Working Report 2010-65

Results of Forest Monitoring on Olkiluoto Island in 2009

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ABSTRACT

Forest investigations carried out on Olkiluoto aim to monitor the state of the forest ecosystems, quantify Olkiluoto-specific processes taking place in the forests producing input data for the safety assessment of spent nuclear fuel disposal, and follow possible changes in the forest condition resulting from the intensive construction activities currently being carried out in the area. The forest investigations form a part of the monitoring programme being carried out on Olkiluoto Island under the management of Posiva Oy. This report focuses on activities performed on bulk deposition and forest intensive monitoring plots (MRK and FIP plots) in 2009. In general, the deposition levels in 2009 in the open area and in stand throughfall were quite comparable to those in earlier years, although sulphur and calcium depositions were somewhat higher in the open area than in earlier years. The soil solution quality in 2009 was also quite comparable to that in earlier years. The NH_4-N and NO_3-N concentrations were low at all depths in the mineral soil of the FIP plots. There appeared to be a gradual decrease in sulphate concentrations in the mineral soil during the monitoring period. In 2009 the monthly level of transipiration in the Scots pine dominated stand was comparable to previous years (2007-2008). Instead, monthly transpiration in the Norway spruce dominated stand was clearly lower in 2009 than in 2007-2008. Annual total litterfall production was smaller in 2008 than in 2007. The most notable differences between the plots were detected in Al and N concentrations. The Al concentration was higher in living pine needles than in spruce needles. High Al and Fe concentrations were found in remaining litter, and are most likely due to soil dust. The average defoliation level of the pines was 4.6 % and of the spruces 24.1 %, indicating a good crown condition: the pines were classified as non-defoliated and the spruces as slightly defoliated. The minirhizotrone images filmed in 2009 in the FIP stands showed that within the two first growing seasons most of the roots observed as new stayed alive. Therefore, for determining the root turnover rate, the minirhizotrone images will also be taken in the growing season of 2010.

Keywords: Bulk deposition, defoliation, fine root elongation and longevity, forest ecosystems, litterfall production, soil solution chemistry, stand throughfall, tree stand transpiration.

METSIEN TILAN SEURANTA 2009

TIIVISTELMÄ

Olkiluodon metsäntutkimusten tavoitteena on seurata metsien tilaa ja mitata metsissä tapahtuvia prosesseja. Tuloksia tarvitaan käytetyn ydinpolttoaineen loppusijoituksen turvallisuusarvioinnissa. Lisäksi tutkimuksilla seurataan alueen voimakkaan rakennustoiminnan mahdollisesti aiheuttamia muutoksia metsissä. Metsäntutkimukset ovat osa Posivan toteuttamaa ympäristön seurantaohjelmaa Olkiluodossa. Tässä raportissa esitetään keskeiset tulokset laskeuma-alojen ja metsien intensiiviseurannan alojen (MRK- ja FIP-alat) seurannasta vuonna 2009. Laskeuman analyysitulokset olivat suunnilleen samalla tasolla kuin aikaisempina vuosina lukuun ottamatta avoimien alojen rikki- ja kalsiumlaskeumia, jotka olivat hieman nousseet. Maaveden ominaisuuksissakaan ei ollut pääsääntöisesti havaittavissa muutoksia aikaisempiin vuosiin verrattuna. NH_4-N ja NO_3-N pitoisuudet olivat poikkeuksellisen alhaiset kaikissa tutkituissa maakerroksissa. Muutaman vuoden seurannan aikana on todettu maaveden sulfaattipitoisuuksien vähittäinen lasku. Männikön (FIP4) kuukausihaihdunta oli samalla tasolla, mutta kuusikon puuston haihdunta oli selvästi pienempi kuin aikaisempina vuosina (2007-2008). Vuotuinen kariketuotanto oli vuonna 2008 pienempi kuin 2007. Merkittävimmät erot FIP-alojen välillä havaittiin karikefraktioiden Al- ja N-pitoisuuksissa: Al-pitoisuudet olivat selvästi korkeammat elävissä männyn kuin kuusen neulasissa. Muussa karikkeessa mitattiin korkeat Al- ja Fe-pitoisuudet, mikä selittynee maapölyllä. Männyissä ei havaittu harsuuntumista (harsuuntumisaste 4,6 %) ja kuusissakin vain vähän (24,1 %), joten molempien puulajien latvuskunto oli hyvä. Vuoden 2009 miniritsotronikuvat osoittivat, ettei hienojuurissa ollut kahden vuoden seurannan jälkeenkään havaittavissa merkittävää kuolemista. Näin ollen hienojuurten uusiutumisnopeuden selvittämiseksi juurikuvauksia jatketaan myös 2010.

Asiasanat: Harsuuntuminen, hienojuurten uusiutumisnopeus, karikesato, laskeuma, maavesi, metsikkösadanta, metsäekosysteemit, puuston haihdunta.

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1 INTRODUCTION

Forest investigations carried out on Olkiluoto aim to monitor the state of the forest ecosystems, quantify Olkiluoto-specific processes taking place in the forests producing input data for the safety assessment (Hjerpe et al. 2010, Posiva 2010) of spent nuclear fuel disposal, and follow possible changes in the forest condition resulting from the intensive construction activities currently being carried out in the area, as well as the future construction of the spent nuclear fuel repository. In addition, the forest investigations provide data for a range of modelling purposes either in terms of input data or validation data. The forest investigations form a part of the monitoring programme being carried out on Olkiluoto Island under the management of Posiva Oy (Posiva 2003). This report focuses on activities performed in 2009.

2 MONITORING SYSTEM

2.1 Description of the forest monitoring network

The monitoring system consists of several overlapping levels (Figure 1). The first level is used for following changes in land use by interpreting aerial images. The second level is vegetation-type mapping, the purpose of which was to classify the vegetation and its distribution for use as a basis for the monitoring of primary plant succession caused by the post-glacial land uplift (about 6 mm/year, e.g. Haapanen et al. 2009) at the plant community level and the possible anthropogenic environmental impact (Haapanen 2009). Forest resources have also been mapped from the same vegetation polygons. The third monitoring level (FET, Forest ExTensive monitoring plots, Figure 2) is a grid of systematically located plots which are used to describe biomass distribution of forests and to monitor growth and other changes in tree stands. A part of the FET plots has been selected for further studies (FET sub-set). In these plots the vegetation is inventoried and the soil, needles and vegetation are sampled at intervals of 5 to 10 years in order to identify soil properties, vegetation composition and nutrient concentrations of plants and trees (for more details, see Tamminen et al. 2007, Haapanen 2009). The last two levels (MRK and FIP, Figures 1 and 2) comprise plots where observations are made daily or even hourly (see Ch. 2.2). The intensity of the sampling efforts increases towards the sixth monitoring level (Figure 1).

Due to continues changes in land use on Olkiluoto Island, it is not always possible to record the up-to-date extent of each monitoring network.

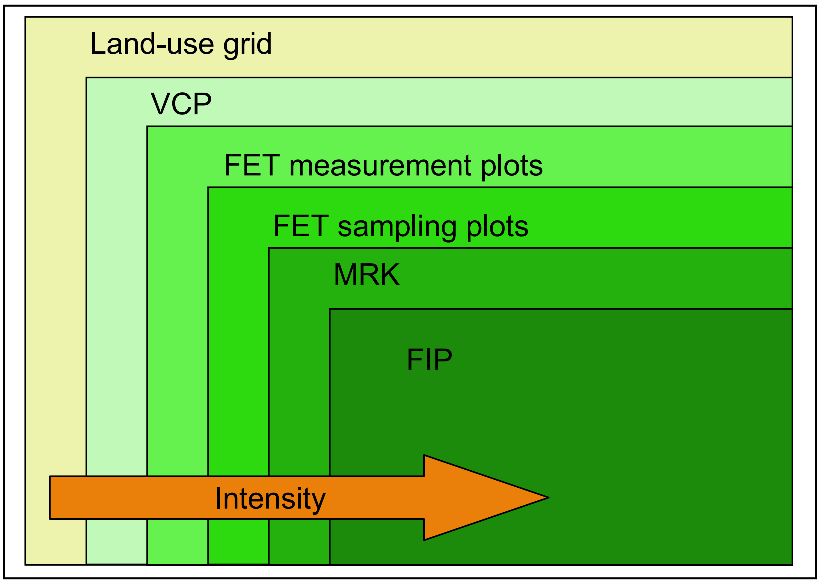


Figure 1. *Forest monitoring levels. The outermost land-use grid consists of plots at 50 m intervals. These have been visually interpreted for land-use. VCP contains the vegetation polygons, from which the forest resources have also been inventoried. The numbers of currently monitored plots are 485 (FET), 94 (FET sampling plots), 6 (MRK) of which 4 belong to the FIP grid as well. Grids have been modified (plots added/removed) according to increased knowledge of data needs and land-use changes on the island.*

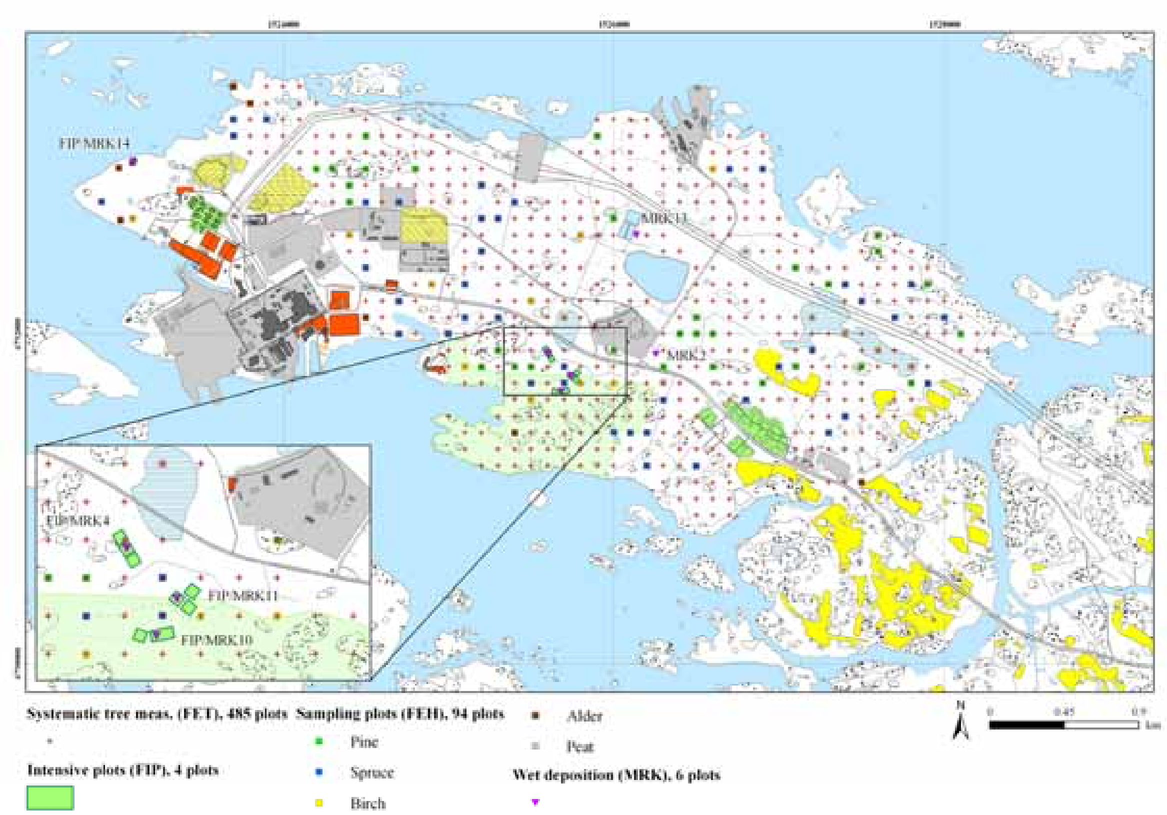


Figure 2. *Forest monitoring locations in 2009. Map layout by Jani Helin/Posiva Oy.*

2.2 Description of the MRK and FIP networks

2.2.1 Bulk deposition and stand throughfall plots (MRK)

The construction activities and rock crushing (i.e. new nuclear power plant OL3, and an underground rock characterisation facility and an access to the spent fuel repository) on the Olkiluoto Island are producing a potentially negative impact on forests, primarily in the form of stone dust. To monitor the effects on the forests, a bulk deposition and stand throughfall monitoring network with rainwater and snow collectors was established in 2003. The annual precipitation and interception of the tree canopies are also recorded on these plots. Currently four of the monitoring plots are within FIP plots and two in open areas (MRK13 was established in May 2009, see Figure 3). Rainwater is collected every two weeks and snow every four weeks, and from these samples the deposition is analysed for the mean pH and the amounts of a range of anions, cations and other elements.

Spruce and pine needles were also collected annually from all the seven forested sample plots of the bulk deposition and stand throughfall monitoring network between 2003 and 2007 to follow the foliar element concentrations (Rautio et al. 2009). Special attention was paid to the assessment of the effects of particulate matter originating from the construction activities on the foliar concentrations by means of different washing procedures. Since 2007 the sampling has been carried out biennially.

Figure 3. *A new monitoring plot in an open area (MRK13) with five rainwater and two snow collectors was established in the vicinity of the Korvensuo freshwater reservoir in May 2009 (Photo: A. Ryynänen/Metla, see also Figure 2).*

2.2.2 Forest intensive monitoring plots (FIP)

In order to gain a better understanding of the effects of different stress factors on the forests, as well as understanding and quantifying the different processes typical of forest ecosystems on Olkiluoto Island, an intensive monitoring system similar to the Level II ICP Forests programme in Finland (e.g. Raitio et al. 2001) was established on Olkiluoto Island. The aim of the intensive monitoring activities is to continuously follow changes taking place in the nutrient budgets and fluxes in the soil, tree stands and vegetation at both the stand and the catchment level to cover the seasonal, annual and long-term variation.

Each FIP plot (excluding FIP14) consists of three square sub-plots (30 m x 30 m, total area 900 m^2) coded as OA1, OA2 and OA3. The corners of the sub-plots, as well as their centre points, have been marked in the field using numbered poles. An approximately 5 to10 m wide strip has been left between and around the sub-plots for possible future use in special studies, and for additional sampling. This area constitutes the fourth sub-plot (OA4). OA1 is reserved for tree growth measurements, and OA3 for vegetation studies. Sampling methods that may have a detrimental long-term effect on the soil or stand, e.g. litter sampling, deposition and soil water collection, are concentrated on sub-plot OA2.

FIP14 consists only of one square sub-plot (OA2, total area 900 m^2) where litter sampling, deposition, soil water collection and micro-meteorological measurements are concentrated on. Plot FET930231 (total area 300 m^2) which is used for tree growth measurements and vegetation studies (see Figure 2) is located beside the OA2 sub-plot.

Table 1. *Performed monitoring activities and their frequency on the FIP plots.*

	Performed activities FIP4	FIP10	FIP11	FIP14	Normal Frequency
Establishment, start of equipment installations	2003	2003	2007	2009	
Location and measurement of trees	2004	2005	2008	2009	
Vegetation inventory (OA3)	2003, 2004, 2005, 2008	2003, 2004, 2005, 2008	2008		Every 3 yrs
Soil condition	2007	2007	2007	2008	Every 10 yrs
Stand throughfall and precipitation measurements (MRK, OA2)	2003	2005	2007	2009	Continuous
Sap flow measurements	2007	2007	no	no	Continuous
Soil water sampling (OA2)	2003	2005	2007		Continuous
Litterfall sampling (OA2)	2004	2005	2007	2009	Continuous
Foliage sampling (OA2)	2003, 2004, 2005, 2006, 2007, 2009	2004, 2005, 2006, 2007, 2009	no	2009	Every 2 yrs
Micrometeorology (OA2)	2004	2005	2007	2009	Continuous
Stem diameter growth (OA2)	2004	2005	no	no	Continuous
Tree growth (OA1)	2009	2009			Every 5 yrs
Crown condition survey	2006	2006	no	no	Annual

The first intensive monitoring plots were established in the small Liiklansuo catchment area, which represents the most important types of forest vegetation found on Olkiluoto Island. FIP4 was marked out in a 37-year-old Scots pine (*Pinus sylvestris*) stand (compartment no. 401.1, Rautio et al. 2004) and FIP10 in a 91-year-old Norway spruce (*Picea abies*) stand (compartment 366.1, Rautio et al. 2004) in August, 2003. The soil type on both plots was fine-textured till according to the compartment-wise inventory (Rautio et al. 2004). Both the Scots pine plot and the Norway spruce plot represent herb-rich heath forests (i.e. *Oxalis-Myrtillus* forest type, Salemaa & Korpela 2008). The third intensive monitoring plot (FIP11) was established in a young birch dominated stand in the Liiklansuo catchment area during 2006–2007. This birch dominated plot (FIP11) is located on a rocky site and the vegetation represented partly mesic heath forests vegetation (i.e. *Myrtillus* type) and partly herb-rich heath vegetation (i.e. *Oxalis-Myrtillus* type, Salemaa & Korpela 2008). The fourth FIP plot (FIP14, Figure 4) was established in an alder stand in 2009. The instrumentation of the plot is presented in Table 2 and in Appendix 1.

Figure 4. *Black alder dominated plot FIP14 in April-May and in February (Photos: L. Aro and J. Ilomäki/ Metla).*

Table 2. *The instrumentation of the plot FIP14 with main installation information (i.e. the installation site in relation to ground level and the date of installation).*

Description	Instrument	Quantity	Installation site	Date
Soil temperature	Vishay-10k	13	-10 … -90 cm	3.11.2009
Air temperature	Vishay-10k	1	2 m	3.11.2009
Soil moisture	Theta Probe	2	-20 cm	3.11.2009
Relative humidity	HMP45D	1	2 m	3.11.2009
Power source	Solar panel	1		3.11.2009
Data logger	GWMS	3		3.11.2009
Soil solution	Plate lysimeter	4	-5 cm	29.10.2009
Litterfall	Litterfall sampler	12	150 cm	15.5.2009
Stand throughfall	Snow sampler	5	180 cm	17.9.2009
Stand throughfall	Rainwater collector	20	40–60 cm	15.5.2009

Soil profile descriptions and soil sampling were carried out on the FIP plots 4, 10 and 11 in 2007, and in the vicinity of FIP14 (i.e. FET930231) in October 2008. The soil on the plot FIP4 was podzolized to some extent, and all three soil profiles were classified as Haplic Arenosols, resembling Haplic Podzols. Two profiles on plot FIP10 were also classified as Haplic Arenosols and one profile as Haplic Gleysols. On the plot FIP11 two profiles were classified as Haplic Gleysols and one as Histic Gleysols (Tamminen & Aro 2008). The soil profile on FET930231 was classified as Haplic Arenosol.

The trees growing on the Scots pine plot (FIP4) were measured in 2004. According to the results, the mean age of the stand was 38 years, mean height 17 m, basal area 32 m^2 and mean volume 268 m^3/ha (Aro 2006). Four years later (i.e. in Spring 2009) the corresponding figures for Scots pine on sub-plot OA2 were 42 years, 18 m, 34 m^2 and 303 m^3/ha, respectively.

The trees growing on the Norway spruce plot (FIP10) were measured in 2005. The spruce stand was silviculturally relatively over-aged (on average 93 years), and there was a lot of dead wood lying on the forest floor. Deciduous trees were also growing among the spruces. According to the results of the stand measurement, the mean height of the spruces was 19 m, basal area 34 m^2 and mean volume 386 m^3/ha (for the birches, 23 m, 7 m^2 and 74 m^3/ha, respectively) (Aro 2006). Three years later the corresponding figures for the trees (Norway spruce and birch) on sub-plot OA2 were 20 m, 42 m^2 and 473 m^3/ha, respectively.

The trees growing on the plot with the young mixed stand (FIP11) were measured in June 2008. 42 743 young trees were growing on sub-plot OA-2. Downy birch (*Betula pubescens*), with a stem number of 34 779/ha, was the dominant tree species. The mean height of the trees was 2.3 m, basal area 5 m^2/ha, and mean volume 16.8 m^3/ha (Aro 2009). The trees growing on the black alder dominated plot (FIP14) were measured in November 2009 and the stand characteristics are presented in Table 3.

Table 3. *The basic stand characteristics of the alder dominated plot (FIP14) in November 2009.*

Plot no.	Sub-plot no.	Tree species	Stem number	Basal area with bark, m^2/ha	Mean diameter weighted with basal area, cm	Mean height (arithmetical), m	Dominant height (100/ha), m	Lower limit of crown, m	Stem volume with bark, m^3/ha
14	OA2	Black alder	1200	23.51	19.64	10.31	17.08	5.21	142.76
14	OA2	Norway spruce	11	0.33	19.55	12.00	12.00	1.30	1.88
14	OA2	Other deciduous	44	0.59	14.31	8.00	8.00	2.08	2.50
14	OA2	Total	1256	24.43	19.51	10.24	17.08	5.06	147.14

The results on tree stand characteristics for five growing seasons after previous measurements on sub-plot OA1 of FIP4 and FIP10 were reported by Ryynänen (2009). The Scots pine dominated sub-plot was measured on 26.3.2009 and the Norway spruce dominated sub-plot on 29.9.2009. Tree species, canopy layer, diameter at a height of 1.3 m in two directions, tree height and the height of the lower living crown limit, as well as the state of health (damage symptoms, cause and degree) were recorded or measured for each of the trees. Tree stand characteristics were calculated with the KPL computer program package developed for computing stand and single-tree characteristics on the basis of sample plot measurements (Heinonen 1994).

An increase in the crown limit from 8.95 m to 10.86 m during 2004-2009 and the high basal area (32.82 m^2) in the pine dominated FIP4 showed clearly that thinning will be necessary in the near future (Table 4). There were signs of infection by *Peridermium* stem rust in several pine trees and therefore thinning should be targeted at infected trees. The birches have reached their mature age on the plot FIP10. Plant competition-caused self-thinning is a normal age-related phenomenon in natural stands and will probably continue during the following monitoring period.

Table 4. *The basic stand characteristics of Scots pine (FIP4) and Norway spruce (FIP10) dominated plots during 2004-2009.*

Year	Plot no.	Sub-plot no.	Tree species	Stem number	Basal area with bark m^2/ha	Mean diameter weighted with basal area, cm	Mean height, (arithmetical), m	Lower limit of crown, m	Dominant height (100/ha), m	Stem volume with bark, m^3/ha
2004	04	1	Scots pine	878	28.65	21.09	16.85	8.95	17.86	237.50
2009	04	1	Scots pine	867	32.82	22.69	18.18	10.86	19.13	290.36
2005	10	1	Norway spruce	722	30.03	29.82	18.34	8.25	27.58	341.47
2009	10	1	Norway spruce	667	30.59	31.44	18.50	8.17	27.31	340.50
2005	10	1	Birch	189	7.42	25.22	23.68	15.44	25.02	83.19
2009	10	1	Birch	133	5.63	25.76	23.77	13.97	24.29	63.80

3 MATERIAL AND METHODS

3.1 Bulk deposition and stand throughfall on MRK plots

Deposition loads on the forest and forest floor were monitored using a deposition monitoring network (MRK plots). The monitoring was performed during the first five months of the year 2009 on 4 plots, of which one was located in open area (MRK2), one in the Scots pine stand (MRK4), one in the Norway spruce stand (MRK10), and one plot (MRK11) in a young mixed stand. Bulk deposition was monitored in a new open area (MRK13) from June 2009 onwards and stand throughfall was also monitored in the alder dominated stand (FIP14) from July 2009 onwards.

The results for bulk deposition and stand throughfall during the period 7.1.2009 - 11.1.2010 are presented in this report (Ch. 4.1), and the deposition for this period is denoted in the following as the deposition for the year 2009. The results for 2009 are compared to the deposition load during the period 2004-2008 on Olkiluoto, as well as to the deposition load on two intensively monitored plots (one pine and one spruce) in Juupajoki and two plots (one pine and one spruce) in Tammela, southern Finland (EU Forest Focus, UN/ECE ICP Forests monitoring plots).

The samples were collected at predetermined intervals (at 2-week intervals during the snow free period, and at 4-week intervals during the winter) on Olkiluoto and mailed to Rovaniemi by the staff of Posiva Oy. This procedure was used in order to minimise contamination of the samples (while still in the collectors) through microbial growth during the warmer parts of the year. All the samples were stored in a cold room prior to making bulked samples in the laboratory. The chemical analyses (Table 5) were carried out by the laboratory staff of the Rovaniemi Research Unit and the Central Laboratory, Metla.

The major problem in collecting deposition is the avoidance of contamination caused by bird droppings in the rainfall collection equipment. Bird droppings contain appreciable amounts of P which result in elevated phosphate concentrations in samples. The field workers had strict instructions to exclude samples from individual collectors where there is evidence of bird droppings.

There were no problems, in general, in the field work, transport of the samples to the laboratory or during the chemical analyses that can be considered to have had a significant effect on the results for 2009.

Table 5. *Performed analyses and their limits of quantification (LOQ) for water samples of bulk deposition and stand throughfall.*

Variable	Unit	LOQ
pH		
Alkalinity	mmol/l	
H+	mg/l	
Conductivity	µS/cm/25 °C	8
DOC	mg/l	0.6
Tot-N	mg/l	0.05
NH_4-N	mg/l	0.03
NO_3-N	mg/l	0.04
Ca	mg/l	0.0004
Mg	mg/l	0.001
K	mg/l	0.06
Na	mg/l	0.01
PO_4-P	mg/l	0.13
SO_4-S	mg/l	0.05
Cl	mg/l	0.1
Al	mg/l	0.03
Fe	mg/l	0.002
Mn	mg/l	0.001
Cu	mg/l	0.004
Zn	mg/l	0.002
Si	mg/l	0.006

3.2 Soil solution on FIP plots

3.2.1 Method of sampling soil solution

The chemical composition of soil solution is being monitored continuously during the snow-free period on FIP plots at Olkiluoto as a part of a comprehensive study on the functioning of forest ecosystems on the island. Changes in the chemical composition of rainfall (bulk precipitation) are being followed as the water first passes down through the tree canopy (stand throughfall), and then down the soil profile in the form of soil solution (Figure 5). Soil solution is sampled at different depths down the soil profile, thus providing information about soil formation processes. In addition to determining the concentrations of individual ions, the amount of water passing down through the soil is also being measured and modelled in order to be able to determine ion fluxes between the individual soil horizons in tree stands.

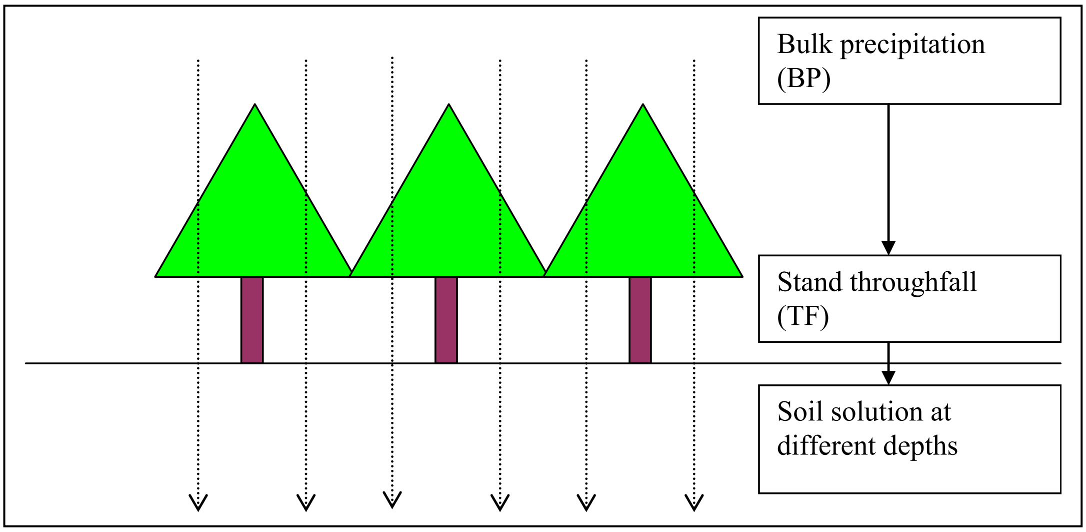


Figure 5. *A schematic presentation showing the path of water down through forest ecosystems, and the different components taken for chemical analysis (Derome 2007).*

Two sampling techniques are being used for sampling soil solution in the stands:

- Tension lysimetry (suction-cup lysimeters) installed at different depths, primarily in the mineral soil
- Zero-tension lysimetry (plate lysimeters) installed immediately below the organic layer

The two procedures differ considerably with respect to the soil solution fraction sampled, the effects of sampling on the site, as well as the extent to which they provide information about temporal and spatial variation in the properties of soil solution. Of the two methods, zero-tension lysimetry is the only one which samples a clearly definable fraction of the soil water, i.e. free-flowing water that percolates down through the soil when the field capacity is exceeded. Even so, there are drawbacks to this method because zero-tension lysimeters, for technical reasons, do not necessarily collect all of the free-flowing water at the sampling point, and the volume of water collected/surface area of the collector is therefore not always equal to the water flux at the sampling point. Tension lysimetry samples a relatively broad fraction of the soil water. However, soil water samples are obtained by this technique only when the magnitude of the negative pressure (vacuum) applied exceeds that of the hydraulic forces holding the water in the soil. Tension lysimetry obviously also samples free-flowing water when it is present.

The sampling of soil solution started on FIP4 (Scots pine stand) on 18.5.2004, on FIP10 (Norway spruce stand) on 19.7.2005, and on FIP11 (young mixed stand) on 1.6.2007.

The layout (location, depths and replications) of the lysimeters on the three plots is comparable to that used in establishing the intensive monitoring plots of the ICP Forests (UN/ECE)/Forest Focus (EU) programmes. Furthermore, the sampling procedure and the pre-treatment and analysis of the soil solution samples are carried out in accordance with the ICP Forests Sub-manual on Soil Solution Collection and Analysis.

The soil solution samples were collected at predetermined intervals on Olkiluoto and sent to Rovaniemi by the staff of Posiva Oy. The chemical analyses were carried out by the laboratory staff of the Rovaniemi Research Unit and the Central Laboratory, Metla.

3.2.2 Amounts of percolation water

Percolation water was collected during the snow-free periods in 2004-2009 on plot FIP4, in 2005-2009 on plot FIP10, and in 2007-2009 on plot FIP11, using plate lysimeters with a surface area of 0.1 m^2 (40 cm x 25 cm), located at a depth of 5 cm, i.e. immediately below the organic layer. On plot FIP4 there was a total of 8 plate lysimeters at 4 sampling points (2 replications/point). On plot FIP10 there was a total of 12 plate lysimeters, and on plot FIP11 a total of 8 plate lysimeters, located systematically over the plot. The collection period of the percolation water starts in the spring after snowmelt when the ground is no longer frozen.

The amount of water percolating down to different depths in the soil is determined by a number of factors:

1) The amount of water falling on the forest floor as rain or snow. In a tree stand, this is the amount of stand throughfall (Figure 5).
2) Some of the water in stand throughfall is lost from the snow cover during the winter through evaporation directly from the snow surface. This can be especially high during spring when, even though the air temperature is below freezing point, solar radiation causes the sublimation of ice directly into water vapour that is released into the atmosphere.
3) Some of the water (as snow) falling on the forest floor is lost during snowmelt in the form of horizontal runoff out of the stand. This can be considerable if the ground immediately below the melting snow cover is still frozen, thus preventing the water from passing down into the soil
4) During the period extending from spring to autumn, a variable proportion of the water falling onto the forest floor is recycled back into the atmosphere though the uptake of water by the tree stand and ground vegetation (as evapo-transpiration). The plate lysimeters are located below the organic layer, which is the layer in the soil that contains the highest proportion of plant roots.
5) Some of the water (as rain) that collects on the surface of the ground vegetation during the snowfree period may evaporate directly into the atmosphere, especially during warm periods.
6) During the summer especially, the intensity (amount) of stand throughfall strongly affects the amount of percolation water: high precipitation events result in more percolation water owing to the proportionally smaller amount of water lost through evapo-transpiration.

In addition to the above natural factors, there are also technical problems during the snowmelt period: the capacity (volume) of the bottles used to collect the water samples may not always be sufficient to hold all the water running out of the plate lysimeters. Under such conditions, the amount of percolation water will be underestimated. On Plot

FIP10 there are also problems in the spring with an excessively high water table and inundation by high sea water; the plot is located only a few meters above sea level and water may pass into the collection bottles that is not derived from precipitation.

3.2.3 Chemical composition of the soil solution on FIP plots

Soil solution was collected in the Scots pine stand using 8 plate lysimeters at a depth of 5 cm, and suction cup lysimeters at depths of 10, 20 and 30 cm, in four observation clusters on the plot during the snow-free period. Soil solution was collected in the Norway spruce stand using 12 plate lysimeters systematically located at a depth of 5 cm on the plot during the snow-free period. The 24 suction cup lysimeters were located at depths of 20 and 30 cm (12 for each depth). Soil solution was collected in the young mixed stand using 8 plate lysimeters located at a depth of 5 cm, and 12 suction cup lysimeters at depths of 10, 20 and 30 cm (4 each for depth), systematically located on the plot during the snow-free period. The samples from each plate lysimeter were analysed separately, and the samples obtained with the suction cup lysimeters were bulked to give one sample per depth per monitoring plot.

Table 6. *Performed analyses and their limits of quantification (LOQ) for soil solution.*

Variable	Unit	LOQ
pH		
Alkalinity	mmol/l	
Conductivity	µS/cm/25 °C	8
DOC	mg/l	0.6
Tot-N	mg/l	0.05
NH_4-N	mg/l	0.03
NO_3-N	mg/l	0.04
Na	mg/l	0.01
PO_4-P	mg/l	0.13
SO_4-S	mg/l	0.05
Cl	mg/l	0.1
Al	mg/l	0.03
B	mg/l	0.004
Ca	mg/l	0.0004
Cd	mg/l	0.001
Cr	mg/l	0.001
Cu	mg/l	0.004
Fe	mg/l	0.002
K	mg/l	0.06
Mg	mg/l	0.001
Mn	mg/l	0.001
Na	mg/l	> 1
Ni	mg/l	0.01
P	mg/l	0.06
Pb	mg/l	0.015
S	mg/l	0.07
Si	mg/l	0.006
Zn	mg/l	0.002

3.3 Tree stand transpiration on the plots FIP4 and FIP10

The tree stand transpiration measurements on Olkiluoto Island were initiated on FIP4 and FIP10 in early May and early June 2007, respectively. The aim was to measure tree-level transpiration as a basis for calculating stand transpiration rate and variability in the FIP areas. A measurement system by UP GmbH, based on the constant heat method, was installed. Water movement is measured with a pair of needle sensors (30-40 mm long, 2 mm in diameter), which are radially inserted into the sapwood of a tree at a ca. 1.5 m height with a vertical spacing of 10 to 15 cm (Granier 1985;, Köstner et al. 1996). Both sensors have a thermocouple for recording temperature. The upper sensor is heated constantly with 0.2W direct power and the temperature difference between the needles is monitored. Temperature differences between the sensors have been related to the mass flow of water based on empirical calibration (Granier 1985) with several tree species. The maximum temperature difference is during the night, when sap flow is assumed to be 0. In the daytime high flow lowers the difference because water flux transports the heat away from the upper needle. The measured flow density is extrapolated for the whole tree by multiplying by the tree sapwood area (Granier 1985). Since weather conditions (humidity, wind, radiation) determine the rate of transpiration, the meteorological data collected in the FIP4 weather station can be used in studying the variability of transpiration in relation to variations in local weather. The establishment of the system, calculation of sapwood area and results for 2007 and 2008 were presented earlier in memos by Hökkä (2008a, b).

Some problems occurred in sap flow measurements especially during the winter season in 2009. The quality of data was worse on the plot FIP4 in 2009 than in previous years. Some measuring observations were missing which resulted in unreal peaks in calculated transpiration. Data gaps were observed on the following days: 3.-5.1., 14.1., 16-17.1., 31.1.-1.2., 16.-19.2., 26.3.-27.3., 14.-18.12., 21.-22.12. and 31.12. Therefore calculated values for tree transpiration can be considered reliable only for the period from the end of March to the beginning of December. In addition, an interesting phenomenon where daily transpiration increased towards midnight during some days was observed. The reason for this is unknown but one explanation could be a measuring error in the system.

The quality of transpiration data from the plot FIP10 was better than that from the plot FIP4. However, several errors were detected in sap flow signals during the winter season. This resulted in six extremely high transpiration peaks during late winter and one in December. Tree transpiration values can be considered reliable for the period from April to November.

Table 7. *Maximum acceptable values of transpiration at single tree and tree stand levels.*

Level	Time unit	Max value	Unit
Tree stand	per hour	0.25 (min=0)	mm
	per day	2.5 (min=0)	mm
	per mounth	50 (min=0)	mm
Single tree	per hour	5	dm^3
	per day	45	dm^3

3.4 Litterfall production and element return to the forest floor on FIP plots

Litterfall was collected using 12 traps (UN/ECE 2004a) located systematically on FIP4 (pine), FIP10 (spruce) and FIP11 (in deciduous forest) plots in 2008. The litterfall collectors were funnel-shaped traps with a collection area of 0.5 m^2 placed about 1.5 m above ground level. Litterfall collection was started on the plots (FIP4, FIP10, FIP11) on 1st April 2008. Since the last collection date in 2007 was in mid November, the mass of first collection in 2008 represents the litterfall of the whole previous winter.

In 2008 the collected litter was divided into eight different fractions:

1= dead pine needles (brown needles)
2= living pine needles (green needles)
3= spruce needles
4= leaves
5= remaining litter
6= small branches
7= branches
12= remaining litter in branch traps

Fractions 1-6 were collected using the funnel type litterfall traps used in the ICP Forests programme (UN/ECE 2004a). Branches (fraction 6) collected by this trap (Figure 34a) are rather small. To collect the whole spectrum of branch litter we used a new type of traps that are positioned on the ground (Figure 6). These new "branch traps", which consist of a nylon fabric stretched on a frame of approximately two centimeters height, were developed in the Finnish Forest Research Institute specifically to collect branch litter that is missed by the funnel type litterfall traps used in the ICP Forests programme (UN/ECE 2004a) mainly to collect foliage litter (Figure 6). These branch traps are similar to the funnel traps in size (0.5 m^2). 12 branch traps were positioned close to each funnel trap. Branch traps were used in plots FIP4 and FIP10, and litter collection started in autumn 2008 (sampling dates 23.7., 20.8., 18.9. and 15.10.).

Litterfall production (dry mass in grams/m^2; 105°C) is reported for each of these fractions separately for each collection. Element concentrations (aluminium, boron, calcium, chromium, copper, iron, potassium, magnesium, manganese, nickel, phosphorus, sulphur, zinc, carbon and nitrogen) were determined if there was enough material in a given litter fraction to allow homogenization (grinding) and microwave digestion in acid (HNO_3/H_2O_2) preceding chemical analysis. Concentrations of cadmium, molybdenum and lead were in most cases below the limit of quantification, and hence are not reported here.

Figure 6. *Litterfall traps on an FIP plot. Green funnel type litterfall trap used in ICP Forests programme (UN/ECE 2004a) and new "branch trap" (circle on the ground on the right side) developed to collect branch litter. (Photo: L.Aro/ Metla).*

3.5 Defoliation of trees on the plots FIP4 and FIP10

Visual assessment of the crown condition on intensive monitoring plots at Olkiluoto was carried out according to the guidelines of the UN/ECE crown condition sub-manual (UN/ECE 2004b).

3.6 Fine root elongation and longevity on FIP plots

The study was carried out on the intensive monitoring plots FIP4, FIP10 and FIP11. Fine root elongation and longevity were monitored using the minirhizotrone (MR) method (Majdi et al. 2005). In June 2007 three clear plexiglass MR tubes were installed vertically in the soil, and three tubes horizontally within the organic layer of each stand (Helmisaari et al. 2009). There was a one-year conditioning period without taking any images, and filming was started in June 2008. Images were taken four times during the 2008 growing season (26.6., 15.8, 11.9 and 15.10) and five times during the 2009 growing season (26.5., 1.7., 4.8., 3.9. and 6.10.).

Images were taken continuously on two sides (A and B) of each tube, the two holes in each tube allowing positioning of the MR camera (Bartz Technology Inc., CA). Images were taken in the vertical tubes as a continuous image column from the soil surface down to depths in the mineral soil without any fine roots. The total number of images in the column in a vertical tube was 19 on FIP4, 15-16 on FIP10 and 12-16 on FIP11. As the size of each image was 1.4 x 1.8 cm, the total length of the image column was therefore 17-27 cm. In the horizontal tubes, images were taken throughout the whole length of the tube, resulting in 31-34 images on FIP4 and 50-53 on FIP10 and FIP11. Thus, in 2008 altogether a total of 3392 images were taken during the whole growing season, and 848 images at each filming session: 212, 376 and 260 images in FIP4, FIP10 and FIP11, respectively. As there was one more filming session in 2009, altogether a total of 4206 images were taken during the whole growing season, 836-844 images at each filming session: 206-208, 372-376 and 258-260 images on FIP4, FIP10 and FIP11, respectively.

The length and mean diameter of the fine roots were analyzed by manual tracing on the digital images with a computer mouse using the image analysis WinRHIZO Tron MF (Regent, Quebec, Canada) software. Captured images in the windows of the tubes were viewed as a time sequence. The date for when a root was first observed and the date of its death or disappearance were recorded. The data files produced by WinRhizo Tron were in ASCII text format, which is well-suited for manipulation into spreadsheet-style programs such as Excel. All the data files (ASCII text format) were converted into Excel format, each column having a defined format.

All new roots were followed when they were not yet suberized, i.e. white, turgid, and growing. The same roots were monitored and classified at each filming session as living, dead or disappeared. Roots were recorded as dead when they were black, no longer turgid, and were losing their outer suberized layer. The diameter, length and surface area of each root and EcM tip were recorded, and each root was classified as a tree, dwarf shrub or grass/herb root. Data and all figures have been stored in POTTI (Posiva's research result database).

Elongation and longevity are not reported here because none of the roots died in 2008 and most of them were still alive in 2009. A minor part of the roots died during the growing season in 2009, and we expect substantially more roots to die during 2010. This means that the imaging and analysis will have to continue for one more growing season before elongation and longevity can finally be reported.

The SRL (specific root length, length/weight) and SRA (specific root area, surface area/weight) of the finest roots (diameter <1 mm) were determined with WinRHIZO^{TM} Pro (Regent Instruments Inc.) from biomass samples taken in 2008. The main results are reported in this report.

We did an additional root sampling in August 2009 in the FIP11 stand for analyses on fine root ectomycorrhizal (EcM), root tip morphology and dominating EcM colonising fungi by morphotyping and DNA sequencing. From the same samples a DGGE-analysis was also performed for determining the diversity of the microbial communities in the rhizosphere. This study strengthens the fine root biomass study (Helmisaari et al. 2009) as we applied and linked various root traits to characterise the fine root adaptation mechanisms of the entire fine root system.

The root morphological study is cooperation with Dr. Ivika Ostonen and prof. Krista Lõhmus at the University of Tartu, Estonia within the project *Fine root adaptation strategies in European coniferous and deciduous forests along a latitudinal gradient*, 2008-2011, funded by the Estonian Science Foundation. From Finland, the birch stands FIP11 and ICP Level II stands at Punkaharju and Kivalo were chosen to represent birch stands as they all have excellent background information. The results are ready in summer 2010, and will be included in the final report of the root studies.

3.7 Temperature sum and precipitation in the area

The length of the growing season and corresponding effective temperature sum (threshold +5^{o}C, measuring height 2 m) on FIP plots (code for Olkiluoto weather stations, WOM) for 2009 were as follows:

FIP4 (WOM2)	24.4. – 10.10.2009	1398 d.d.
FIP10 (WOM3)	24.4. – 8.10.2009	1297 d.d.
FIP11 (WOM4)	24.4. – 8.10.2009	1246 d.d.

The annual precipitation based on the data of station WOM1 (exposed to marine influence) was 309 mm (Haapanen 2010).

The effective temperature sum (threshold +5^{o}C) and annual precipitation as recorded at the Pori Airport weather station (Source: Finnish meteorological institute):

Year	Temperature sum, d.d.	Precipitation, mm
2003	1396	523
2004	1338	564
2005	1419	679
2006	1659	653
2007	1420	720
2008	1292	693
2009	1420	505

3.8 Data in POTTI

Data from measurements and analyses have been stored in POTTI (Posiva's research result database). Definitions for data in POTTI are presented in Appendix 2.

4 RESULTS AND DISCUSSION

4.1 Bulk deposition and stand throughfall

The amount of precipitation in 2009 in open areas (bulk deposition, BD) and stand throughfall (TF) was lower than in earlier years (2004-2008). There were no clear increasing or decreasing trends in pH of BD and TF during the period 2004-2009, although the mean pH was rather high (>pH 5.5) in BD during 2009. The pH values were at a level slightly above the values measured at the ICP-Forests monitoring plots (reference plots) located at Juupajoki and Tammela in central and southern Finland.

There was variation in the deposition of total nitrogen in BD and TF during 2004-2009, but the values were comparable with those on the reference plots at Juupajoki and Tammela. There was also a variation in NH_4-N (Figure 7) and NO_3-N (Figure 8) deposition in BD and TF between the years, but the values were comparable to those measured at Juupajoki and Tammela. The NO_3-N deposition was lower in 2009 than in earlier years. The deposition of nitrogen compounds in TF was generally lower than that in BD due to nitrogen uptake by the tree canopies (absorption into the needles, utilization by the mosses, lichens and microflora on the needle surfaces). This is a well-documented phenomenon in coniferous stands in Finland, indicating that the deposition of nitrogen compounds is relatively low.

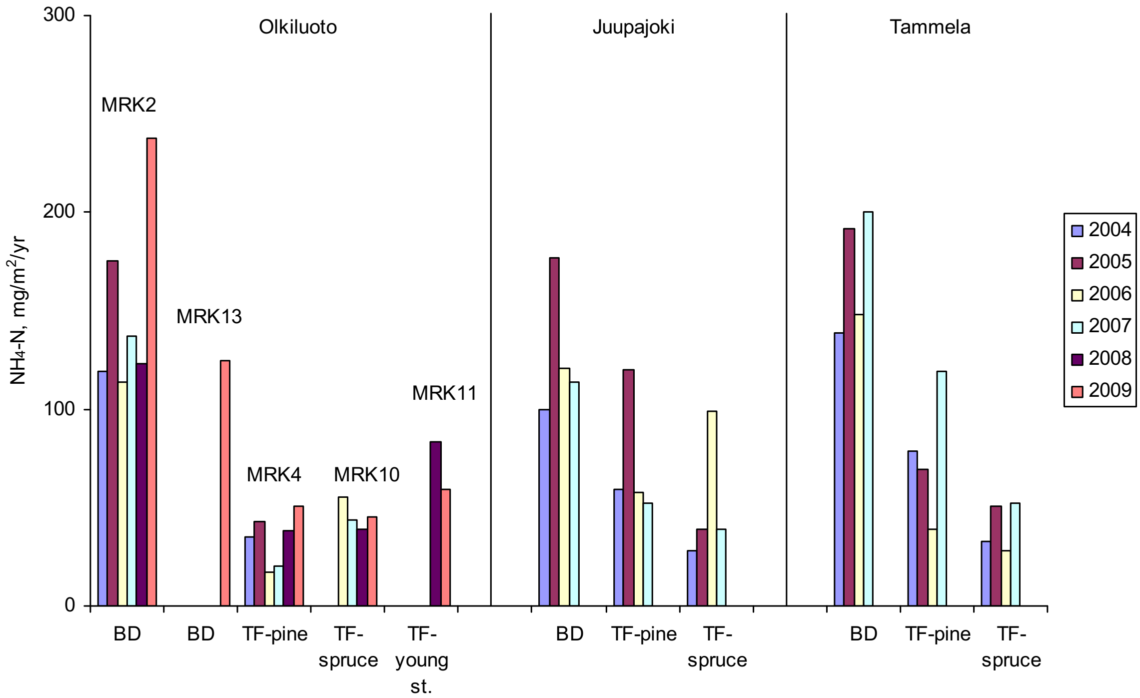


Figure 7. *The NH_4-N deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2009. The sample plots and tree species are indicated in the Figure (young st. = young mixed stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison. (The deposition for plot MRK13: values from MRK2 during 7.1.09-11.5.09 and from MRK 13 during 8.6.09-11.1.10.).*

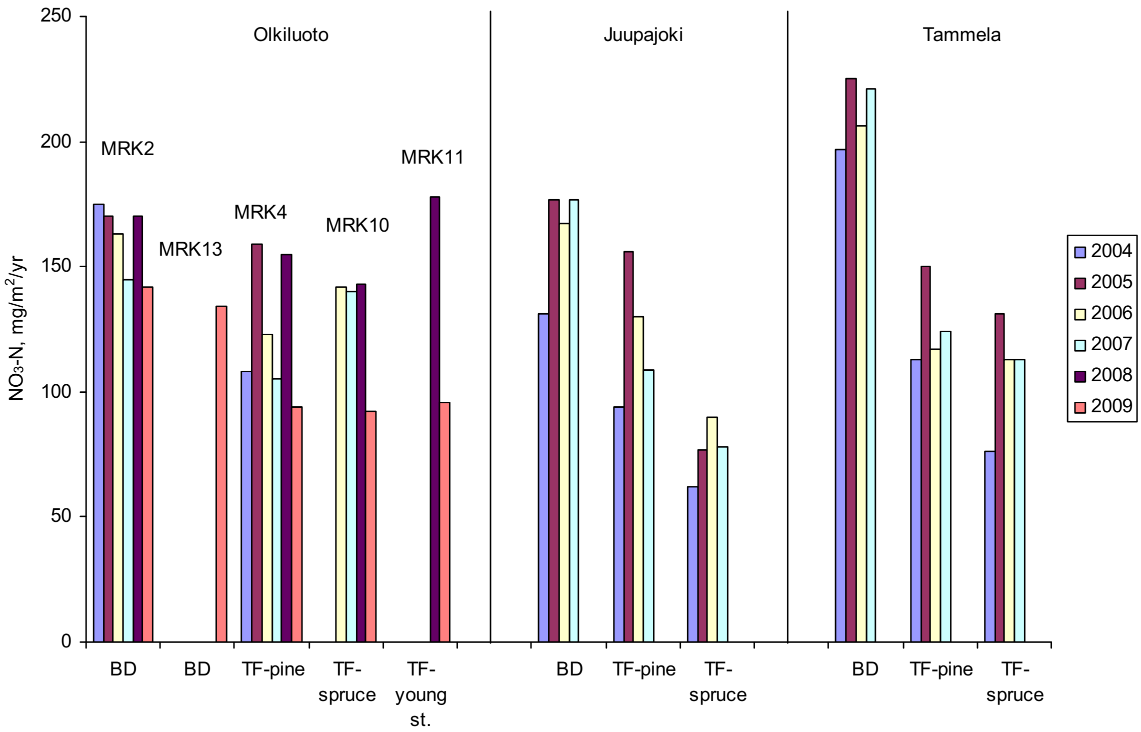


Figure 8. *The NO_3-N deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2009. The sample plots and tree species are indicated in the Figure (young st. = young mixed stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison.*

In 2009 the sulphur (SO_4-S) deposition in BD on plot MRK2 was the highest for the whole monitoring period (2004-2009). However, on plot MRK13 (BD, open area) the sulphur deposition was somewhat lower and comparable to the reference plot at Tammela (Figure 9). The situation with TF during 2009 was the opposite, since the lowest sulphur deposition values for the whole monitoring period (2004-2009) were determined in 2009. The TF deposition at the Tammela spruce plot was clearly higher than in Olkiluoto or Juupajoki.

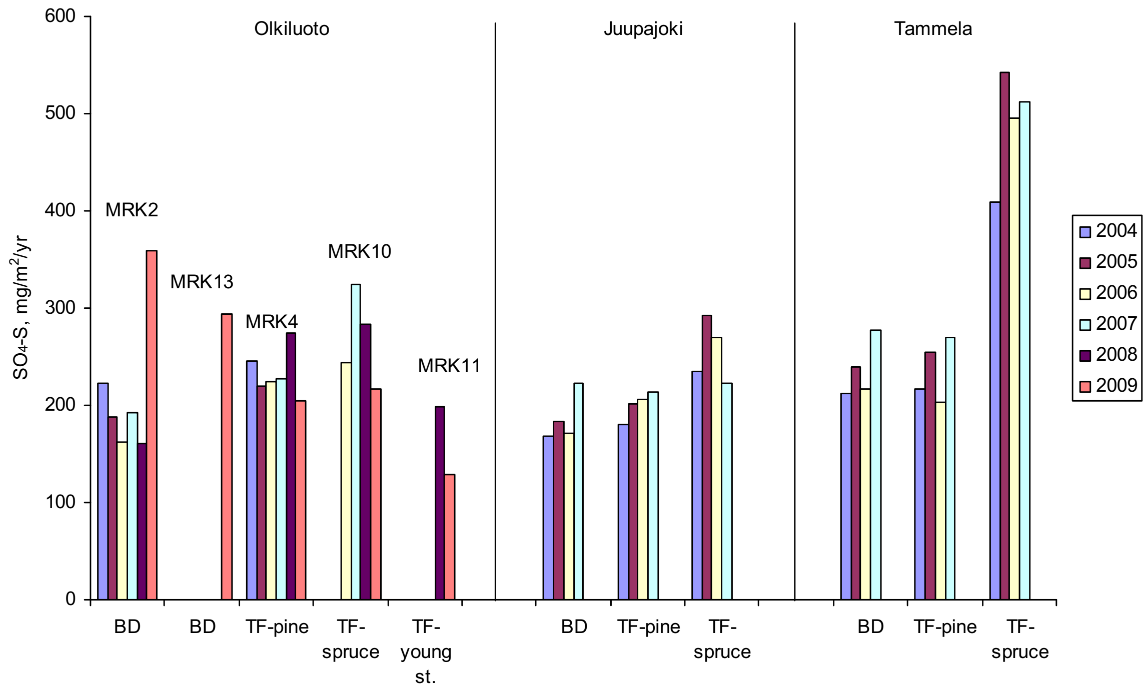


Figure 9. *The SO_4-S deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2009. The sample plots and tree species are indicated in the Figure (young st. = young mixed stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison.*

The deposition of base cations (Ca, Mg, K) in BD on plot MRK2 was somewhat higher or at a similar level compared to the situation on the reference plots at Tammela and Juupajoki. The Ca deposition was the highest on plot MRK2 in 2009 compared to the earlier years. The relatively high deposition of Cl (with associated Na) at Olkiluoto is due to the proximity of the sea. The dissolved organic carbon (DOC) amounts in BD and TF were comparable to the values on the reference plots, indicating leaching of DOC from the tree canopies. The deposition of Al, Fe, Mn, Si, Cu, Zn and PO_4-P in BD and TF were relatively similar in 2009 compared to the values in earlier years.

In general, the deposition levels in 2009 in the open area and in stand throughfall were quite comparable to those in the earlier years, although sulphur and calcium depositions were somewhat higher in the open area than in earlier years.

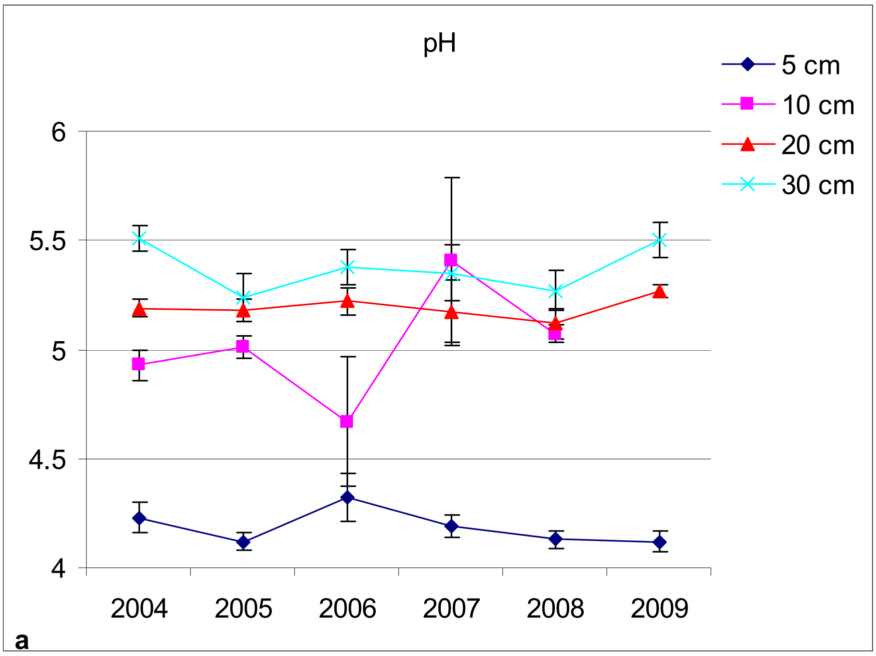
4.2 Soil solution

The proportion of percolation water passing down to a depth of 5 cm on plot FIP4 varied between 16 to 23 % of the input to the forest floor (stand throughfall) during the period 2004-2009. Corresponding values on the plots FIP10 (during 2005-2009) and FIP11 (during 2007-2009) were 1-28 % and 1-17 %, respectively. The lowest values for the proportion of percolation water on FIP10 during 2005-2006 were explained by problems with the lysimeters which, however, are now functioning correctly. The amount of water passing down through the organic layer on plot FIP11 in 2009 was lower than that on the other two plots, presumably due to the highly effective interception of rainwater and strong rate of evapo-transpiration by the abundant ground vegetation and dense sapling stand on this plot.

Overall, the pH of the soil solution clearly increased with increasing depth on FIP4 (Figure 10). The pH of the soil solution at depths of 5, 20 and 30 cm remained relatively constant throughout the 6-year monitoring period, without any increasing or decreasing trends. In contrast, there was large variation at a 10 cm depth in 2006 and 2007. Otherwise the pH values at all depths were fully comparable to a site of similar fertility at Tammela. Overall, the DOC concentration of the soil solution clearly decreased with increasing depth (Figure 10). The DOC concentrations in all six years were considerably higher at a 5 cm depth than at the reference site, but not excessively high for forest soils rich in organic matter under a coniferous tree stand. At depths of 10, 20 and 30 cm the DOC concentrations decreased relatively strongly in 2005, and this trend appears to have continued up until 2009. The installation of the suction cup lysimeters in 2003 undoubtedly caused a short-term flush of DOC.

There were some changes in the pH of the soil solution on FIP10 during 2008-2009: the pH at 5 cm increased from 4.18 to 4.34, and at 20 and 30 cm it decreased from 5.59 and 6.30 to 5.04 and 5.40, respectively. However, the pH at 30 cm reached the level measured during 2005-2007. The DOC concentrations at all three depths were considerably higher than the reference site, but not excessively high for forest soils rich in organic matter under a coniferous tree stand. The higher DOC concentrations are probably also associated with the disturbance in the soil caused by the installation of the lysimeters. However, there are no signs of the DOC concentrations decreasing now that the lysimeters have already been 5 years in the soil.

The pH of the soil solution is relatively high at all sampling depths on FIP11. The high DOC concentrations are almost certainly due to the disturbance of the soil during lysimeter installation: the cutting of roots and temporary improvement in aeration in the organic layer frequently result in the dissolution of humus substances (e.g. fulvic acids) and organic compounds with a smaller molecular weight which, in addition to carbon, also contain nitrogen.



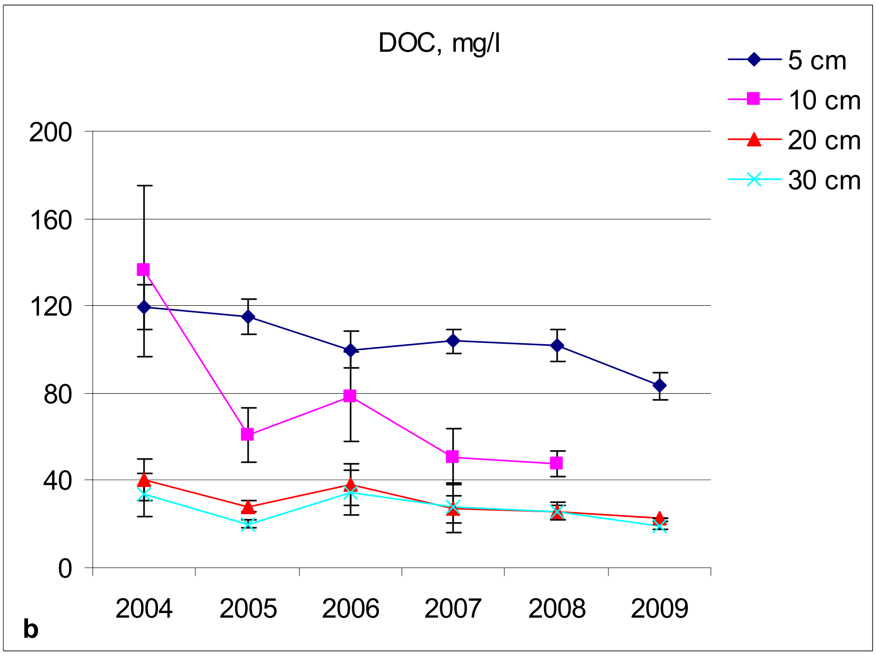
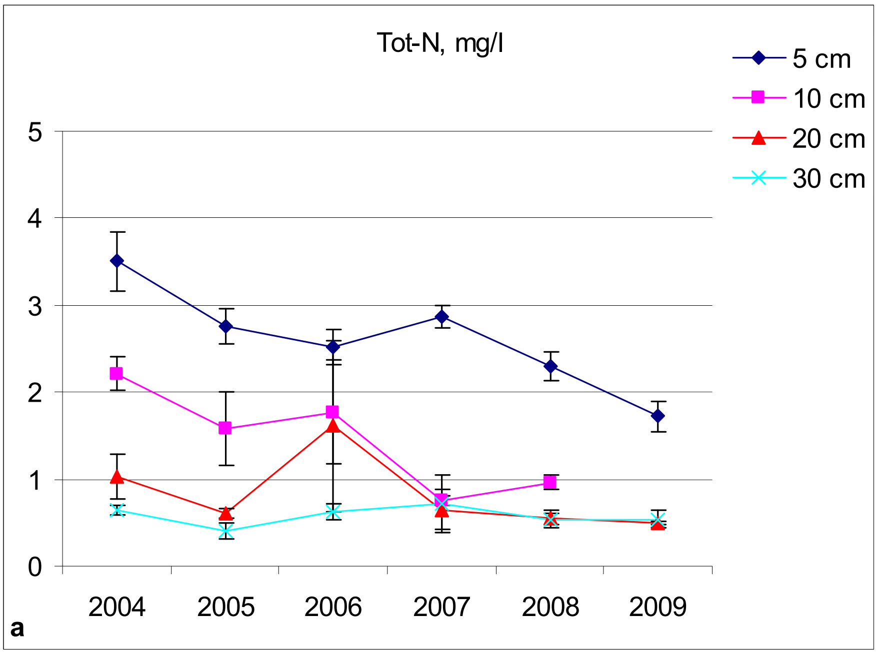


Figure 10. *Annual mean pH (a) and dissolved organic carbon (DOC) (b) concentration at different depths on plot FIP4 (Scots pine stand) at Olkiluoto during the snow-free period in 2004-2009. The bars denote the standard error of the mean.*

Total nitrogen which, in addition to ammonium and nitrate, also includes organic dissolved nitrogen, obviously closely followed the pattern for the DOC concentrations on FIP4 and FIP10 (Figures 10 and 11). At all depths, ammonium and nitrate accounted for only about 10% of the total amount of nitrogen dissolved in the soil solution, i.e. most of the nitrogen in the soil solution is so-called dissolved organic nitrogen (DON). The NH_4-N, and especially the NO_3-N concentrations, were extremely low at all depths in the mineral soil of the FIP plots throughout the monitoring period. The low concentrations are primarily due to the fact that nitrogen is the main factor limiting tree growth in coniferous stands in Finland; the available nitrogen (NH_4 and NO_3) mineralized from the organic layer is rapidly taken up by the roots of the trees and ground vegetation.

Sulphate concentrations at a 5 cm depth on FIP4 were considerably lower in all six years than those at the reference site, but at other depths were relatively similar. Instead, sulphate concentrations were approximately the same on FIP10 as those for the corresponding reference site at a 5 cm depth. There was a clear overall increase in sulphate concentrations with increasing depth on FIP4 (Figure 11). Similar trends in sulphate concentration have been reported at all the ICP Forests Level II plots in Finland (Derome et al. 2007). There also appears to be a gradual decrease in sulphate concentrations in the mineral soil.

Chloride concentrations were extremely high at all depths on all three FIP plots throughout the monitoring period; it is clear that there is a considerable input of NaCl in deposition derived from the sea. Phosphate concentrations were in general very low. Phosphate concentrations are very low in the soil solution at most forested sites in Finland (Derome et al. 2007).



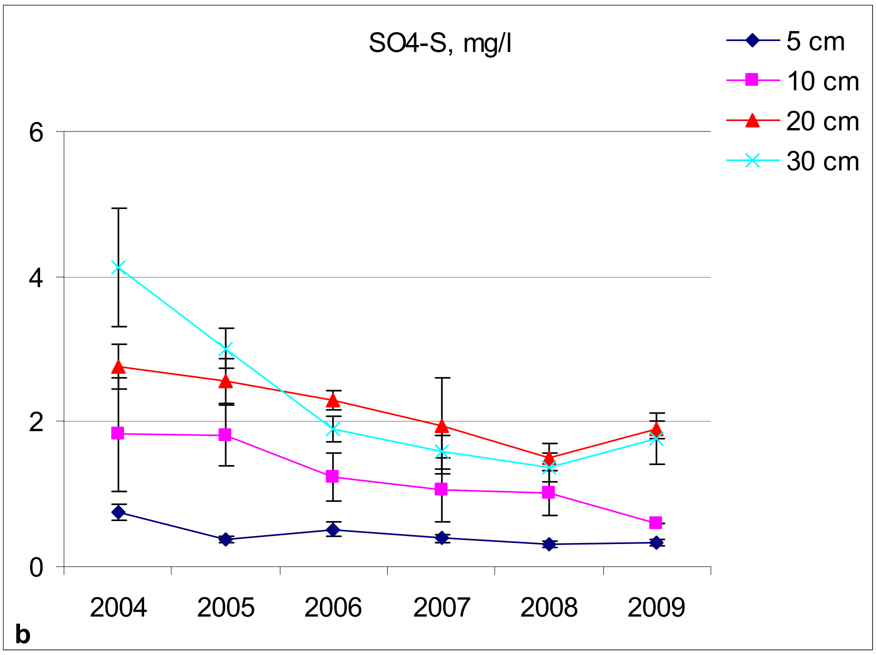


Figure 11. *Annual mean total nitrogen (Tot-N) (a) and sulphate (SO_4-S) (b) concentrations at different depths on plot FIP4 (Scots pine stand) at Olkiluoto during the snowfree period in 2004-2009. The bars denote the standard error of the mean.*

The concentrations of the three important plant nutrients (Ca, Mg, K) were relatively elevated, especially in the mineral soil (10, 20 and 30 cm) on FIP4 at the start of the monitoring period in 2004. Since then, the concentrations in the mineral soil have fallen and are now approaching the levels for the reference site. This suggests that there has been a short-term flush of these nutrients following the installation of the lysimeters (as for DOC). On FIP10 and FIP11, however, the concentrations of Ca, Mg and K were strongly elevated at all depths in the soil during the monitoring period. The soil on these plots at Olkiluoto is very young, and weathering processes in the mineral soil will be relatively strong and release abundant amounts of these three nutrients. The high concentrations of Na at all depths are due to both the input from the sea and the weathering of minerals.

On the plot FIP4, the concentrations of total Al at all depths were relatively similar in all six years, and higher than the values for the reference site at deeper (10 – 30 cm) depths. The concentration of Al^{3+} was in general higher compared to the reference site. However, the concentrations are still much lower than the widely accepted toxicity level of 2 mg/l. The Fe concentrations showed considerable year-to-year variation, and remained higher at depths of 10-30 cm than at the reference site. The Mn concentrations at all depths were very similar in all six years, and similar to the concentrations at the reference site. The Si concentrations at a depth of 5 cm during 2005-2009 were considerably higher than the corresponding values in 2004, and higher than the corresponding concentrations at the reference site.

On the plot FIP10, the total Al concentrations were lower at a 5 cm depth, but the Al^{3+} (a depth of 5 cm) and Mn concentrations (all depths) were relatively similar to the reference values. In contrast, the concentrations of Fe and Si were strongly elevated at depths of 20 and 30 cm. The high Si values are undoubtedly due to the young age of the soil: Si plays an important role in soil-forming processes (podzolisation) under coniferous tree species.

On the plot FIP11, elements associated with soil-forming (podzolisation) processes (e.g. Al, Fe, Si) are present in relatively high concentrations, but this is to be expected because the intensive uptake of nutrients (and corresponding release of protons) by the roots of the young stand and dense ground vegetation result in an increase in the dissolution of these elements through the weathering of soil minerals (the overburden on Olkiluoto Island is very young, in many places less than 600 years old). Manganese concentrations are extremely low. This may be related to the fact that the pH is somewhat elevated.

The concentrations of heavy metals (Cd, Cr, Ni, Pb) at all depths at Olkiluoto during 2004-2009 continued in many cases to be close or below the limit of quantification (LOQ for Cd = 0.001 mg/l, for Cr = 0.001 mg/l, for Ni = 0.010 mg/l, for Pb = 0.015 mg/l).

4.3 Tree stand transpiration

The monthly stand level transpiration of Scots pine (FIP4) and Norway spruce (FIP10) dominated stands is presented in Figure 12. Stand transpiration was higher in the pine stand than in the spruce stand during the growing season. In 2009 the monthly level of transpiration on the plot FIP4 was comparable to previous years (2007-2008). Instead, monthly transpiration in the Norway spruce dominated stand was clearly lower in 2009 than in 2007-2008. High values in winter months are due to errors in data and thus not reliable.

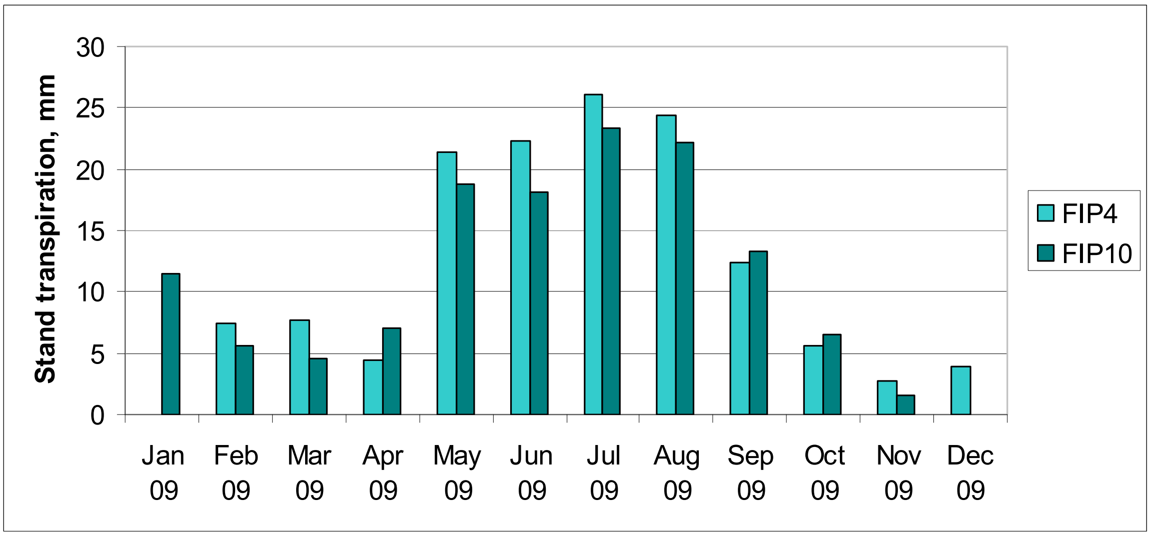


Figure 12. *Monthly stand level transpiration on FIP4 and FIP10 sample plots in 2009. Results are only reliable for the period of April-November.*

4.4 Litterfall production and element return to the forest floor

Annual total litterfall production was somewhat smaller in 2008 (the branch traps were already in use) than in 2007 (all branches were included in the fraction 6, Rautio & Aro 2009). However, this difference between years is natural annual variation. As a reference Ukonmaanaho et al. (2008) reported litterfall production (without large branches, i.e. fraction 7 here) of 226 g/m^2 for Scots pine and 350 g/m^2 for Norway spruce in 13 Finnish ICP Forests plots (mainly in southern Finland) during 1996-2003. On FIP11 (young deciduous trees) the mass of litterfall production was much lower than on FIP4 and FIP10 (Figure 13).

The most notable differences between the plots are those of Al and N concentrations (Tables 8 and 9). Al is commonly higher in living pine needles than in spruce needles and this can also be seen in the Al concentration (Table 8) in litterfall on the pine plot (FIP4) vs. on the spruce plot (FIP10). High Al (Table 8) and Fe (Table 10) concentrations in fraction 5 (remaining litter) are most likely due to soil dust. The highest N concentrations were detected in fraction 4 (leaves). The highest N concentrations in leaves occurred during summer (i.e. non-senescent leaves) but senescent leaves also contained approximately as much N as green pine needles (Table 9). C concentrations varied between 47.2 and 57.3 m-% in different litter fractions of the FIP plots.

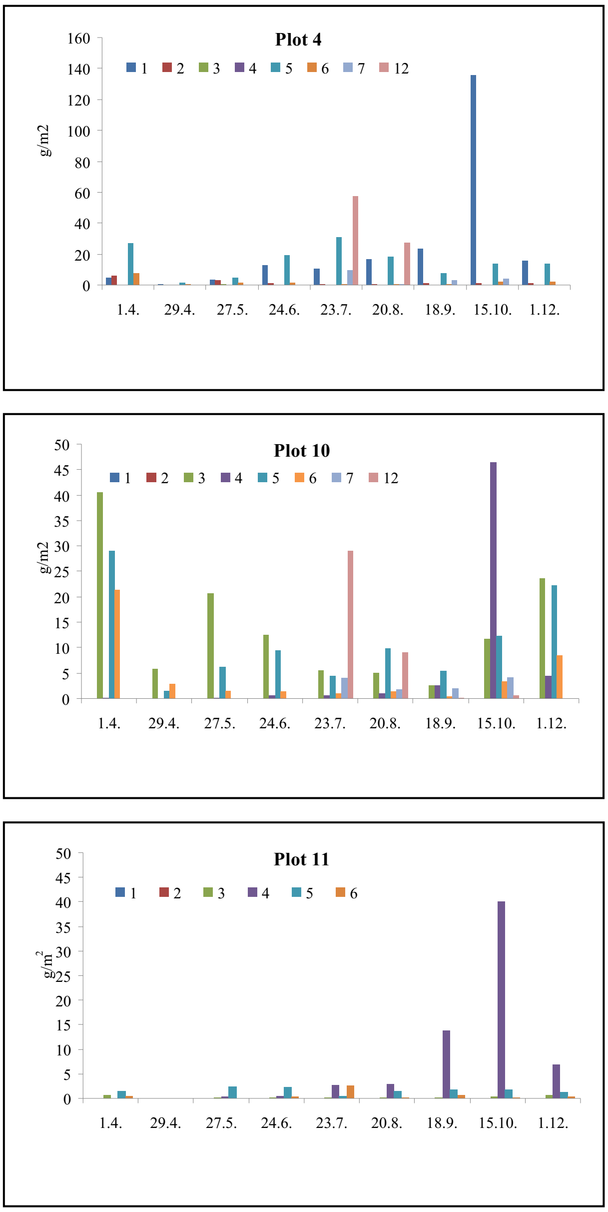


Figure 13. *Mass (g_{dw}/m2) of different fractions of litterfall on different collection dates during 2008 on the plots FIP4, FIP10 and FIP11. Fraction legends refer to: 1 = pine brown needles, 2 = pine green needles, 3 = spruce needles, 4 = leaves, 5 = remaining litter, 6 = small branches, 7 = branches from branch traps and 12 = remaining litter in branch traps.*

Table 8. *Aluminium concentrations (mg/kg) in the seven fractions of litterfall on the FIP plots during 2008.*

		Litter fraction[1]						
Plot	Date	1	2	3	4	5	6	7
4	1.4.	599	419			1270	459	
	29.4.	406	317			2220	526	
	27.5.	427	386	132		1300	354	
	24.6.	437	362			728	458	
	23.7.	411	218			410	459	464
	20.8.	378	212			865	351	501
	18.9.	327	215			835	394	420
	15.10.	365	262			648	470	461
	1.12.	381	323			717	412	
10	1.4.			69		694	292	
	29.4.			65.9		880	221	
	27.5.			63.4		567	200	
	24.6.			91.4	320	716	242	
	23.7.			57	295	897	254	192
	20.8.			52.9	209	732	317	109
	18.9.			52.4	101	876	220	86.6
	15.10.			62.3	56.6	268	265	203
	1.12.			60.3	175	263	270	
11	1.4.			500		4470	318	
	29.4.							
	27.5.			50.6		744		
	24.6.				310	956		
	23.7.				76	1010		
	20.8.				138	529		
	18.9.				44.6	642		
	15.10.			65.2	46.7	303		
	1.12.			89.7	184	983		

1) Litter fractions: 1 = pine brown needles, 2 = pine green needles, 3 = spruce needles, 4 = leaves, 5 = remaining litter, 6 = small branches, 7 = branches from "branch traps"

Table 9. *Nitrogen concentrations (m-%) in the seven fractions of litterfall on the FIP plots during 2008.*

		Litter fraction[1]						
Plot	Date	1	2	3	4	5	6	7
4	1.4.	0.977	1.53			0.58	0.659	
	29.4.	0.987	1.3			1.39	0.892	
	27.5.	1.43	1.47	1.08		1.52	0.782	
	24.6.	1.27	1.41			1.06	0.813	
	23.7.	0.965	1.44			0.836	0.912	0.499
	20.8.	0.861	1.2			0.731	1.03	0.815
	18.9.	0.597	1.4			0.876	0.961	0.469
	15.10.	0.515	1.37			0.632	0.714	0.624
	1.12.	0.743	1.48			0.788	0.839	
10	1.4.			1.01		1.07	0.958	
	29.4.			0.953		1.14	0.866	
	27.5.			1.08		1.54	1.02	
	24.6.			1.14	3.3	1.78	1.34	
	23.7.			0.982	2.34	1.56	1.04	0.907
	20.8.			0.981	1.81	1.38	1.1	0.645
	18.9.			0.926	1.27	1.89	1.08	0.647
	15.10.			0.792	0.983	1.02	1.03	0.986
	1.12.			0.768	1.03	0.922	0.855	
11	1.4.			0.871		1.42	1.02	
	29.4.					2.04		
	27.5.			1.13	4.44	1.5		
	24.6.			0.99	3.06	2.11		
	23.7.				2.38	2.44		
	20.8.				1.27	2.03		
	18.9.				1.28	2.17		
	15.10.			0.819	1.11	1.67		
	1.12.			0.695	0.988	1.64		

[1)] Litter fractions: 1 = pine brown needles, 2 = pine green needles, 3 = spruce needles, 4 = leaves, 5 = remaining litter, 6 = small branches, 7 = branches from "branch traps"

Table 10. *Iron concentrations (mg/kg) in the seven fractions of litterfall on the FIP plots during 2008.*

		Litter fraction[1]						
Plot	Date	1	2	3	4	5	6	7
4	1.4.	440	197			5880	435	
	29.4.	203	94.6			3230	486	
	27.5.	183	146	123		1730	251	
	24.6.	196	118			850	419	
	23.7.	181	57.6			344	434	413
	20.8.	166	61.8			958	225	423
	18.9.	128	61.2			923	304	446
	15.10.	138	62			653	456	399
	1.12.	174	91.7			705	338	
10	1.4.			91		1040	417	
	29.4.			81.8		1360	323	
	27.5.			87.6		875	295	
	24.6.			126	548	1110	350	
	23.7.			72.6	473	1290	280	291
	20.8.			62.3	363	987	449	169
	18.9.			59.9	218	1240	339	140
	15.10.			75.9	145	508	389	310
	1.12.			75.1	307	371	388	
11	1.4.			801		7500	511	
	29.4.							
	27.5.			85.1		1190		
	24.6.				516	1410		
	23.7.				165	1570		
	20.8.				271	662		
	18.9.				135	925		
	15.10.			84.4	137	494		
	1.12.			95.4	364	1470		

[1)] Litter fractions: 1 = pine brown needles, 2 = pine green needles, 3 = spruce needles, 4 = leaves, 5 = remaining litter, 6 = small branches, 7 = branches from "branch traps"

4.5 Defoliation

The degree of defoliation of Scots pine and Norway spruce was determined on the FIP plots during 31.8–1.9.2009. The average defoliation level of the pines was 4.6 % (±1.0, sd) and of the spruces 24.1 % (±2.5), indicating good crown condition: the pines were classified as non-defoliated and the spruces as slightly defoliated (Table 11). The defoliation degree levels were in good agreement with the results for the ICP Level II plots in Tammela (Lindgren et al. 2007). The increase in defoliation of the pine in 2007 was due to severe infection by Peridermium stem rust on one pine on FIP4-OA2 (tree nr. 344; the degree of defoliation increased from 15 % to 85 % during 2006 – 2007). In 2008, tree 344 was already dead and it was replaced with tree nr. 334.

Table 11. *Number of assessed trees (Nr.) and defoliation degree (%) of the trees on the FIP plots by sub-plot during 2006-2009.*

Plot	Sub-plot	Species	Nr.	Defoliation 2006	2007	2008	2009
4	1	Scots pine	20	3.2	3.4	5.2	4.5
	2	Scots pine	20	3.2	7.7	4.9	5.7
	3	Scots pine	20	4.2	2.9	3.7	3.3
	4	Scots pine	20	4.5	3.3	3.8	4.9
	Mean			3.7	4.3	4.4	4.6
	SD			0.7	2.2	0.8	1.0
10	1	Norway spruce	20	15.8	19.8	17.5	21.0
	2	Norway spruce	20	18.8	18.8	19.3	26.0
	3	Norway spruce	20	15.5	20.8	18.5	23.3
	4	Norway spruce	20	21.3	17.8	18.3	26.3
	Mean			17.8	19.3	18.4	24.1
	SD			2.7	1.3	0.7	2.5

4.6 Fine root elongation and longevity

SRL (specific root length) was highest for birch trees: SRL was 36.8 ±10.0 meters per gram of fine roots (with a diameter less than 1 mm) active in nutrient uptake (e.g. Figure 14). The respective values for Scots pine and Norway spruce were 20.0 ± 4.5 m g^{-1} and 22.0 ± 5.1 m g^{-1} . Birch also had the highest SRA (specific root area) for nutrient uptake, 47.1 ± 10.7 m^2 per kg of fine roots, and for pine and spruce the SRA values were 37.3 ± 7.3 and 36.0 ± 6.3 m^2 kg^{-1}, respectively.

These differences between tree species (e.g. Figures 14-16) are in accordance with the trends reported in Ostonen et al. (2007). The tree species with high SRL and SRA invest their root biomass more effectively than species with low SRL. Birch trees increase their root surface length by producing thinner roots that have a larger SRA for a given investment of carbon. Increases in SRA and SRL permit a tree species to increase the volume of soil explored per unit of biomass invested in fine roots (Ostonen et al. 2007).

The fine root diameter differed by tree species, being highest for pine, 0.61 ± 0.07 mm, followed by spruce 0.53 ± 0.06 mm and lowest for birch 0.41 ± 0.03 mm. The root diameter measured from minirhizotrone images for the first monitoring year was almost two times smaller (0.23 to 0.35 mm; Helmisaari et al. 2009), but the differences between species were comparable in these two studies. The new roots analysed from 2008 minirhizotrone images were less than a year old, whereas the larger diameter of soil core fine roots indicates that the bulk of fine roots may be older than one year. Indeed, the minirhizotrone images filmed in 2009 in the FIP stands show that within the two first growing seasons most of the roots observed as new stayed alive. Therefore, for determining the root turnover rate the minirhizotrone images will also be taken in the growing season 2010. An example of those images is presented in Figure 17.

Figure 14. *A birch root sample for SRL and SRA measurements from the organic layer of FIP11 showing fine roots of different diameter and their ectomycorrhizal short root tips.*

Figure 15. *A Scots pine root sample for SRL and SRA measurements from the upper mineral soil of FIP4 showing fine roots of different diameter. The larger, conducting fine roots are on the left, and the smaller fine roots are on the right with a large number of ectomycorrhizal short root tips.*

Figure 16. *A Norway spruce root sample for SRL and SRA measurements from the upper mineral soil of FIP10 showing fine roots of different diameter and their ectomycorrhizal short root tips.*

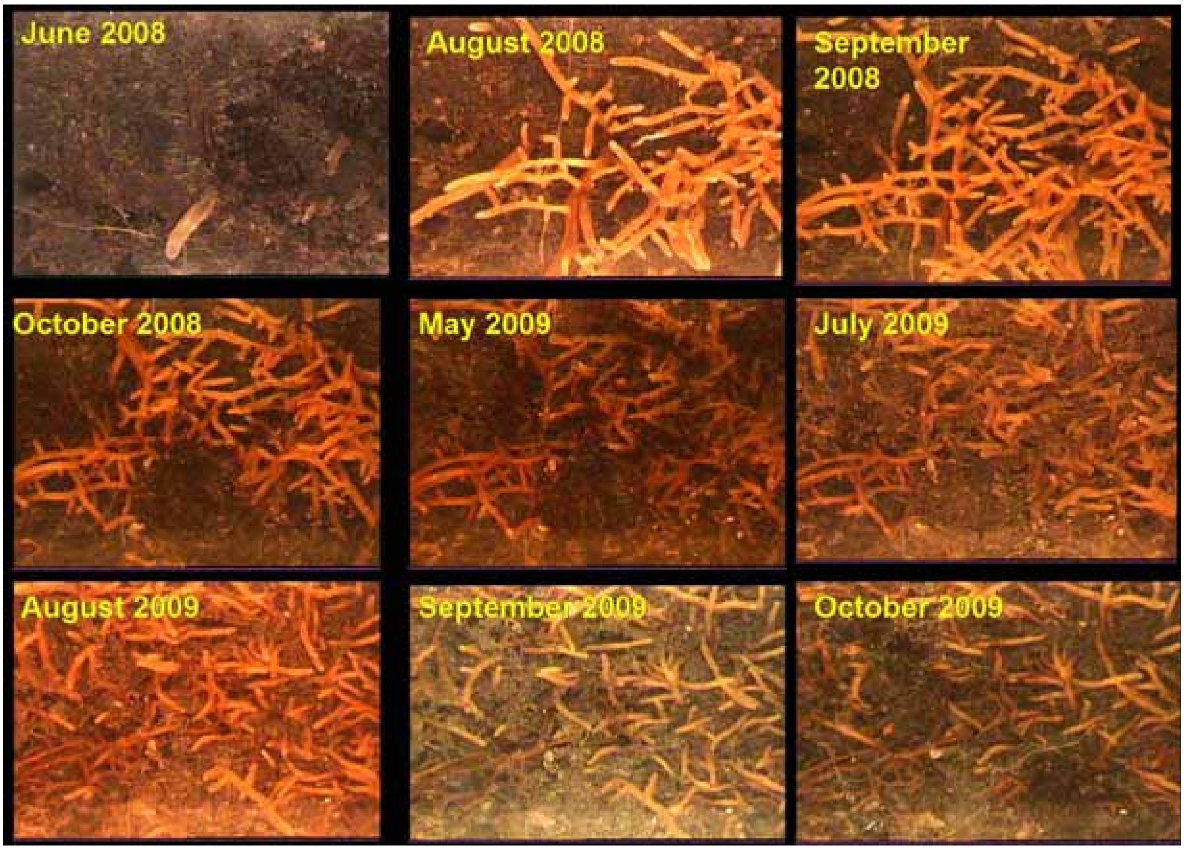


Figure 17. *Minirhizotrone images of ectomycorrhizal fine roots from the birch stand FIP11. Images are from the horizontal tube no 6, filmed in the growing seasons 2008 and 2009. Grazing by a soil animal, probably an earth worm, is visible in the image from October 2008, causing fine root death and replacement by new root growth during the growing season 2009.*

5 CONCLUDING REMARKS

The forest investigations form a part of the monitoring programme being carried out on Olkiluoto Island under the management of Posiva Oy. This report focused on activities performed on bulk deposition and forest intensive monitoring plots (MRK and FIP plots) in 2009, excluding litterfall production, results of which cover the previous year (2008). All the data have been stored in POTTI (Posiva research result database) and only the main findings are presented in this report.

There were only minor changes in monitoring networks during 2009. One new bulk deposition plot (MRK13, open area) was established in May 2009. The fourth FIP plot (FIP14) was established in the alder stand close to the shoreline in Ulkopäänniemi.

In general, the deposition levels in 2009 in the open area and in stand throughfall were quite comparable to those in earlier years, although sulphur and calcium depositions were somewhat higher in the open area than in earlier years.

The soil solution quality in 2009 was also quite comparable to that in earlier years. The NH_4-N and NO_3-N concentrations were low at all depths in the mineral soil of the FIP plots. There appears to have been a gradual decrease in sulphate concentrations in the mineral soil during the monitoring period.

In 2009 the monthly level of transpiration on the Scots pine dominated plot FIP4 was comparable to previous years (2007-2008). Instead, monthly transpiration in the Norway spruce dominated stand FIP10 was clearly lower in 2009 than in 2007-2008.

Annual total litterfall production was smaller in 2008 than in 2007. The most notable differences between the plots were detected in Al and N concentrations. The Al concentration was higher in living pine needles than in spruce needles. High Al and Fe concentrations were found in remaining litter, and were most likely due to soil dust. The average defoliation level of the pines was 4.6 % and of the spruces 24.1 %, indicating good crown condition: the pines were classified as non-defoliated and the spruces as slightly defoliated.

The minirhizotrone images filmed in 2009 in the FIP stands showed that within the two first growing seasons most of the roots observed as new stayed alive. Therefore, for determining the root turnover rate, the minirhizotrone images will also be taken in the growing season 2010.

SRL (specific root length) was highest for birch trees: SRL was 36.8 ±10.0 meters per gram of fine roots (with a diameter less than 1 mm) active in nutrient uptake (e.g. Figure 46a). The respective values for Scots pine and Norway spruce were 20.0 ± 4.5 m g^{-1} and 22.0 ± 5.1 m g^{-1}. Birch also had the highest SRA (specific root area) for nutrient uptake, 47.1 ± 10.7 m^2 per kg of fine roots, and pine and spruce SRA values were 37.3 ± 7.3 and 36.0 ± 6.3 m^2 kg^{-1}, respectively.

Finally, some improvements in monitoring networks should be considered. In order to increase the reliability of stand level estimates of transpiration, a decision has already been made to increase the number of sap flow sample trees during 2010. Similarly the installation of new branch litter collectors on the plot FIP14 has been decided. The degree of defoliation of trees could be determined every second year instead of an annual assessment.

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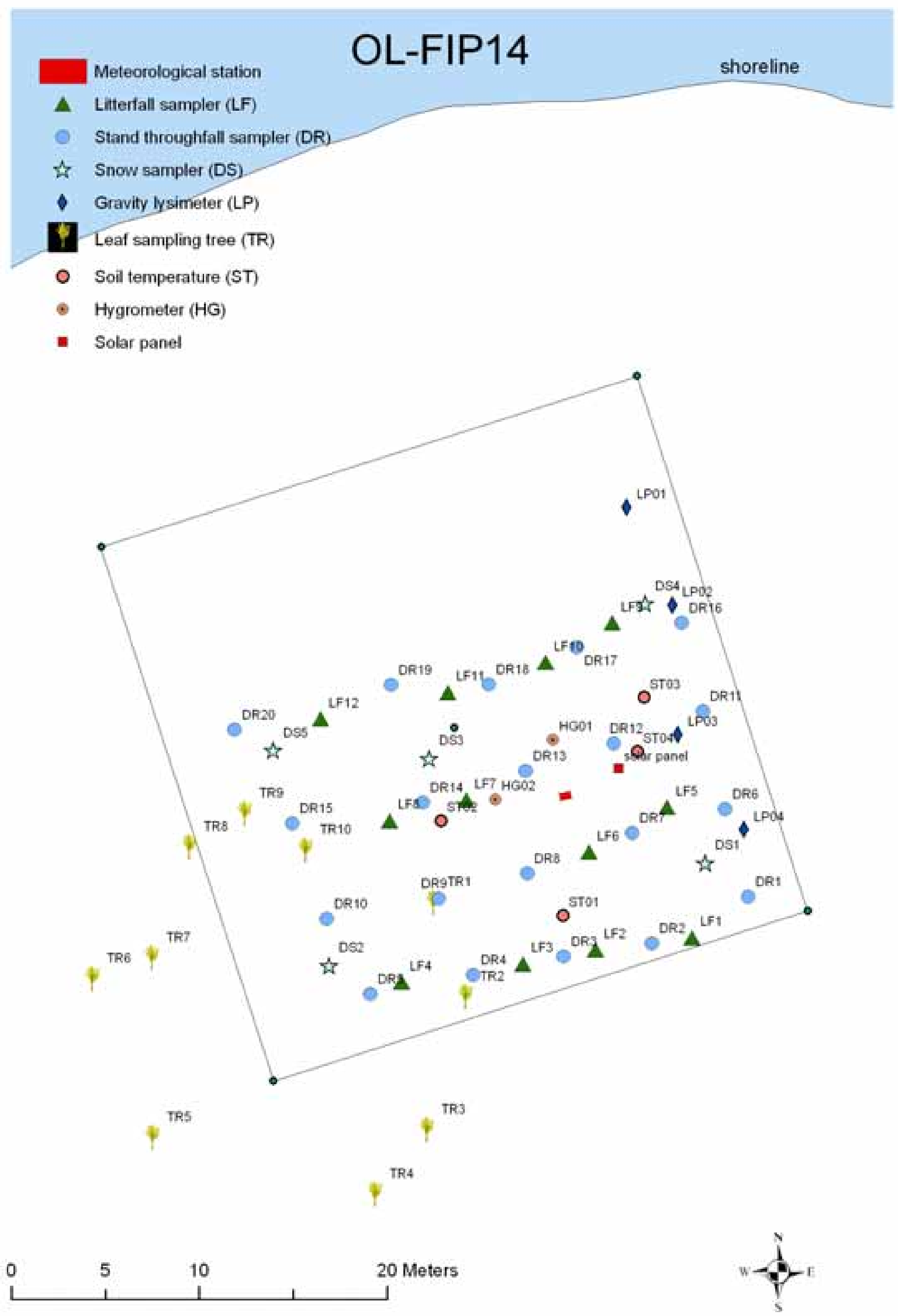
Appendix 1. Location of instruments on FIP14.



Appendix 2. Data definition in POTTI.

DATA. Weather observations in a forest stand

WOM 2

Science	ENVI
Method Categories	Vegetation inventories
Method	WOM2, Weather Observation Mast 2
Description	Posiva Oy Memo POS-003125, Posiva WR 2009-45
Target type	Weather mast
Target	WOM2
Processing stage	MEAS
Subtext files	
Method variables	Date Channel1 Soil temperature -30 cm °C Channel2 Soil temperature -40 cm °C Channel3 Soil temperature -50 cm °C Channel4 Soil temperature -60 cm °C Channel5 Soil temperature -70 cm °C Channel6 Soil temperature -80 cm °C Channel7 Soil temperature -90 cm °C Channel8 Battery voltage (V) Channel9 Soil temperature -10 cm 1 °C Channel10 Soil temperature -10 cm 2 °C Channel11 Soil temperature -10 cm 3 °C Channel12 Soil temperature -20 cm 1 °C Channel13 Soil temperature -20 cm 2 °C Channel14 Soil temperature -20 cm 3 °C Channel15 Temperature (inside crown), 9 m (mean) °C Channel16 Temperature (top of mast), 24 m (mean) °C Channel17 Girth Band 1, tree No. 395 mm Channel18 Girth Band 2, tree No. 93 mm Channel19 Temperature, 2 m°C Channel20 Proportional humidity, 2 m % Channel21 Air pressure, 2m hPa Channel25 PAR-radiation, 24 m (mean) µmol s-1 m-2 Channel26 Total radiation, 24 m (mean) W m-2 Channel27 Proportional humidity, 9 m (mean) % Channel28 Wind direction, 24 m (mean) ° Channel29 Wind speed, 24 m (mean) m/s Channel30 Soil moisture –20 cm 1% Channel31 Soil moisture –20 cm 2% Channel32 Rain mm

	Channel33 Temperature (inside crown), 9 m (min) °C Channel34 Temperature (inside crown), 9 m (max) °C Channel35 Temperature (top of mast), 24 m (min) °C Channel36 Temperature (top of mast), 24 m (max) °C Channel37 PAR-radiation, 24 m (min) µmol s-1 m-2 Channel38 PAR-radiation, 24 m (max) µmol s-1 m-2 Channel39 Total radiation, 24 m (min) W m-2 Channel40 Total radiation, 24 m (max) W m-2 Channel41 Proportional humidity, 9 m (min) % Channel42 Proportional humidity, 9 m (max) % Channel43 Wind direction, 24 m (min) ° Channel44 Wind direction, 24 m (max) ° Channel45 Wind speed, 24 m (min) m/s Channel46 Wind speed, 24 m (max) m/s
Method parametes	Document reference

WOM 3

Science	ENVI
Method Categories	Vegetation inventories
Method	WOM3, Weather Observation Mast 3
Description	Posiva WR 2009-45
Target type	Weather mast
Target	WOM3
Processing stage	MEAS
Subtext files	
Method variables	Date Channel1 Soil temperature -30 cm (°C) Channel2 Soil temperature -40 cm (°C) Channel3 Soil temperature -50 cm (°C) Channel4 Soil temperature -60 cm (°C) Channel5 Soil temperature -70 cm (°C) Channel6 Soil temperature -80 cm (°C) Channel7 Soil temperature -90 cm (°C) Channel8 Battery voltage (V) Channel9 Soil temperature -10 cm 1 (°C) Channel10 Soil temperature -10 cm 2 (°C) Channel11 Soil temperature -10 cm 3 (°C) Channel12 Soil temperature -20 cm 1 (°C) Channel13 Soil temperature -20 cm 2 (°C) Channel14 Soil temperature -20 cm 3 (°C) Channel17 Girth Band 1, tree No. 29 (mm)

	Channel18 Girth Band 2, tree No. 119 (mm) Channel19 Temperature, 2 m(°C) Channel20 Proportional humidity, 2 m (%) Channel30 Soil moisture –20 cm 1(%) Channel31 Soil moisture –20 cm 2(%) Channel32 Rain (mm)
Method parametes	Document reference

WOM4

Science	ENVI
Method Categories	Vegetation inventories
Method	WOM4, Weather Observation Mast 4
Description	Posiva WR 2009-45
Target type	Weather mast
Target	WOM4
Processing stage	MEAS
Subtext files	
Method variables	Date Channel1 Soil temperature -30 cm (°C) Channel2 Soil temperature -40 cm (°C) Channel3 Soil temperature -50 cm (°C) Channel4 Soil temperature -60 cm (°C) Channel5 Soil temperature -70 cm (°C) Channel6 Soil temperature -80 cm (°C) Channel7 Soil temperature -90 cm (°C) Channel8 Battery voltage (V) Channel1B Soil temperature -10 cm 1 (°C) Channel2B Soil temperature -10 cm 2 (°C) Channel3B Soil temperature -10 cm 3 (°C) Channel4B Soil temperature -20 cm 1 (°C) Channel5B Soil temperature -20 cm 2 (°C) Channel6B Soil temperature -20 cm 3 (°C) Channel7B Soil temperature –20 cm 1 (%) Channel8B Soil temperature –20 cm 2 (%) Channel1C Temperature, 2 m (°C) Channel6C Channel7C Proportional humidity, 2 m (%) Channel8C Rain (mm)
Method parametes	Document reference

WOM5

Science	ENVI
Method Categories	Vegetation inventories
Method	WOM5, Weather Observation Mast 5
Description	Posiva WR 2010-45
Target type	Weather mast
Target	WOM5
Processing stage	MEAS
Subtext files	
Method variables	Date Channel1 Soil temperature -30 cm (°C) Channel2 Soil temperature -40 cm (°C) Channel3 Soil temperature -50 cm (°C) Channel4 Soil temperature -60 cm (°C) Channel5 Soil temperature -70 cm (°C) Channel6 Soil temperature -80 cm (°C) Channel7 Soil temperature -90 cm (°C) Channel8 Battery voltage (V) Channel1B Soil temperature -10 cm 1 (°C) Channel2B Soil temperature -10 cm 2 (°C) Channel3B Soil temperature -10 cm 3 (°C) Channel4B Soil temperature -20 cm 1 (°C) Channel5B Soil temperature -20 cm 2 (°C) Channel6B Soil temperature -20 cm 3 (°C) Channel7B Soil temperature -20 cm 1 (%) Channel8B Soil temperature -20 cm 2 (%) Channel1C Temperature, 2 m (°C) Channel7C Proportional humidity, 2 m (%)
Method parametes	Document reference

DATA. Wet deposition analysis

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Wet deposition analysis
Description	Posiva WR 2009-45
Target type	Wet deposition monitoring plot
Target	MRKgroup
Processing stage	MEAS

Subtext files	
Method variables	Lab ID Plot Type Sampling date Amount (l/m2 = mm) pH Alkalinity (mmol/l) H+ (mg/l) Conductivity (µS/cm) Conductivity_ctrl DOC (mg/l) DOC_ctrl TOT-N (mg/l) TOT-N_ctrl NH4-N (mg/l) NH4-N_ctrl NO3-N (mg/l) NO3-N_ctrl Ca (mg/l) Ca_ctrl Mg (mg/l) Mg_ctrl K (mg/l) K_ctrl Na (mg/l) Na_ctrl PO4-P (mg/l) PO4-P_ctrl SO4-S (mg/l) SO4-S_ctrl Cl (mg/l) Cl_ctrl Al (mg/l) Al_ctrl Fe (mg/l) Fe_ctrl Mn (mg/l) Mn_ctrl Cu (mg/l) Cu_ctrl Zn (mg/l) ZN_ctrl Si (mg/l) Si_ctrl Notes
Method parametes	

DATA. Forest inventory: tree measurements

Science	ENVI
Method Categories	Vegetation inventories
Method	Forest inventory: tree measurements (FET)
Description	FET: Posiva WR 2005-39, p. 7-9
Target type	Forest extensive monitoring plot
Target	FETgroup
Processing stage	MEAS
Subtext files	VMI9.pdf
Method variables	FET/ FIP ID Tree ID TR-1 Subplot OA-1 (compartment number) Zone ID MZ-1 (radius of tree measurement plot, m) New center distance m New center direction 0-360 Degrees Tree distance cm (from new center) Tree direction 0-360 Degrees (from new center) Tree Northing N & m (-) & - & 6780000 & 6799000 Tree Easting N & m (-) & - & 15200000 & 15300000 Tree species (class: 1=Scots pine, 2=Norway spruce, 3=silver birch, 4=downy birch, 5=aspen, 6=grey alder, 7=black alder, 8=rowan, 9=goat willow …… etc) Diameter at a height of 1.3m (mm) Tree class (class) Tree class extension (class) Crown layer (class) Age (for sample trees, y) Age_ctrl Mode of regeneration (for sample trees) Upper diameter (at 6.0m, cm of trees over 8m in height (for sample trees)) Upper diameter_ctrl Dead branch limit (for sample trees) (dm) Dead branch limit_ctrl Lower limit of living crown (for sample trees) (dm) Lower limit of living crown_ctrl Height (dm, for sample trees) Height_ctrl Length of broken stem (for sample trees) (dm) Damage symptoms (for sample trees) Damage symptoms_ctrl Time of damage occurrence (for sample trees) (y) Time of damage occurrence_ctrl Cause of damage (for sample trees)

	Degree of damage (for sample trees) Surveyor Date of inventory
Method parametes	Classification system Document reference Measured by Time

Science	ENVI
Method Categories	Vegetation inventories
Method	Forest inventory: tree measurements (FIP/MRK)
Description	MRK: Lindroos et al. 2008 (Kronodoc POS-003852); FIP: Aro 2006 (Kronodoc POS-003125)
Target type	Forest intensive monitoring plot, Wet deposition monitoring plot
Target	FIP MRK
Processing stage	MEAS
Subtext files	VMI9.pdf
Method variables	FIP/MRK ID Tree ID TR-1 Subplot OA-1 (compartment number) Zone ID MZ-1 (radius of tree measurement plot, m) Tree distance cm (from center) Tree direction 0-360 Degrees (from center) (Tree Northing N & m (-) & - & 6780000 & 6799000 Tree Easting N & m (-) & - & 15200000 & 15300000 Tree species (class: 1=Scots pine, 2=Norway spruce, 3=silver birch, 4=downy birch, 5=aspen, 6=grey alder, 7=black alder, 8…. as agreed) Crown layer (class) Tree group (class) D_1.3_1 D_1.3_2 Technical quality (class) Lower limit of living crown (dm) Height (dm) Damage symptoms (class) Time of damage occurrence Cause of damage (class) Degree of damage (class) Surveyor Date of inventory Sample tree

Method parametes	Classification system Document reference Measured by Time

DATA. Forest inventory by plots: plot characterists

Science	ENVI
Method Categories	Vegetation inventories
Method	Forest inventory by plots: plot characteristics
Description	
Target type	Forest extensive monitoring plot
Target	FETgroup
Processing stage	MEAS
Subtext files	
Method variables	FET ID Subplot Sample trees Limitations in wood prod. Limitations in wood prod. sg Estim prop of sp in rp_9.77 Estim prop of sp in rp_5.64 Estim prop of sp in rp_3.09 Land class Land sub-class Main site type Mixed site type Site type Site type extension State of drainage Drainage carried out Time of drainage Ditch spacing Condition of ditches Position of storey Number of tree storeys Development class Development class_2 Proportion of v_a_r_s Dominant tree species Prop of domin.tree species 1st sub-tree species Prop of 1st sub-tree species 2nd sub-tree species Proportion of conifers 1

	Proportion of conifers 2 Stem number Total number of seedlings Age at breast height Damage symptom Time of occurrence of damage Cause of damage Degree of damage Beard lichens Foliose lichens Crustose lichens Quality of tree stand Cause of decrease in quality Fellings carried out Time of fellings Site preparation Time of site preparation S-cultural meas carried out Time of s-cultural measures Data link to field form 1 Data link to field form 2
Method parametes	Classification system Document reference Surveyor

DATA. Vegetation nutrition analysis

Science	ENVI
Method Categories	Vegetation inventories
Method	Vegetation nutrition analysis
Description	
Target type	Forest extensive monitoring plot, (Forest intensive monitoring plot)
Target	FET, (FIP)
Processing stage	MEAS
Subtext files	
Method variables	FET/FIP ID Sample ID Plant species Plant part: whole, all aboveground, stem, branches, shoots, leaves, buds, roots, rhizome, berries/fruits, flowers, inflorescences, light-coloured (for lichens), not known etc. Age class (c, c+1 ...c+n, young shoots)

	Sampling date (dd.mm.yy) Analysing date Partition ID Lab ID Al (mg/kg_{dw}) Al_ctrl B (mg/kg_{dw}) B_ctrl Ca (g/kg_{dw}) Ca_ctrl Cd (mg/kg_{dw}) Cd_ctrl Cr (mg/kg_{dw}) Cr_ctrl Cu (mg/kg_{dw}) Cu_ctrl Fe (mg/kg_{dw}) Fe_ctrl K (g/kg_{dw}) K_ctrl Mg (g/kg_{dw}) Mg_ctrl Mn (mg/kg_{dw}) Mn_ctrl Mo (mg/kg_{dw}) Mo_ctrl Na (mg/kg_{dw}) Na_ctrl Ni (mg/kg_{dw}) Ni_ctrl P (g/kg_{dw}) P_ctrl Pb (mg/kg_{dw}) Pb_ctrl S (mg/kg_{dw}) S_ctrl Zn (mg/kg_{dw}) Zn_ctrl C (m-%, dw) C_ctrl H (m-%, dw) H_ctrl N (m-%, dw) N_ctrl
Method parametes	Sampling round

DATA. Soil chemical analysis

Science	ENVI
Method Categories	Soil inventories
Method	Soil chemical analysis (METLA)
Description	Posiva WR 2007-78
Target type	Forest intensive monitoring plot, Forest extensive monitoring plot
Target	FIP FET
Processing stage	MEAS
Subtext files	
Method variables	FET/FIP ID Sampling point ID (e.g. repeat HS1-HS3, MS1-MS2, PS1-PS3 etc.) Sample type (mineral soil, humus, peat, litter) Top of sampling interval (only mineral soil and peat, from mineral and peat soil surface, cm) Bottom of sampling interval (only mineral soil and peat, from mineral and peat soil surface, cm) Sampling date Analysing date Partition ID (e.g. parallel or control analyses) Moisture (%) Ash content (%) Organic matter (%) Al (mg/kgdw) B (mg/kgdw) Ca (mg/kgdw) Cd (mg/kgdw) Cr (mg/kgdw) Cu (mg/kgdw) Fe (mg/kgdw) K (mg/kgdw) Mg (mg/kgdw) Mn (mg/kgdw) Mo (mg/kgdw) Na (mg/kgdw) Ni (mg/kgdw) P (mg/kgdw) Pb (mg/kgdw) S (mg/kgdw) Zn (mg/kgdw) C (m-%, dw) H (m-%, dw) N (m-%, dw) pH-H2O pH-CaCl2

	Exchangeable acidity (Hmmol) (mg/kgdw) Al_BaCl2 (mg/kgdw) Ca_BaCl2 (mg/kgdw) Fe_BaCl2 (mg/kgdw) K_BaCl2 (mg/kgdw) Mg_BaCl2 (mg/kgdw) Mn_BaCl2 (mg/kgdw) Na_BaCl2 (mg/kgdw) P_BaCl2 (mg/kgdw)
Method parametes	Sampling round Document reference

Science	ENVI
Method Categories	Soil inventories
Method	Soil chemical analysis (METLA)
Description	Posiva WR 2007-78
Target type	(Forest intensive monitoring plot), Forest extensive monitoring plot
Target	(FIP) FET
Processing stage	PROC
Subtext files	
Method variables	FET/ FIP ID Sampling point ID (e.g. repeat HS1-HS3, MS1-MS2 etc.) Sample type (mineral soil, humus, peat, litter) Top of sampling interval (only mineral soil and peat, from mineral and peat soil surface, cm) Bottom of sampling interval (only mineral soil and peat, from mineral and peat soil surface, cm) Sampling date Analysing date Partition ID (e.g. parallel or control analyses) Lab ID OM_kgha (kg/ha dw) amount of organic matter (in dw) C_kgha (kg/ha dw) total carbon amount, Leco CHN-2000 or Leco CHN-1000 analyser, dw N_kgha (kg/ha dw) total nitrogen amount, Leco CHN-2000 or Leco CHN-1000 analyser, dw Ca_exc_kgha (kg/ha dw) amount of exchangeable base cation, dw, BaCl2 extraction K_exc_kgha (kg/ha dw) amount of exchangeable base cation, dw, BaCl2 extraction Mg_exc_kgha (kg/ha dw) amount of exchangeable base cation, dw, BaCl2 extraction Na_exc_kgha (kg/ha dw) amount of exchangeable base cation, dw,

	BaCl2 extraction	
	Al_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	B_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Ca_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Cd_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Cr_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Cu_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Fe_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	K_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Mg_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Mn_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Mo_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Na_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Ni_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	P_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Pb_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	S_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	Zn_kgha (kg/ha dw)	total element amount, wet digestion+ICP/AES, dw
	BC_sum (mmol/kg)	sum of base cation concentrations (mmol/kg): Cammol+Kmmol+Mgmmol+Nammol
	CEC (mmol(+)/kg)	cation exchange capacity (BC sum+exchangeable acidity)
	BS (%)	Base saturation = 100*BC/CEC
Method parametes	Sampling round Document reference	

DATA. Foliage chemical analysis

Science	ENVI
Method Categories	Vegetation inventories
Method	Foliage chemical analysis
Description	
Target type	Forest extensive monitoring plot, (Forest intensive monitoring plot)
Target	FET (FIP)
Processing stage	MEAS
Subtext files	
Method variables	FET/FIP ID Sampling point ID (e.g. repeat 1…., TRxx etc.; composite sample) Number of sample trees Tree species Sample type (needle, leaf) Age class (c, c+1, …. c+n) Sampling date Analysing date (mostly date of approval) Partition ID (e.g. parallel or control analyses) Lab ID Al (mg/kgdw) B (mg/kgdw) Ca (g/kgdw) Cd (mg/kgdw) Cr (mg/kgdw) Cu (mg/kgdw) Fe (mg/kgdw) K (g/kgdw) Mg (g/kgdw) Mn (mg/kgdw) Mo (mg/kgdw) Na (mg/kgdw) Ni (mg/kgdw) P (g/kgdw) Pb (mg/kgdw) S (mg/kgdw) Zn (mg/kgdw) C (m-%, dw) H (m-%, dw) N (m-%, dw) Dry weight (g) *(of 100 needles/leaves)*
Method parametes	Document reference Sample taken by Sampling round

DATA. Sampler and sensor locations

FIP

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Sampler and sensor locations
Description	
Target type	Forest intensive monitoring plot
Target	FIP
Processing stage	MEAS
Subtext files	
Method variables	FIP ID Easting Northing Sampler type in Finnish Sampler type Sampler ID Sampler/sensor depth/height cm (in relation to soil surface: + upwards, - depth in soil) Notes
Method parametes	Survey type Surveyed by

MRK

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Sampler and sensor locations
Description	
Target type	Wet deposition monitoring plot
Target	MRK
Processing stage	MEAS
Subtext files	
Method variables	MRK ID Sampler type in Finnish Sampler type Number Northing Easting
Method parametes	Survey type Surveyed by

DATA. Forest soil water analysis

Science	ENVI
Method Categories	Vegetation inventories
Method	Forest soil water analysis
Description	
Target type	Test pit, Investigation trench, Infiltration test area
Target	KK TK TMA10
Processing stage	MEAS
Subtext files	
Method variables	Lab ID Evacuation day Sampling day Analysing date Analysed by Plate lysimeter Sample Depth (m) Sample type Conductivity (µS/cm / 25°C) pH Alkalinity (mmol/l) Cl (mg/l) PO4-P (mg/l) NO3-N (mg/l) SO4-S (mg/l) NH4-N (mg/l) TOT-N (mg/l) DOC (mg/l) Al (mg/l) B (mg/l) Ca (mg/l) Ca_2 (mg/l) Cd (mg/l) Cr (mg/l) Cu (mg/l) Fe (mg/l) K (mg/l) K_2 (mg/l) Mg (mg/l) Mn (mg/l) Na (mg/l) Na_2 (mg/l) Ni (mg/l)

	P (mg/l) Pb (mg/l) S (mg/l) Si (mg/l) Zn (mg/l)
Method parametes	

DATA. Sap flow measurement

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Sap flow measurement
Description	Hökkä 2008 (Kronodoc POS-003795), Prosalog Manual version 1.1 (2005), UP Sap Flow-System User Manual Version 2.6
Target type	Forest intensive monitoring plot
Target	FIP
Processing stage	MEAS
Subtext files	
Method variables	FIP ID Date (dd.mm.yyyy hh:mm:ss) Sap flow signal_tree 1 (mV) Sap flow signal_tree 2 (mV) Sap flow signal_tree 3 (mV) Sap flow signal_tree 4 (mV)
Method parametes	Document reference

DATA. Sap flow measurement: tree stand transpiration.

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Sap flow measurement: tree stand transpiration
Description	Hökkä 2008 (Kronodoc POS-003795), Prosalog Manual version 1.1 (2005), UP Sap Flow-System User Manual Version 2.6
Target type	Forest intensive monitoring plot
Target	FIP
Processing stage	PROC

Subtext files	
Method variables	Date (dd.mm.yyyy hh:mm:ss) Stand transpiration (mm)
Method parametes	Calibration method Document reference Processed by

DATA. Spring and ditch water chemical analysis

Science	ENVI
Method Categories	
Method	Spring and ditch water chemical analysis
Description	
Target type	Spring, Ditch
Target	TMAspring DI10
Processing stage	MEAS
Subtext files	
Method variables	Subplot Analysing date Analysed by Sample type Conductivity (µS/cm / 25°C) pH Alkalinity (mmol/l) DOC (mg/l) TOT-N (mg/l) Cl (mg/l) PO4-P (mg/l) NO3-N (mg/l) SO4-S (mg/l) NH4-N (mg/l) Al (mg/l) B (mg/l) Ca (mg/l) Ca_2 (mg/l) Cd (mg/l) Cr (mg/l) Cu (mg/l) Fe (mg/l) K (mg/l) K_2 (mg/l) Mg (mg/l) Mn (mg/l)

	Na (mg/l) Na_2 (mg/l) Ni (mg/l) P (mg/l) Pb (mg/l) S (mg/l) Si (mg/l) Zn (mg/l)
Method parametes	

DATA. Nutrient analysis of litter fractions

Science	ENVI
Method Categories	Continuous forest monitoring
Method	Nutrient analysis of litter fractions
Description	Aro 2006 (Kronodoc POS-003125); Rautio, P. & Aro, L. 2009 (Kronodoc POS-005671)
Target type	Forest intensive monitoring plot
Target	FIP
Processing stage	MEAS
Subtext files	
Method variables	FIP ID Sampling date Analysing date Partition ID Lab ID Litter fraction Moisture (%) Ash content (%) Al (mg/kgdw) B (mg/kgdw) Ca (g/kgdw) Cd (mg/kgdw) Cr (mg/kgdw) Cu (mg/kgdw) Fe (mg/kgdw) K (g/kgdw) Mg (g/kgdw) Mn (mg/kgdw) Mo (mg/kgdw) Na (mg/kgdw) Ni (mg/kgdw) P (g/kgdw)

	Pb (mg/kgdw) S (mg/kgdw) Zn (mg/kgdw) C (m-%, dw) N (m-%, dw) H (m-%, dw) Remarks
Method parametes	