2.36	0.96	0.63	0.70	1372	25.7	44.5
		sd	± 1.34	± 1.646	± 0.785	± 0.166	± 0.116	± 0.077	± 192.3	± 14.25	± 37.77
12 Tammela	12	mean	8.6	9.56	1.86	0.95	0.83	0.72	982	29.4	55.5
		sd	± 1.36	± 1.320	± 0.571	± 0.095	± 0.125	± 0.063	± 138.2	± 3.20	± 25.82
BIRCH LEAVES											
32 Kivalo	3	mean	19.5	6.16	4.73	2.12	2.40	1.18	813	140.4	192.1
		sd	± 13.36	± 2.125	± 2.339	± 0.808	± 1.089	± 0.649	± 342.8	± 55.28	± 197.77
33 Punkaharju	3	mean	19.8	8.90	4.68	2.33	2.18	1.37	833	151.5	143.0
		sd	± 10.07	± 2.665	± 2.933	± 0.964	± 1.079	± 0.574	± 350.1	± 31.73	± 121.04

Table 1b. Annual nutrient concentrations in miscellaneous litterfall fraction on the Scots pine, Norway spruce and birch stands during 1996–2007. Plots are arranged from north to south. Standard deviations (sd) are also indicated.

Plot	n		N	Ca	K	Mg	P	S	Mn	Zn	Fe
					mg g^{-1}					µg g^{-1}	
MISCELLANEOUS LITTERFALL AT PINE STANDS:											
1 Sevettijärvi	3	mean	6.9	1.50	0.94	0.42	0.87	0.64	61	50.2	216.8
		sd	± 1.88	± 0.594	± 0.478	± 0.085	± 0.362	± 0.151	± 19.5	± 51.51	± 121.16
6 Kivalo	12	mean	6.4	2.10	0.92	0.33	0.72	0.46	111	35.8	174.0
		sd	± 2.24	± 0.789	± 0.500	± 0.079	± 0.289	± 0.127	± 81.9	± 10.76	± 94.92
20 Lieksa	9	mean	7.7	3.71	1.22	0.47	0.71	0.58	200	51.3	186.9
		sd	± 1.92	± 1.178	± 0.622	± 0.359	± 0.320	± 0.098	± 172.2	± 37.56	± 76.89
10 Juupajoki	12	mean	9.8	2.26	1.12	0.41	0.87	0.71	114	74.6	311.7
		sd	± 4.11	± 0.752	± 0.570	± 0.142	± 0.430	± 0.222	± 50.9	± 109.94	± 170.56
16 Punkaharju	9	mean	8.5	2.77	1.20	0.36	0.79	0.67	167	38.2	204.5
		sd	± 2.92	± 0.756	± 0.628	± 0.107	± 0.317	± 0.175	± 113.2	± 26.67	± 84.13
13 Tammela	12	mean	8.7	2.80	1.32	0.52	0.75	0.65	244	97.1	241.4
		sd	± 2.12	± 1.386	± 0.734	± 0.349	± 0.346	± 0.143	± 251.7	± 211.71	± 123.00
18 Miehikkälä	6	mean	8.3	2.84	1.03	0.32	0.57	0.61	82	61.3	309.3
		sd	± 1.51	± 1.046	± 0.488	± 0.100	± 0.146	± 0.103	± 46.5	± 132.31	± 149.29
MISCALLANEOUS LITTERFALL AT SPRUCE STANDS											
3 Pallasjärvi	6	mean	13.7	3.76	2.24	0.77	1.66	1.00	506	124.8	301.6
		sd	± 4.44	± 1.470	± 0.951	± 0.123	± 0.602	± 0.229	± 217.0	± 45.29	± 146.31
5 Kivalo	12	mean	12.3	3.08	2.46	0.78	1.35	0.88	788	107.3	289.6
		sd	± 4.74	± 1.619	± 0.863	± 0.259	± 0.513	± 0.254	± 399.7	± 70.06	± 211.78
21 Oulanka	9	mean	10.3	3.83	2.04	0.83	1.21	0.85	468	70.1	236.2
		sd	± 2.68	± 1.690	± 0.920	± 0.607	± 0.406	± 0.143	± 312.2	± 20.92	± 128.82
23 Uusikaarlepyy	9	mean	17.7	3.19	3.26	1.02	1.54	1.40	261	91.5	459.5
		sd	± 4.25	± 0.750	± 1.086	± 0.203	± 0.367	± 0.370	± 66.5	± 42.68	± 311.14
11 Juupajoki	12	mean	13.4	4.08	2.36	0.75	1.34	1.12	644	148.1	461.5
		sd	± 2.90	± 1.219	± 0.733	± 0.201	± 0.354	± 0.201	± 225.9	± 214.05	± 177.39
17 Punkaharju	9	mean	12.1	2.26	2.73	0.76	1.11	1.01	247	61.4	350.9
		sd	± 3.94	± 0.920	± 0.937	± 0.168	± 0.420	± 0.286	± 92.5	± 71.28	± 187.55
19 Evo	9	mean	12.1	5.25	2.33	0.99	0.86	0.98	439	67.8	372.6
		sd	± 2.91	± 1.806	± 1.054	± 0.607	± 0.210	± 0.178	± 247.4	± 16.49	± 157.08
12 Tammela	12	mean	13.6	3.30	2.37	0.85	1.22	1.10	258	150.3	593.1
		sd	± 4.16	± 1.376	± 0.892	± 0.284	± 0.465	± 0.334	± 106.8	± 298.73	± 467.02
MISCELLANEOUS LITTERFALL AT BIRCH STANDS											
32 Kivalo	3	mean	13.9	4.97	1.99	1.06	1.24	0.85	432	180.8	214.7
		sd	± 3.18	± 0.642	± 1.038	± 0.331	± 0.482	± 0.199	± 137.8	± 74.412	± 258.94
33 Punkaharju	3	mean	17.2	5.73	2.78	1.42	1.58	1.05	455	118.0	146.1
		sd	± 7.83	± 1.157	± 1.993	± 0.501	± 0.712	± 0.392	± 162.7	± 42.019	± 74.16

Table 4. The basic stand characteristics of ICP Level II plots (measured during 2009–2010).

Plot nr.	Name	Main species	Stems ha^{-1}	Stem volume m^3 ha^{-1}	Basal area m^2 ha^{-1}	Arithmetic mean height m	Mean diameter cm weighted with basal area	Thinning year during 1995-2010	Stand age	Cajanderian forest type*
1	Sevettijärvi	Pine	350	82	14	11	28		210	UVET
3	Pallasjärvi	Spruce	1107	82	15	10	16		150	HMT
5	Kivalo	Spruce	1648	153	25	11	16	2006	80	HMT
6	Kivalo	Pine	1748	197	27	14	15	2008	65	EMT
10	Juupajoki	Pine	378	240	22	23	28		90	VT
11	Juupajoki	Spruce	852	419	38	21	26	2006	90	OMT
12	Tammela	Spruce	663	360	33	22	26		70	MT
13	Tammela	Pine	619	306	29	22	25		70	VT
16	Punkaharju	Pine	741	362	32	24	24	2005	90	VT
17	Punkaharju	Spruce	370	435	34	28	35	**2010	80	OMT
19	Evo	Spruce	1258	711	58	20	32		180	OMT
20	Lieksa	Pine	371	260	25	21	33		140	EVT
21	Oulanka	Spruce	1197	145	21	9	24		180	HMT
23	Uusikaarlepyy	Spruce	848	443	39	23	26	2006	65	OMT
32	Kivalo	Birch	867	130	18	15	18		55	HMT
33	Punkaharju	Birch	1037	169	18	19	16		25	OMT
34	Luumäki	Pine	625	103	14	14	19		60	CT
35	Luumäki	Spruce	678	284	28	19	27		75	MT

*Cajander, A.K. 1949.
**only dead trees removed