Working Report 2016-22

Results of Forest Monitoring on Olkiluoto Island in 2014

Lasse Aro, Antti-Jussi Lindroos, Pasi Rautio, Ari Ryynänen

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POSIVA OY
Olkiluoto
FI-27160 EURAJOKI, FINLAND
Phone (02) 8372 31 (nat.), (+358-2-) 8372 31 (int.)
Fax (02) 8372 3809 (nat.), (+358-2-) 8372 3809 (int.)

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ABSTRACT

The forest investigations form a part of the monitoring programme being carried out on the Olkiluoto Island nuclear waste repository site 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 2014. Monitoring was initiated on two new FIP plots (15 and 16). There were no other essential changes to the current monitoring networks during 2014.

In general, the level of precipitation was relatively low in 2014. The NH_4-N deposition that decreased in 2012 compared to the situation in 2011 remained relatively low also in 2013 and 2014. The NO_3-N deposition values increased in 2012 and were the highest for the whole monitoring period during 2004-2012. However, in 2013 the NO_3-N deposition decreased and remained at a similar level also in 2014. The SO_4-S and Ca depositions were clearly elevated in 2014 on the plot MRK13 which is located close to the construction activities. The soil solution quality in 2014 was also quite comparable to that in earlier years. Annual total litterfall production (212–434 g_{dw}/m^2 without larger branches) was lower in coniferous plots in 2013 compared to the previous collection period in 2012. Annual variations recorded on Olkiluoto Island are due to natural reasons. High Al and Fe concentrations were found in the remaining litter, and were most likely due to soil dust. The pines were classified as non-defoliated indicating good crown condition of the trees. The spruces were classified as moderately defoliated.

The current annual increment of stem volume (CAI) was very high, 14.2 $m^{3/}$ha/a, in the Scots pine stand on FIP4 during the last five years. CAI was also high in Norway spruce (FIP10, 9.7 $m^{3/}$ha/a during the last five years) and birch (FIP11, 9.3 $m^{3/}$ha/a during the last six years) dominated stands. Instead, CAI was exceptionally low, 4.9 $m^{3/}$ha/a, in the black alder stand (FIP14) during the last five years. In the spruce stand (FIP10) the birches have reached their mature age. Based on the basal area and stem volume, silver birch has become the dominating tree species on the FIP11 plot.

In connection with the forest inventory in 2014, the thickness of litter (4.2 cm, on average) and organic layers (10.8 cm) were measured from the set of FET plots.

No harmful effects of human activities on the forest condition were observed in the nature conservation area.

Keywords: Bulk deposition, forest ecosystems, litterfall production, soil solution chemistry, stand throughfall, tree stand transpiration.

OLKILUODON METSIEN TILAN SEURANNAN TULOKSET VUODELTA 2014

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, joista uusina seurantaan tulivat mukaan FIP15 ja 16) seurannasta vuonna 2014. Vuoden 2014 kokonaislaskeuma oli kohtuullisen pieni. NH_4-N ja NO_3– laskeumat pysyivät edellisen vuoden tasolla. SO_4- ja Ca-laskeumat nousivat selvästi vuonna 2014 edeltäviin vuosiin verrattuna seuranta-alalla MRK13, joka sijaitsee lähellä ONKALOa. Maaveden ominaisuuksissakaan ei ollut pääsääntöisesti havaittavissa muutoksia aikaisempiin vuosiin verrattuna. Vuonna 2013 puuston maanpäällinen kokonaiskariketuotanto (212-434 g_{dw}/m^2 ilman suuria oksia) oli pienempi havupuuvaltaisilla aloilla kuin 2012. Karikemäärän vaihtelut voidaan selittää metsien kehitykseen liittyvillä luonnollisilla syillä. Muussa karikkeessa mitattiin korkeat Al- ja Fe-pitoisuudet, mikä selittynee maapölyllä. Harsuuntumisarvioinnin perusteella mäntyjen latvukset olivat hyvässä kunnossa, mutta ikääntyneiden kuusten latvukset luokiteltiin jo kohtalaisesti harsuuntuneiksi. Edeltävällä viisivuotiskaudella puuston tilavuuskasvu oli suuri männikössä, kuusikossa ja koivikossa (FIP4:llä 14,2, FIP10 9,7 ja FIP11 9,3 m^3/ha/v). Rauduskoivusta oli tullut valtapuulaji FIP11:llä. Sen sijaan tervalepikossa meren rannalla puuston kasvu oli heikkoa (4,9 m^3/ha/v). Olkiluodon metsien puustoinventoinnin yhteydessä arvioitiin myös karike- ja orgaanisen kerroksen paksuudet osalla FET-aloista. Karikekerroksen paksuus oli keskimäärin 4,2 cm ja orgaanisen kerroksen paksuus 10,8 cm. Ihmistoiminnan aiheuttamia muutoksia ei havaittu Olkiluodon vanhojen metsien luonnonsuojelualueen tai sitä ympäröivän NATURA-alueen metsien tilassa.

Avainsanat: Karikesato, laskeuma, maavesi, metsikkösadanta, metsäekosysteemi, puuston haihdunta.

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1 INTRODUCTION

1.1 Background

Forest investigations carried out at 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 2012). A summary of the current studies, observations and measurements is reported annually for each discipline: rock mechanics, hydrology, hydrogeochemistry, the environment and foreign materials. This report on forest monitoring at Olkiluoto in 2014 supplements preceding reporting. Results of forest monitoring during 2009–2013 have been reported by Aro et al. (2010, 2011, 2013, 2014 and 2015).

In respect of monitoring possible environmental impacts of constructing a repository for spent nuclear fuel, and later on the continuation of the monitoring related to the operational safety of the repository, two potential pathways for loads going into forests should be considered. First, the network for monitoring atmospheric deposition should be positioned with consideration to the prevailing wind direction, i.e. north-west, north or north-east of the repository. Currently some MRK and FET sampling plots are located in that area, and their usability for monitoring purposes should be assured in the future. Secondly, in the case of the repository, the Liiklansuo watershed may be one of the most important areas to monitor possible environmental impacts which occur via soil water or surface runoff. Three forest intensive monitoring plots (FIP) have been established in that area.

This report, focusing on regular annual monitoring activities, has been prepared by several authors from the Natural Resources Institute Finland (Luke). Antti-Jussi Lindroos is responsible for bulk deposition, stand through-fall and soil solution chemistry and Pasi Rautio for litterfall production and element return to the forest floor. Ari Ryynänen is responsible for maintenance of the forest intensive (FIP) and wet deposition monitoring plots (MRK), and tree stand characteristics on the FIP plots. He also organized fieldwork during forest inventory of FET plots. Lasse Aro is responsible for the rest. In addition, he has been responsible for the compiling of different chapters, as well as for the final editing of the report.

1.2 Forest inventory based on the FET plots

In addition to annual basic monitoring, a set of the tree stands belonging to the Forest Extensive monitoring plot network (FET, Figure 1, see also Ch. 2.1) was measured in summer 2014. This forest inventory produced information on the current state of forests on Olkiluoto Island, e.g. volume of growing stock, growth of trees, drains, silvicultural measures, biomass distribution, some parameters of carbon balance, biodiversity and felling possibilities in the future. It was carried out for the first time ten years ago, in 2004. The results were compared to the region of Southwest Finland, and they will also be used in biosphere assessment and as background information in many other reports. The results were published separately in the series of Posiva working reports (Korhonen et al. 2016).

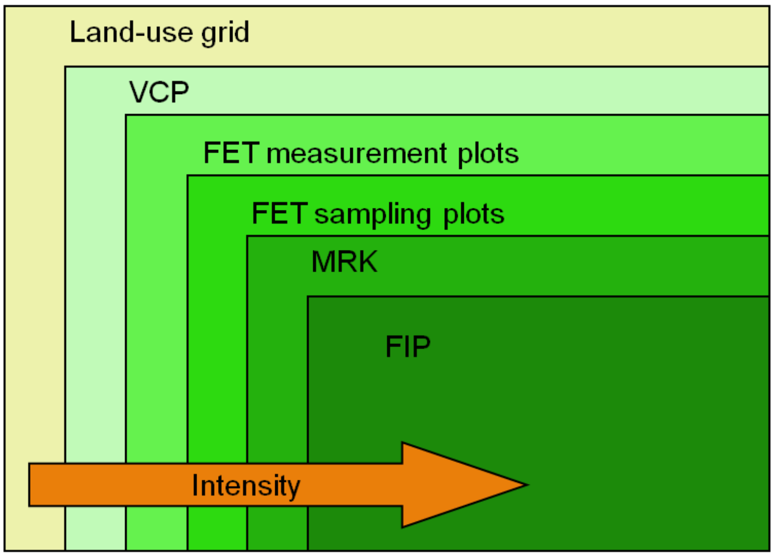

Figure 1. *Forest monitoring levels. The outermost land-use grid consists of plots at 50 m intervals. These have been visually interpreted for land-use. VCP contains the vegetation polygons, from which the forest resources have also been inventoried. The numbers of currently monitored plots are 485 (FET), 94 (FET sampling plots) and 8 (MRK), of which 6 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.*

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 is 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 the 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 subset, i.e. FET sampling plots). 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 mostly made monthly but in some cases even hourly (see Ch. 2.2). The intensity of the sampling efforts increases towards the sixth monitoring level (Figure 1).

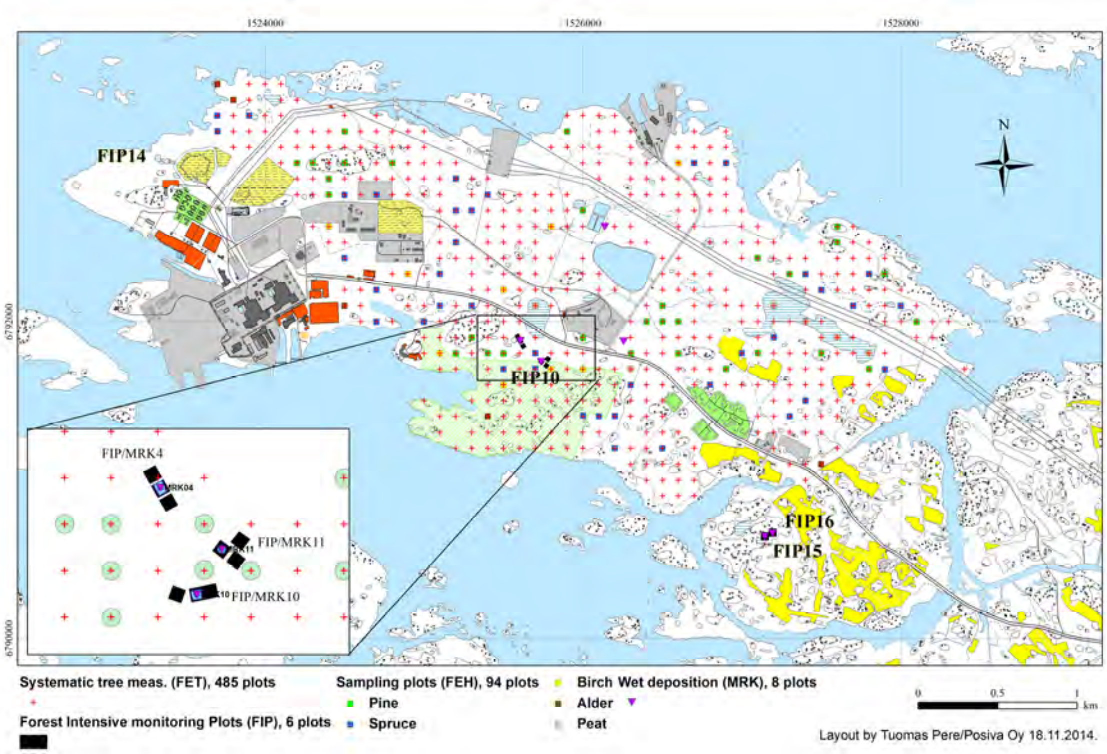

__Figure 2.__ Forest monitoring locations in 2014. Map: Posiva.

Due to continuous changes in land use on Olkiluoto Island, it is not always possible to record the up-to-date extent of each monitoring network for the second and third level. Lists on the targets in use are however regularly updated in relation to the reporting of each study carried out on them as the set of used plots varies depending on each study in question. The extent of FET and FIP networks is up-to-date in Figure 1.

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. an underground rock characterization facility and an access to the spent fuel repository) on 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 six of the monitoring plots are within FIP plots and two in open areas (Figure 3). Rainwater is collected every two weeks and snow every four weeks, and from these samples the deposition (including both dry and wet deposition) is analysed for the mean pH and the amounts of a range of anions, cations and other elements.

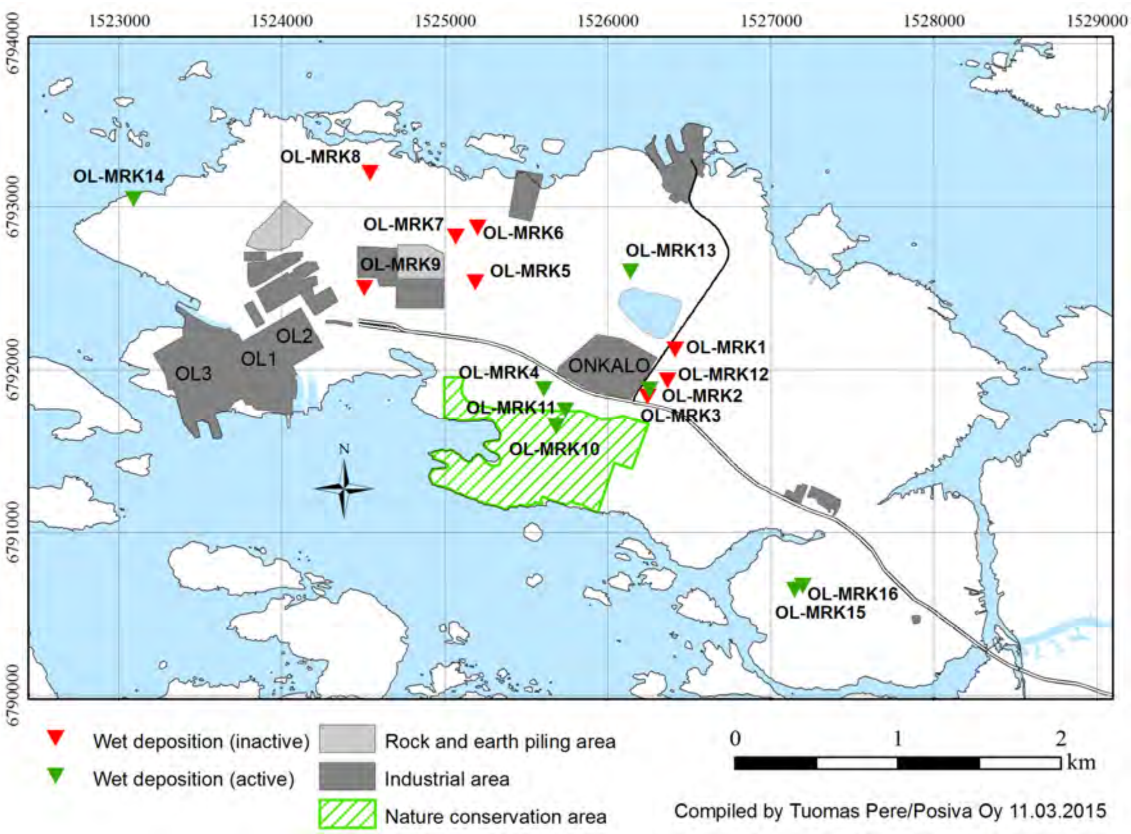

Figure 3. *Location of the wet deposition monitoring plots (MRK plots currently used in wet deposition monitoring are marked with green dots). Map: Posiva.*

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 (Table 1).

Each FIP plot (excluding FIP14, FIP15 and FIP16) 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 of only one square sub-plot (OA2, total area 900 m^2) where litter sampling, deposition, soil water collection and micro-meteorological measurements are concentrated. Plot FET930231 (total area 300 m^2), which can be used for tree growth measurements and vegetation studies (see Figure 2), is located beside the OA2 sub-plot.

FIP15 consists of only one rectangle (OA2, 20 m x 35 m = 700 m^2) where litter sampling and deposition are concentrated. FIP16 consists of only one square sub-plot as well (OA2, 30m x 30m = 900 m^2) including litterfall and deposition monitoring systems (Aro et al. 2015, p. 10). The same plots are used for tree measurements, i.e. all trees will be measured from the whole plot area every fifth year.

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, Table 2). The third intensive monitoring plot (FIP11) was established in a young birch dominated stand in the Liiklansuo catchment area during 2006–2007 (Figure 2). This birch dominated plot (FIP11) is located partly on a rocky site and the vegetation represented partly mesic heath forest vegetation (i.e. *Myrtillus* type) and partly herb-rich heath vegetation (i.e. *Oxalis-Myrtillus* type). The fourth FIP plot (FIP14, Figure 2) was established in an alder stand of a herb-rich type in 2009. The next FIP plots (FIP15 and FIP16, Figure 2) were established in Scots pine dominated stands growing on a pristine mire and in a rocky site, respectively, in Ilavainen in late 2013. The basic characteristics of the soil and vegetation of the FIP plots is presented in Table 2 and instrumentation in Table 3. Details of tree stand characteristics during 2004–2009 were presented by Aro et al. (2013), but they were updated in 2014.

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

	Performed activities FIP4	FIP10	FIP11	FIP14	FIP15	FIP16	Normal Frequency
Establishment, start of equipment installation	2003	2003	2007	2009	2013	2013	
Location and measurement of trees	2004	2005	2008	2009	2014	2014	
Vegetation inventory (OA3)	2003, 2004, 2005, 2008, 2011	2003, 2004, 2005, 2008, 2011	2008, 2011	2010			Every 5 yrs
Soil condition	2007	2007	2007	2008			Every 10 yrs
Stand throughfall and precipitation measurements (MRK, OA2)	2003	2005	2007	2009	2014	2014	Continuous
Sap flow measurements	2007	2007	no	no	no	no	Continuous
Soil water sampling (OA2)	2003	2005	2007	2010			Continuous
Litterfall sampling (OA2)	2004	2005	2007	2009	2014	2014	Continuous
Foliage sampling (OA2)[1]	2003, 2004, 2005, 2006, 2007, 2009, 2013	2004, 2005, 2006, 2007, 2009, 2013	no	2009			Every 2 yrs
Micrometeorology (OA2)	2004	2005	2007	2009			Continuous
Stem diameter growth (OA2)	2004	2005	no	no	no	no	Continuous
Tree growth (OA1)	2009, 2014	2009, 2014	2014	2014			Every 5 yrs
Crown condition survey [2]	2006	2006	no	no			Biennial
Soil microbial community structure and activity	2006	2006					
Biomass and chemical composition of vegetation and humus layers	2008	2008	2008				
Fine root biomass	2008	2008	2008				
Fine root elongation and longevity	2008 – 2011	2008 – 2011	2008 – 2011				

[1] not sampled in 2011 because results in 2009 showed no significant changes compared to the previous sampling round

[2] annually 2006–2010, biennially 2010 –

Table 2. *Basic characteristics of soil and vegetation of the FIP plots (FIP4-FIP14, Aro et al. 2014).*

FIP plot	Site type	Soil profiles	Humus thickness (cm)	Dominating tree species	The most abundant plant species in bottom and field layers
4	Herb-rich heath forest	Haplic Arenosol	4.4	Scots pine	Red-stemmed feather-moss, bracken
10	Herb-rich heath forest	Haplic Arenosol / Haplic Gleysol	9.6	Norway spruce	Red-stemmed feather-moss, bilberry
11	Mesic heath / Herb-rich heath forest	Haplic Gleysol / Histic Gleysol	7.5	Downy birch	Red-stemmed feather-moss, lingonberry
14	Herb-rich forest (grove)	Haplic Arenosol	5.7	Black alder	*Brachythecium oedipodium*, bracken [1]
15	Pristine pine mire	Histosol		Scots pine	
16	Rocky forest	Leptosol		Scots pine	

[1] based on the vegetation survey of FET930231 (Aro et al. 2011)

2.2.3 Maintenance of the FIP and MRK plots

In general, there were no major problems in the basic maintenance of the FIP and MRK plots during 2014. On the FIP4 plot one pump of the suction cap lysimeter system was replaced in spring 2014. Duckboards were rebuilt on the plots FIP4 and FIP10 in January 2014 (FIP4 only partly at first but it was complemented 3-7.11.2014, Figure 4). In addition, new duckboards were built on the FIP15 on 13-14.5.2014 (Figure 4).

The weather mast on the FIP4 plot (WOM2) should be inspected every fifth year. It was done on 14.10.2014. There was no serious damage to the mast. Some minor renovations were made according to recommendations by Trans-Antenni Oy: a vertical profile was replaced with a newer model (Figure 5), a warning sign “Falling ice and snow” was placed beside the mast, corroded bolts were replaced with galvanized ones and locked by punching threads, and guy wires were tensioned. The new recommendation for inspection of the weather mast WOM2 is eight to ten years after the previous inspection (Mastotyön … 2013).Thus the next inspection of the mast should take place in 2022.

***Table 3**. The instrumentation of the FIP plots with main installation information (i.e. the installation site in relation to the ground level and the date of installation).*

Description	FIP plot	Instrument	Quantity	Installation site	Date
Air temperature	4	FW-5k	3	2, 9 & 24 m	1.9.2004
	10	FW-5k	1	2 m	23.5.2005
	11	FW-5k	1	2 m	19.6.2007
	14	Vishay-10k	1	2 m	3.11.2009
Radiation	4	LI-190/200SZ	2	24 m	1.9.2004
Air pressure	4	PTB210	1	2 m	26.4.2005
Wind	4	Adcon	1	24 m	1.9.2004
Relative humidity	4	HMP45D	2	2 & 9 m	1.9.2004
	10	HMP45D	1	2 m	23.5.2005
	11	HMP45D	1	2 m	19.6.2007
	14	HMP45D	1	2 m	3.11.2009
Precipitation	4	RMY-52203	1	1 m	1.9.2004
	10	RMY-52203	1	1 m	23.5.2005
	11	RMY-52203	1	1 m	19.6.2007
Soil temperature	4	FW-5k, Vishay-10k	13	-10 … -90 cm	1.9.2004
	10	FW-5k	13	-10 … -90 cm	23.5.2005
	11	FW-5k	13	-10 … -90 cm	19.6.2007
	14	Vishay-10k	13	-10 … -90 cm	3.11.2009
Soil moisture	4	Theta Probe	2	-20 cm	1.9.2004
	10	Theta Probe	2	-20 cm	23.5.2005
	11	Theta Probe	2	-20 cm	19.6.2007
	14	Theta Probe	2	-20 cm	3.11.2009
Soil solution	4	Plate lysimeter	8	-5 cm	Sept. 2003
		Suction cup	12	-10, -20, -30 cm	Sept. 2003
	10	Plate lysimeter	12	-5 cm	May 2005
		Suction cup	24	-20, -30 cm	May 2005
	11	Plate lysimeter	8	-5 cm	13.12.2006
		Suction cup	12	-10, -20, -30 cm	13.12.2006
	14	Plate lysimeter	4	-5 cm	29.10.2009
Litterfall	4	Funnel type sampler	12	150 cm	June 2004
		Branch type	12	0 cm	7.5.2008
	10	Funnel type sampler	12	150 cm	12.5.2005
		Branch type	12	0 cm	7.5.2008
	11	Funnel type sampler	12	150 cm	25.4.2007
	14	Funnel type sampler	12	150 cm	15.5.2009
		Branch type	12	0 cm	30.6.2010
	15	Funnel type sampler	12	150 cm	14.5.2014
	16	Funnel type sampler	12	150 cm	14.5.2014

***Table 3 cont'd**. The instrumentation of the FIP plots with main installation information (i.e. the installation site in relation to the ground level and the date of installation).*

Description	FIP plot	Instrument	Quantity	Installation site	Date
Stand throughfall	4	Snow sampler	5	180 cm	2.6.2003
		Rainwater collector	20	40–60 cm	2.6.2003
	10	Snow sampler	5	180 cm	23.5.2005
		Rainwater collector	20	40–60 cm	23.5.2005
	11	Snow sampler	5	180 cm	16.11.2007
		Rainwater collector	20	40–60 cm	May 2007
	14	Snow sampler	5	180 cm	17.9.2009
		Rainwater collector	20	40–60 cm	15.5.2009
	15	Snow sampler	5	180 cm	14.5.2014
		Rainwater collector	20	40–60 cm	14.5.2014
	16	Snow sampler	5	180 cm	14.5.2014
		Rainwater collector	20	40–60 cm	14.5.2014
Tree growth	4	Girth band	2	130 cm	1.9.2004
	10	Girth band	2	130 cm	23.5.2005

Figure 4. *Rebuilt duckboards on FIP10 (a, b) and FIP4 (c) in January 2014 and on FIP4 in November 2014 (f-g), and new duckboards on FIP15 in May 2014 (e). In addition, all lysimeter signs were replaced (d). Photos: 4a-d and 4f-g A. Ryynänen, and 4e J. Ilomäki/Luke.*

Figure 5. *A vertical profile (left, marked with an arrow) was replaced with a newer model (right). Photos: A. Ryynänen/Luke.*

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, Table 4). The monitoring was performed during 2014 on 6 plots, of which two were located in open areas (MRK2 and MRK13), one in the Scots pine stand (MRK4), one in the Norway spruce stand (MRK10), one in the young birch dominated stand (MRK11) and one plot in the alder dominated stand (MRK14). Deposition monitoring was also started on two new Scots pine dominated plots (MRK15 and MRK16) in June 2014.

The results for bulk deposition and stand throughfall during the period 8.1.2014-7.1.2015 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 2014. The results for 2014 are compared to the deposition load during the period 2004-2013 on Olkiluoto, as well as to the deposition load on two intensively monitored plots (one pine and one spruce) in Juupajoki, central Finland and two plots (one pine and one spruce) in Tammela, southern Finland (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 and Vantaa Units. In addition, duplicates of the samples were sent by Posiva to ALS Scandinavia for high-resolution element analysis of elements critical for the safety case. Results of these analyses are reported separately each year as appendixes in Posiva's annual reports of environmental monitoring (e.g. Pere et al. 2015).

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 was 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 2014. However, storm events caused some problems to the collection and samples, but this disturbance was taken into account in the evaluation of the results as well as possible.

Table 4. *Basic characteristics of the establishment and deposition monitoring of the MRK plots. Type: TF=stand throughfall, BD=bulk deposition. V=total stem volume with bark (m^3/ha, all tree species included; see also Aro et al. 2013).*

MRK plot	Established	Type	Tree species (dominating)	V (m^3/ha)	Monitoring period
1	6/2003	TF	Scots pine	134[a]	6/2003 – 3/2008
2	6/2003	BD	open area	0	6/2003 – 12/2007, 4/2008 –
3	6/2003	TF	Scots pine	171[a]	6/2003 – 3/2008
4	6/2003	TF	Scots pine	303[b]	6/2003 –
5	6/2003	TF	Norway spruce	176[a]	8/2003 – 3/2008
6	6/2003	TF	Norway spruce	154[a]	8/2003 – 3/2008
7	6/2003	BD	open area	0	6/2003 – 3/2008
8	6/2003	TF	Norway spruce	221[a]	6/2003 – 3/2008
9	4/2004	BD	open area	0	4/2004 – 3/2008
10	5/2005	TF	Norway spruce	473[b]	5/2005 –
11	5/2007	TF	birch	17[c]	5/2007 –
12	10/2007	BD	open area	0	1/2008 – 3/2008
13	5/2009	BD	open area	0	5/2009 –
14	5/2009	TF	Black alder	147[d]	7/2009 –
15	5/2014	TF	Scots pine	64[e]	6/2014 –
16	5/2014	TF	Scots pine	85[e]	6/2014 –

[a] in March 2007 [b] in May 2008 [c] in June 2008 [d] in November 2009 [e] in March 2014

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
PO_4-P	mg/l	0.13
SO_4-S	mg/l	0.05
Al	mg/l	0.005
B	mg/l	0.004
Ca	mg/l	0.0004
Cd	mg/l	0.0007
Cl	mg/l	0.1
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	0.01
Ni	mg/l	0.002
P	mg/l	0.06
Pb	mg/l	0.005
Si	mg/l	0.006
Zn	mg/l	0.002
Ba	mg/l	0.0001
Nb	mg/l	0.002
Pd	mg/l	0.005
Sn	mg/l	0.004
Sr	mg/l	0.0001
Ta	mg/l	0.006
Te	mg/l	0.010
V	mg/l	0.001
W	mg/l	0.010

3.2 Soil solution on FIP plots

3.2.1 Method of sampling soil solution

The chemical composition of soil solution is 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 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 6). 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 measured and modelled in order to be able to determine ion fluxes between the individual soil horizons in tree stands.

Two sampling techniques are 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 the 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, on FIP11 (young mixed stand) on 1.6.2007, and on FIP14 (alder stand) on 16.6.2010.

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) programme. 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 (Table 6) were carried out by the laboratory staff of the Rovaniemi and Vantaa Units.

3.2.2 Amounts of percolation water

Percolation water was collected during the snow-free periods in 2004-2014 on plot FIP4, in 2005-2014 on plot FIP10, in 2007-2014 on plot FIP11 and in 2010-2014 on FIP14 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. On plot FIP14 there was a total of 4 plate lysimeters at one sampling point. The collection period of the percolation water starts in the spring after snowmelt when the ground is no longer frozen.

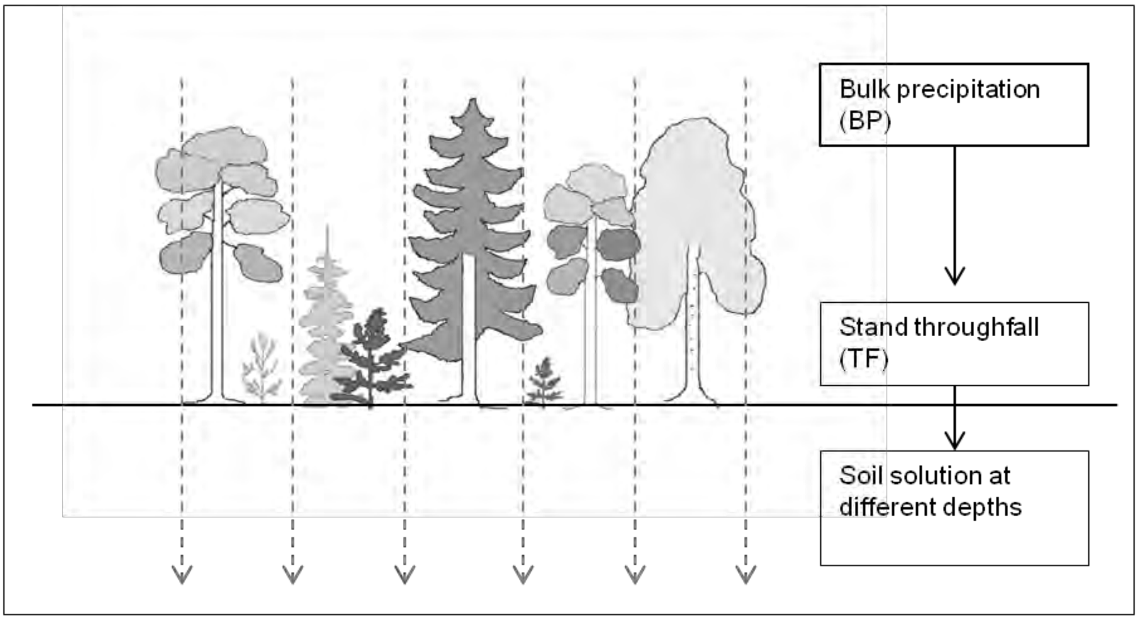

Figure 6. *A schematic presentation showing the path of water down through forest ecosystems, and the different components taken for chemical analysis (Drawing: A. Hamari/Luke).*

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
PO_4-P	mg/l	0.13
SO_4-S	mg/l	0.05
Al	mg/l	0.005
B	mg/l	0.004
Ca	mg/l	0.0004
Cd	mg/l	0.0007
Cl	mg/l	0.1
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	0.01
Ni	mg/l	0.002
P	mg/l	0.06
Pb	mg/l	0.005
S	mg/l	0.07
Si	mg/l	0.006
Zn	mg/l	0.002
Ba	mg/l	0.0001
Nb	mg/l	0.002
Pd	mg/l	0.005
Sn	mg/l	0.004
Sr	mg/l	0.0001
Ta	mg/l	0.006
Te	mg/l	0.010
V	mg/l	0.001
W	mg/l	0.010

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 6).
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 snow-free 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). In the young mixed stand, soil solution was collected 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 for each depth), systematically located on the plot during the snow-free period. Only 4 plate lysimeters were used to collect soil solution in the alder stand. 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 per sampling occasion.

3.3 Tree stand transpiration on the plots FIP4 and FIP10

The tree stand transpiration measurements on Olkiluoto Island were initiated in a Scots pine stand (FIP4) and in a Norway spruce stand (FIP10) in early May and early June 2007, respectively. The measurement system was enlarged with three new trees on both the plots in April 2010. The aim was to measure tree-level transpiration as a basis for calculating the stand transpiration rate and variability in the FIP areas. The measurement system and calculation of stand transpiration was described in more detail by Aro et al. (2014).

Due to missing data or unrealistically high peaks in signal data, it was not possible to report stand level transpiration on a monthly basis for January to March and December (see Aro et al. 2015). Due to technical problems we are not able to report the transpiration of the Norway spruce stand (FIP10) in 2011–2014. Finally, sap flow measurements were finished on the FIP10 plot in 2014. Severe technical problems also occurred in sap flow measurements in the Scots pine stand (especially in the FIP4-SF1 logger system) in 2014. This meant that transpiration calculations of the Scots pine stand were based on three trees only. It is probable that technical problems will stop transpiration rate calculations also in the pine stand in the near future.

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

Litterfall was collected using 12 traps according to the methods defined by UN/ECE ICP Forests (Pitman et al. 2010) located systematically on FIP4 (pine), FIP10 (spruce), FIP11 (deciduous forest) and FIP14 (black alder) plots in 2013. 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 and FIP14) at the end of May 2013. Since the last collection date in 2012 was at the end of November (13.11.2012), the mass of the first collection in May 2013 represents the litterfall of the whole previous winter. Since the pretreatment of litter samples is laborious and time-consuming, the results of litterfall production and its chemical composition are available one year later than the other forest monitoring results.

In 2013 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 (Pitman et al. 2010). Branches (fraction 6) collected by this trap are rather small. To collect the whole spectrum of branch litter we used a new type of traps that are positioned on the ground. These new "branch traps", which consist of a nylon fabric stretched on a frame of approximately two centimetres in 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 (Pitman et al. 2010), mainly to collect foliage litter. 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 on the plots FIP4, FIP10 and FIP14.

Due to harsh environmental conditions (a hard coastal wind and strongly fluctuating sea water level) on the plot FIP14 during winter months, branch traps 5-12 were removed from the site for winter time (from November 2014 to May 2015). Those traps have not always held their original positions, and thus the reliability of the results may be impaired.

Litterfall production (dry mass in grams/m^2; 105°C) is reported for each of these fractions separately for each collection occasion. Element concentrations (aluminium, barium, boron, calcium, carbon, chromium, copper, iron, magnesium, manganese, nickel, nitrogen, phosphorus, potassium, sodium, strontium, sulphur, tin, vanadium and zinc) 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. Here we present concentrations of Al, Fe and N; concentrations of other elements can be found in the POTTI database. Concentrations of cadmium, lead, molybdenum, niobium, palladium, tantalum, tellurium and wolfram were in most cases below the limit of quantification.

3.5 Defoliation of trees on the plots FIP4 and FIP10

A 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 (Eichhorn et al. 2010).

3.6 Tree stand characteristics on the FIP plots

According to the monitoring programme, trees are measured on the FIP plots (sub-plot OA1) every fifth year. 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. Due to the high number of young trees on the FIP11 plot, trees were measured from nine systematically positioned circle plots on sub-plot OA1 (Figure 7). FIP4 was measured on 10.3.2014, FIP10 on 27.10.2014, FIP11 on 11.3.2014, FIP14 on 28.10.2014, FIP15 on 14.3.2014 and FIP16 on 13.3.2014. 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).

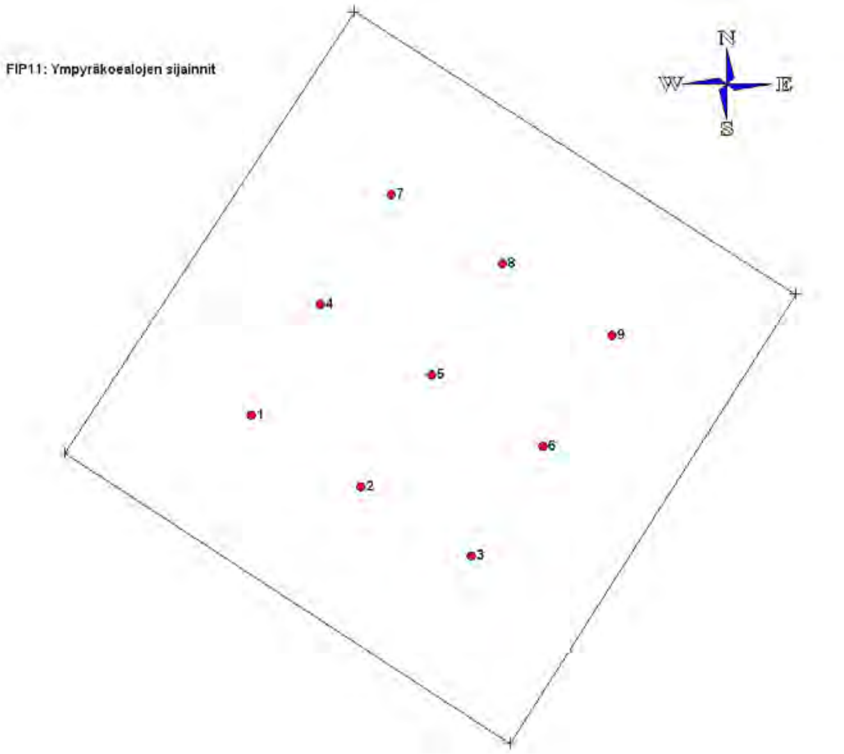

Figure 7. *For the tree stand measurements, nine circles (r=2 m, A=12.56 m^2, resulting in a sampling percentage of 13%) were systematically located on the sub-plot OA1 of the FIP11 (circle no. 5 in the centre of the plot, circles 1, 3, 7 and 9 in the middle of the diagonals).*

3.7 Thickness of the organic layers on the FET plots

In connection with forest stand measurements of FET plots (Korhonen et al. 2016), thickness (accuracy 1 cm) and type of organic layers were also determined. For each plot four investigation points were used positioning 5.64 m north, east, south and west from the plot centre (Maastotyön ohjeet 2014, Fig. 6, p. 3-18). The litter layer was measured separately.

3.8 Temperature sum and stand meteorology in the area

The length of the growing season and corresponding effective temperature sum (GDD, threshold +5^{o}C, measuring height 2 m) on FIP plots (code for Olkiluoto weather stations, WOM) for 2014 were in line with previous years (Figure 8) and were as follows:

FIP4 (WOM2)	17.4.-19.10.2014	1460 GDD
FIP10 (WOM3)	17.4.-4.11.2014	1558 GDD
FIP11 (WOM4)	9.5.-19.10.2014	1389 GDD
FIP14 (WOM5)	9.5.-19.10.2014	1348 GDD

Figure 8. *Effective temperature sum (GDD) in Scots pine (FIP4), Norway spruce (FIP10), birch (FIP11) and black alder (FIP14) dominated stands during 2005-2014.*

Measurement of the stand meteorology suffered some problems during 2014 (Table 7). The revised data were stored in the POTTI database. Original primary data have also been stored in the POTTI database (processing stage=MEAS, status=not in use).

3.9 POTTI database and Kronodoc

Data from measurements and analyses have been stored in the POTTI database (Posiva's research result database). Definitions for data in POTTI are presented in Appendix 1, and a list of data in the POTTI database in Appendix 2. POTTI is a database built to store the official results from Posiva's research activities. The database is based on Oracle and it has a browser interface for both Posiva's internal use and users outside Posiva. The data in the database go through a review process.

In 2011 Posiva and Teollisuuden Voima Oyj (the company which owns and operates two nuclear power plant units, Olkiluoto 1 and Olkiluoto 2 at Olkiluoto) set up a GIS (Geographical Information System) database to use and share geographical information between these two companies on the Olkiluoto Island. The database is built on ESRI ArcGIS Server software and gives the companies better possibilities to plan land use on the island and also for Posiva to store spatial data.

In addition, instructions and manuals of sampling and forest monitoring, preliminary results and reports under preparation have been stored in the Kronodoc system. Kronodoc (BlueCielo ECM Solutions) is a secured documentation system used by Posiva to archive official documents and also to provide an environment for workgroups to share their materials and work with them. Posiva's Kronodoc is divided into different workspaces of which Posidoc (POS prefix) mainly stores administrative or otherwise official internal documents, and Projects (PRJ prefix) is a working space also open for users outside Posiva. Material related to this report available in Kronodoc is shown in Table 8 (for the period 2003-2014, see Appendix 3).

Table 7. *Problems in the stand meteorological measurements, their date of occurrence and the correction method applied on the FIP plots.*

Plot	Parameter	Channel no.	Date	Correction method/ comment
FIP4	Soil temperature -30 cm	1	2014	Not in use
	Soil temperature -10 cm (3)	11	2014	Not in use
	Soil temperature -60 cm	4	5.11.2014	Previous and following true values used to replace data spikes
	Air temp 9 m (min)	33	5.1.2014 13:00	
	Soil moisture –20 cm (2)	31	1.1. - 4.3.2014 13:00	False data removed
			11.11.2014 20:00 – 31.12.2014	
	All	All	6.12. 06:00 - 7.12.2014 10:00	False data removed
	Relative humidity, 9 m (mean, min, max)	27, 41, 42	1.1.– 13.5.2014 8:00	False data removed
FIP10	Soil temperature -30 cm	1	17.1.2014 13:00, 6.2.2014 10:00, 16.2.2014 06:00, 4.5.2014 11:00, 19.11.2014 03:00	Previous and following true values used to replace data spikes
	Soil temperature -70 cm	5	18.1.2014 05:00 27.2.2014 13:00	see above
	Soil temperature -80 cm	6	22.1.2014 18:00 3.3.2014 03:00	see above
	Soil temperature –20 cm (1)	12	20.7.2014 20:00 31.7.2014 12:00 7.8.2014 14:00	see above
FIP11	Soil temperature –10 cm (2)	B2	14.1. 13:00 – 15.1.2014 00:00	No data
	Soil moisture –20 cm (1)	B7	30.5. 13:00 – 31.5.2014 00:00	No data
	Soil moisture –20 cm (2)	B8	8.1. 01:00 – 12:00	No data
	Soil moisture –20 cm (3)	C6	11.12. 02:00 – 12.12.2014 03:00	False data removed
FIP14	Soil moisture –20 cm (1)	B7	31.5. 14:00 – 1.6.2014 11:00	No data
	Soil moisture –20 cm (2)	B8	1.1. 01:00 – 9.1.2014 03:00	False data removed
			22.1. 07:00 – 3.2.2014 09:00	
	Relative humidity, 2 m	C7	6.12. 14:00 – 7.12.2014 13:00	No data

3.10 Sample archiving in the Environment Specimen Bank

Most of the analysed soil and plant samples (Table 9) from permanent monitoring networks on Olkiluoto Island are archived in the Environment Specimen Bank located in Northern Finland, Paljakka. The rest of the samples are archived temporarily at the Parkano Unit of the Natural Research Institute Finland or in Posiva's laboratory in Eurajoki.

Paljakka Environmental Specimen Bank (ESB) provides a high quality storage facility for the conservation of environmental samples. It includes nine fireproof storage rooms focusing on long-term (>10 years) storage and the supply of plant specimens for the needs of biomonitoring and environmental research. Only dried plant material is stored in the Paljakka ESB at the present time. Real-time monitoring of air temperature and humidity is established inside the storage rooms to ensure accurate conditions, since stabilized storage conditions can increase specimen "lifetime" to decades or even hundreds of years. Both the ambient air inside storage rooms and air in storage bags and boxes are monitored. (http://www.metla.fi/metsat/paljakka/ympanp/ympanp-en.htm)

Samples have been dried at 40 °C (mineral soil) or 60 °C (organic material such as humus, peat, different parts of plants and trees, litter fall fractions etc.). Samples of organic material have mostly been archived as powder. These samples can be used as reference material describing conditions before starting to operate a spent nuclear fuel repository. Sample archiving also has the following purposes:

1. Repeat analysis for confirming the quality of the original analysis or determining the significance of deficiencies in the original analysis
2. Deferred analysis allowing priorities to be set for analysis of stored samples subsequent to intensive field sampling
3. Enhanced analysis using improved techniques

Samples in Luke's Parkano unit or in Posiva's laboratory have been stored temporarily either for deferred or enhanced analyses (most of them after pre-treatment at room temperature). Only a minor part of the samples has been stored in a freezer in Eurajoki. Deferred analyses include typical determinations of nutrient concentrations but also some analyses of key elements being important in safety assessment. Enhanced analyses means typically that samples will be analysed with ICP-MS (or similar) in the near future. Later these samples will also be archived in the Environment Specimen Bank.

Table 8. *Material stored in Kronodoc related to forest monitoring on Olkiluoto island in 2014.*

Description	Kronodoc no.
Results of forest monitoring on Olkiluoto Island in 2014, incl. state of forests on Olkiluoto in 2014, defoliation of trees, tree measurements etc.	PRJ-006997
Stand meteorology (FIP plots, WOM2-WOM5)	PRJ-006090
Results of deposition monitoring at MRK and FIP plots	PRJ-004074/POS-010859
Results of litter nutrient analyses in FIP plots	PRJ-006085
Results of soil solution chemistry from lysimeters elsewhere than at the FIP plots	PRJ-006173
Paljakkaan toimitetut Metlan arkistonäytteet (Archive samples stored in the Environmental Specimen Bank of the Finnish Forest Research Institute, Paljakka)	PRJ-005707
Olkiluodon hakkuut (Thinnings on Olkiluoto Island)	PRJ-002838
Ympäristötutkimuksen havaintopaikkakoodit ja numerointi (Codes for study sites in the environmental monitoring)	POS-000523
Seurantatutkimukset metsän intensiivihavaintoaloilla (toiminta kenttätutkimusten yhteydessä) (Monitoring studies on Forest intensive plots, field instructions)	POS-000659
Tietojen tarkastus ja hyväksyntä POTTI-järjestelmässä (Data checking and approving in the POTTI database)	POS-002807
Puuston runkohaihdunnan laskeminen (Estimating tree stand transpiration)	POS-003795

Table 9. *Samples stored in the Environment Specimen Bank of the Natural Resources Institute Finland. Site= monitoring network or research area, Collection period= time of collection of specified sample material, Archived= year of archiving the samples to the Specimen Bank, Box no.= codes for archived sample boxes.*

Material	Site	Collection period	Archived	Box no.
Needles (c, c+1)	MRK	2003 – 2007	2012	540 – 548
Needles, leaves	FET	2005 – 2006	2012	549 – 581
Litter fractions	FIP	2004 – 2008	2012	582 – 585
Plant species samples	FIP	2008	2012	586
Mineral soil, humus	FET	2005	2012	587 – 612
Mineral soil, humus, peat	FIP	2007	2013	772 – 774
Peat samples	FET	2005	2013	775 – 777
Tree leaves (not milled)	FET	2005	2013	778 – 784
Plant species samples	FET	2005	2013	785 – 786
Needles	MRK	2010	2013	787
Litter fractions	FIP	2009	2013	788
Tree samples (wood, bark)	TMA50	2008	2013	789
Tree samples (foliage etc.)	TMA50	2008	2013	790
Litter fractions	FIP	2010 – 2012	2014[a]	791 – 797
Humus samples	FIP	2008	2014[a]	798 – 801
Litter (remaining fraction from branch traps)	FIP	2008 – 2013	2014[a]	802 – 829
Litter fractions	FIP	2013	2014[a]	830 – 831

[a] will be transported to Paljakka Environment Specimen Bank in 2015

4 RESULTS AND DISCUSSION

4.1 Bulk deposition and stand throughfall

The amount of precipitation in 2014 in open areas (bulk deposition, BD) and stand throughfall (TF) was at a relatively similar level to that in 2013 (Figure 9). There were no clear increasing or decreasing trends in the pH of BD and TF during the period 2004-2014. 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 respectively.

There was variation in the deposition of total nitrogen in BD and TF during 2004-2014. The values were lower in BD during 2013 and 2014 compared to 2012 and 2011. In 2011 deposition was the highest for the whole monitoring period. There was also variation in NO_3-N (Figure 10) deposition in BD and TF over the years, but the values were in general comparable to those measured at the Juupajoki and Tammela reference plots. However, the highest NO_3-N deposition so far in BD in Olkiluoto was measured in 2012 but the values decreased in 2013 and remained at a similar level also in 2014. The NH_4-N (Figure 11) deposition increased clearly in 2011 compared to earlier years on both BD plots and one TF plot, MRK14. These values were also higher than those on the references plots in Juupajoki and Tammela. The highest annual N_{tot} and NH_4-N deposition in TF during 2004-2014 was measured on the new black alder plot in 2011. The increase in NH_4-N deposition was considered to probably be due to the construction activities in the area. However, in 2012-2014 the NH_4-N deposition decreased on these plots to a level close to the general level during the whole monitoring period as well as close to the level on the reference plots.

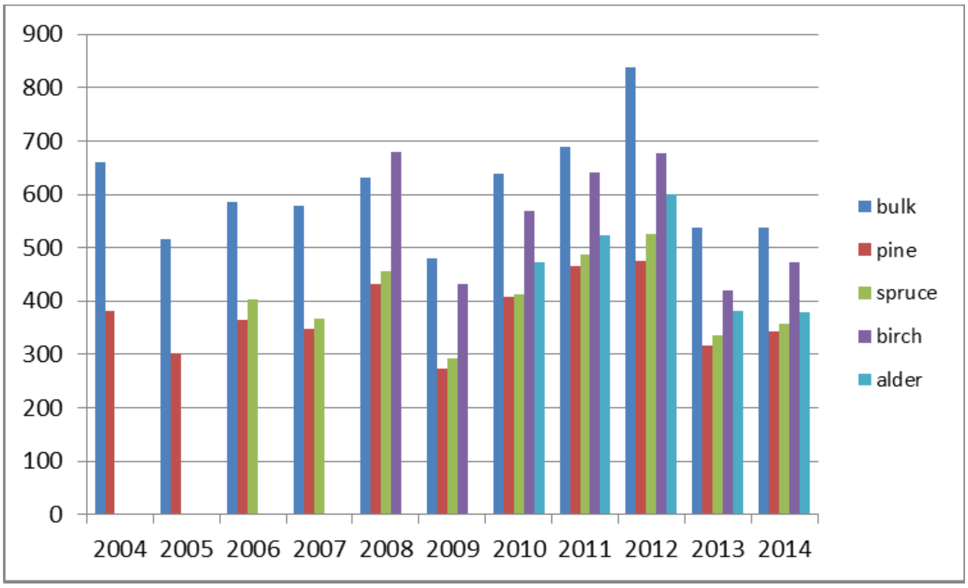

Figure 9. *Annual precipitation (mm) in open areas (bulk deposition) and stand throughfall in Scots pine (FIP4), Norway spruce (FIP10), birch (FIP11) and black alder (FIP14) dominated stands during 2004-2014.*

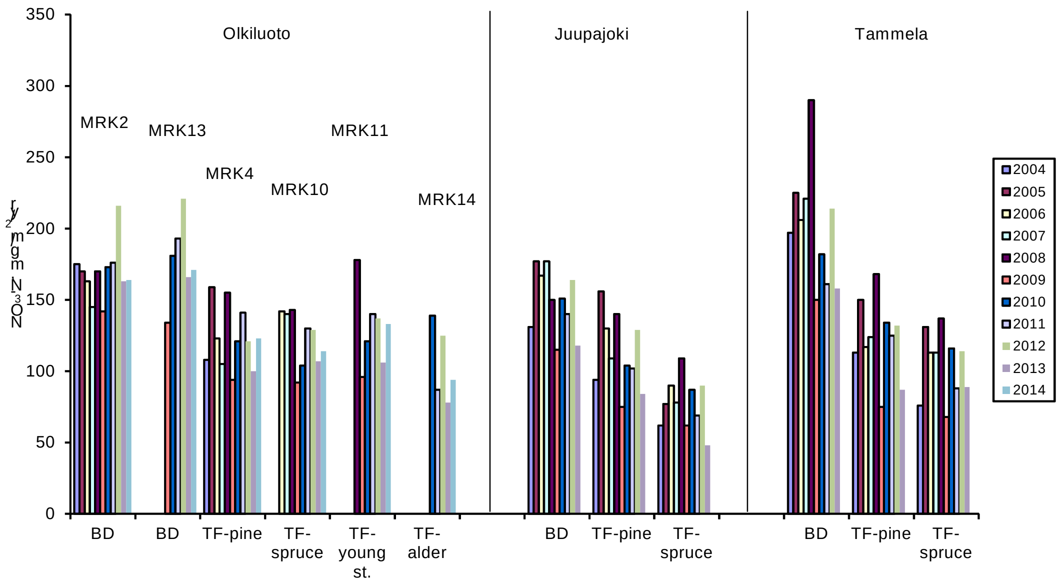

Figure 10. *The NO_3-N deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2014. The sample plots and tree species are indicated in the Figure (young st.= young birch dominated stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison.*

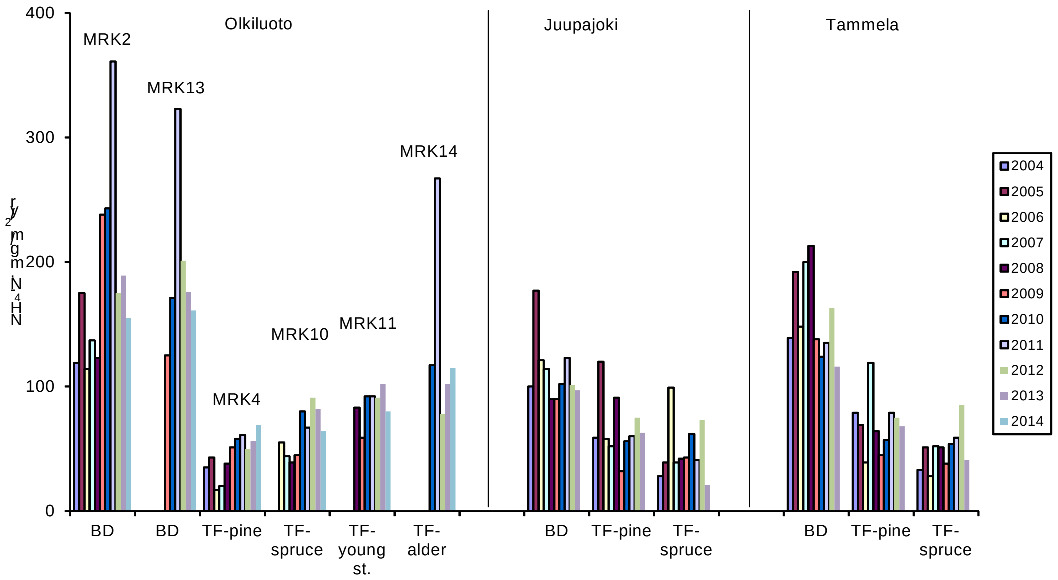

Figure 11. *The NH_4-N deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2014. The sample plots and tree species are indicated in the Figure (young st.= young birch dominated stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison.*

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 and utilization by the mosses, lichens and microflora on the needle surfaces). Nitrogen retention in the tree canopies is a well-documented phenomenon in coniferous stands in Finland.

The sulphur (SO_4-S) deposition in BD on plot MRK2 was in general higher during 2009-2014 compared to that during 2004-2008. On the plot MRK13 (BD, open area) the sulphur deposition was comparable to that on plot MRK2 except in 2014. The S deposition in an open area on Olkiluoto was higher during 2009-2014 than on the reference plots at Tammela and Juupajoki (Figure 12). The TF deposition at the Tammela spruce plot was clearly higher than in Olkiluoto or Juupajoki. The SO_4-S and Ca depositions were clearly elevated in 2014 on the plot MRK13 which is located close to the construction activities. Elevated concentrations of these elements were detected in BD especially in June 2014 (Figure 13), and this fact was reflected also in the annual deposition. A possible reason for this observation could be the $CaSO_4$ used in the construction activities. The SO_4-S and Ca concentrations followed each other closely also in TF (Figure 14).

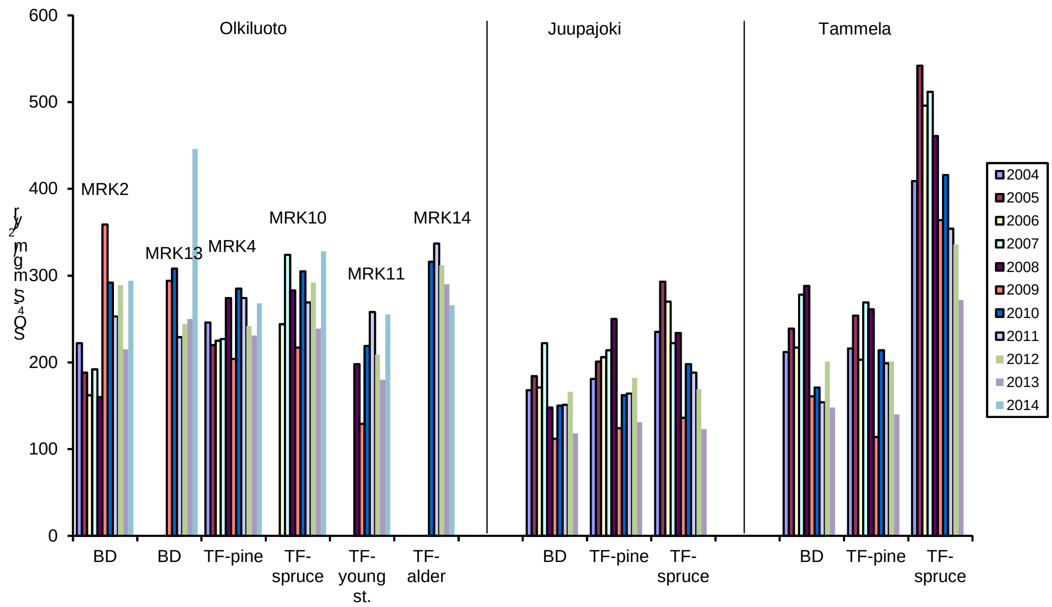

Figure 12. *The SO_4-S deposition in bulk deposition (BD, open area) and stand throughfall (TF, inside the stand) on Olkiluoto in 2004-2014. The sample plots and tree species are indicated in the Figure (young st.= young birch dominated stand). Reference values for ICP Forests plots at Juupajoki and Tammela are given for comparison.*

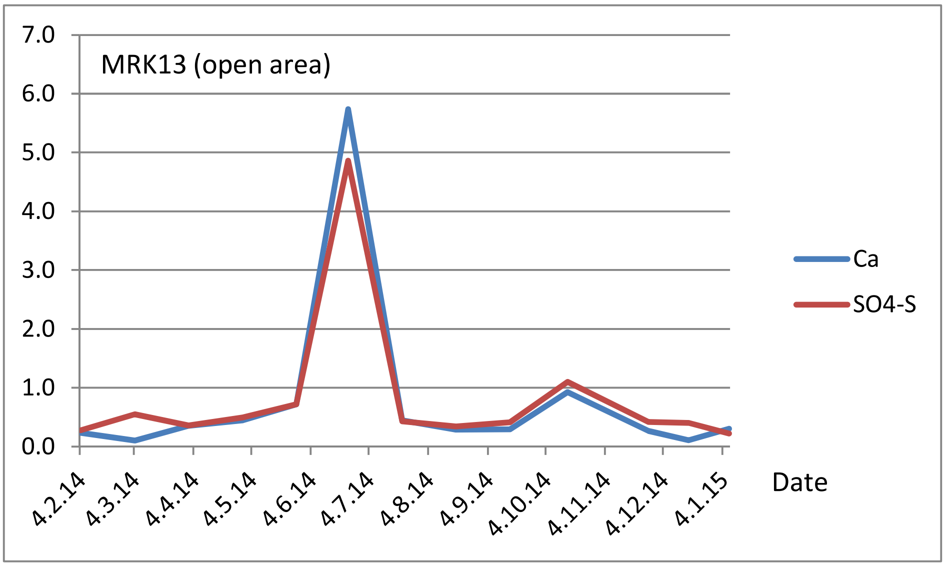

Figure 13. *Ca and SO_4 concentrations (mg/l) in bulk deposition (BD) on the MRK13 plot in 2014.*

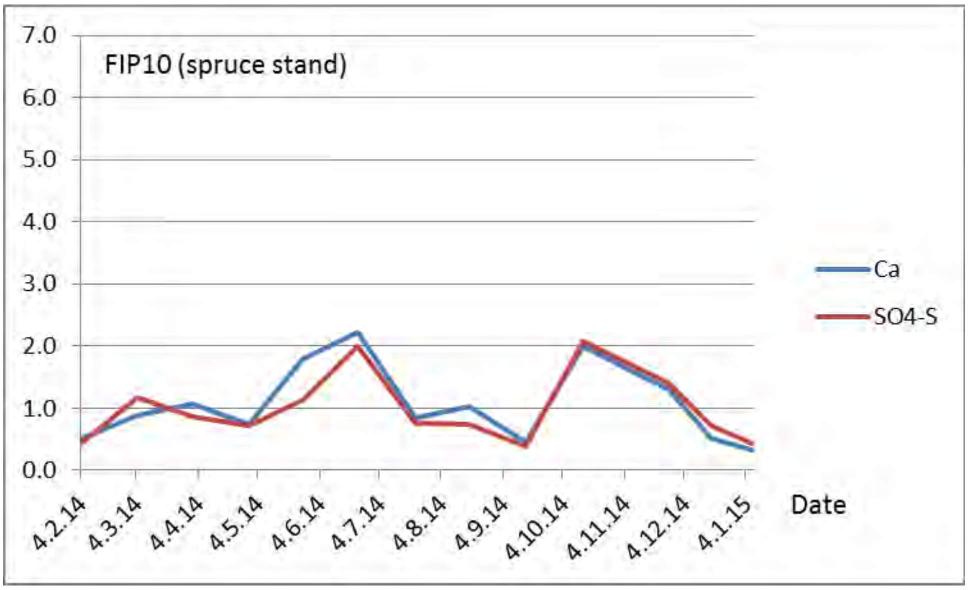

Figure 14. *Ca and SO_4 concentrations (mg/l) in stand throughfall (TF, inside the spruce stand) on the FIP10 plot in 2014.*

The deposition of base cations (Ca, Mg and 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 higher on plot MRK2 in 2009-2014 compared to 2004-2008. The relatively high deposition of Cl (with associated Na) at Olkiluoto is due to the proximity of the sea. This was especially the case on the new black alder plot MRK14 in 2011-2014. Storm events in the late autumn probably also affected these values somehow due to the fact that the sea is located close to the plots. 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 was relatively similar in 2014 compared to the values in earlier years.

The concentrations of all the measured BD and TF samples during 2014 were below or close to the limit of quantification for Cd, Cr, Ni, Pb, Nb, Pd, Sn, Ta, Te, V and W. Measureable concentrations could be determined generally in BD and TF samples in 2014 for Ba and Sr.

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 snow-free period of 2004-2014. In 2014 the value was 17%. Corresponding values on the plots FIP10 (during 2005-2014) and FIP11 (during 2007-2014) were 1-28% (10% in 2014) and 1-17% (9% in 2014), 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 proportion of percolation water passing down to a depth of 5 cm on plot FIP14 (black alder) was 22% of the input to the forest floor (stand throughfall) during 2010, 23% during 2011, 29% during 2012, 20% during 2013, and 21% during 2014, i.e. comparable to the other plots.

Overall, the pH of the soil solution clearly increased with increasing depth on FIP4. The pH of the soil solution at depths of 5-30 cm remained relatively constant throughout the 11-year monitoring period, without any strong increasing or decreasing trends. However, the pH at a depth of 5 cm has decreased slightly over the years (Figure 15, depth 5 cm). The pH values at a depth of 5 cm were fully comparable to a site of similar fertility at Tammela (years 2004-2010, Nieminen et al. 2013). There has been a slightly decreasing trend in the DOC concentration at a depth of 5 cm during the monitoring period 2004-2013, but the DOC concentration increased in 2014 (Figure 15). Overall, the DOC concentration of the soil solution clearly decreased with increasing depth (Figure 16). The reason for this decrease is the fact that DOC is precipitated into the enrichment layer (B-horizon) of the forest soils under the conditions leading to podzolisation. The DOC concentration decreases also due to biological degradation processes. The decrease in DOC values with increasing depth is a very typical phenomenon in Finnish forest soils. The DOC concentrations at a 5 cm depth during all the 11 years were 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. The installation of the suction cup lysimeters in 2003 undoubtedly caused a short-term flush of DOC.

The pH of the soil solution at depths of 5, 20 and 30 cm on FIP10 during 2014 was comparable to a general level measured on this plot during the earlier years (2005-2013). However, the pH has decreased slightly over the years at a depth of 5 cm as was also the case for the plot FIP4 (Figure 15, depth 5 cm). The pH values at a depth of 5 cm were fully comparable to a site of similar fertility at Tammela (years 2005-2010, Nieminen et al. 2013). The DOC concentrations at all three depths were relatively high, but not excessively high for forest soils rich in organic matter under a coniferous tree stand. There has been a slightly decreasing general trend in the DOC concentration at a depth of 5 cm during the monitoring period 2004-2014 (Figure 15).

The pH of the soil solution is relatively high at all sampling depths on FIP11 (Figure 15). The DOC concentrations were relatively high at depths of 10-30 cm, but at a depth of 5 cm, the values have been lower compared to the situation on the plots FIP4 and 10 (Figure 15).

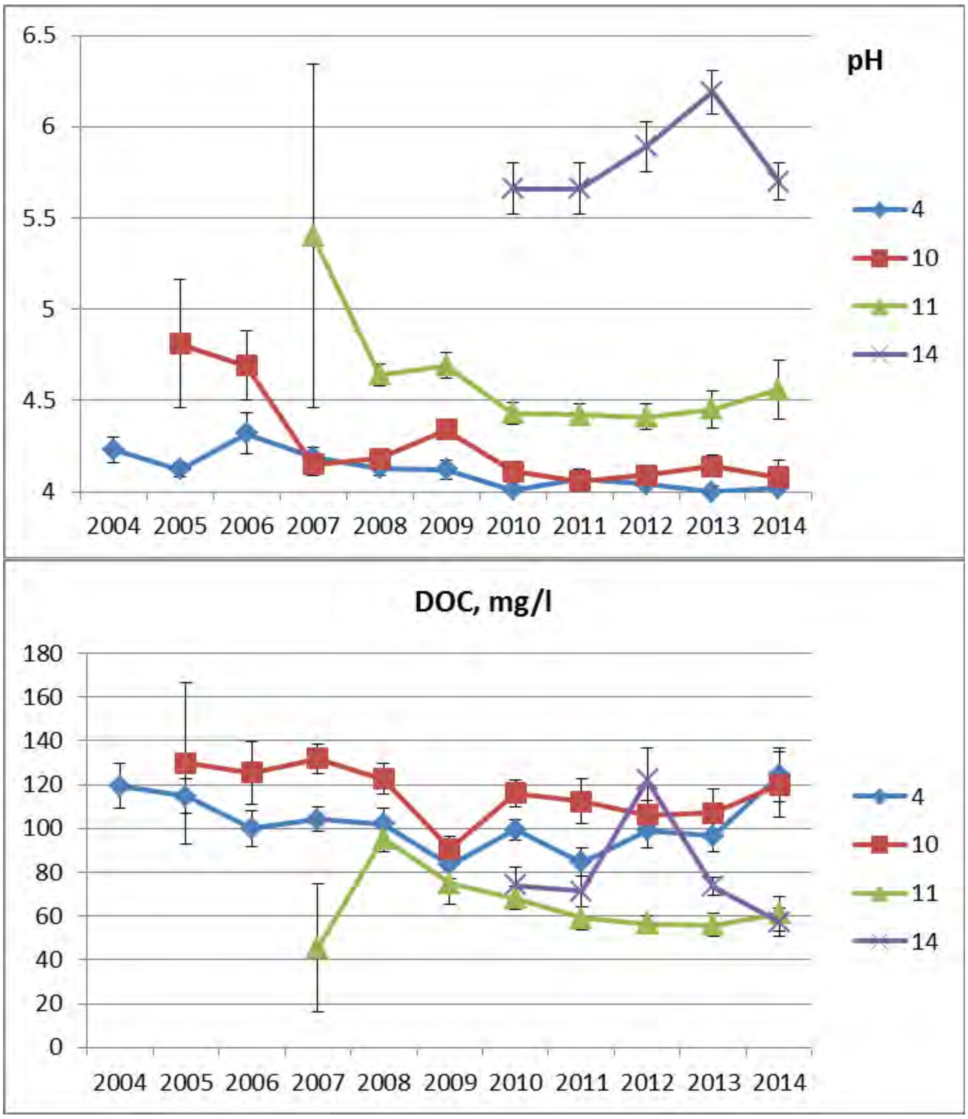

Figure 15. *Annual mean pH and dissolved organic carbon (DOC) concentration at a depth of 5 cm on plots FIP4 (pine stand), FIP10 (spruce stand), FIP11 (birch dominated stand) and FIP14 (alder stand) at Olkiluoto during the snow-free period in 2004–2014. The bars denote the standard error of the mean.*

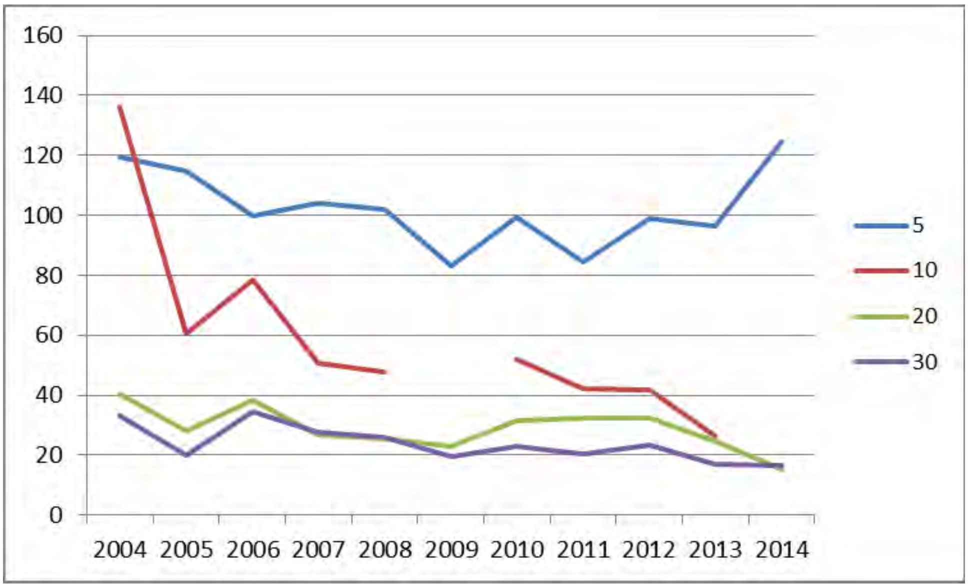

Figure 16. *Dissolved organic carbon (DOC, mg/l) concentration in the soil solution at depths of 5, 10, 20 and 30 cm on the plot FIP4 (Scots pine stand).*

Total nitrogen which, in addition to ammonium and nitrate, also includes organic dissolved nitrogen, obviously closely followed the pattern for the DOC concentrations on the plots FIP4, 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 (Figure 17), 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. The low NO_3-N concentrations in the soil solution mean low nitrate leaching from the forest soils indicating that the soils are far from the so-called nitrogen saturation point. High nitrate leaching could weaken the ground water quality. It has been proposed that nitrate leaching would be elevated if the NO_3-N concentration exceeded 1 mg/l in the soil solution. The nitrate concentrations were far below this limit in Olkiluoto also in 2014. The nitrogen situation was totally different on the black alder plot, FIP14, where nitrate concentrations were high in the soil solution in 2010 and even in 2011-2014, although the concentration has clearly decreased (Figure 17).

Sulphate concentrations at a 5 cm depth on FIP4 were at the same level in all 11 years as those at the reference site (Nieminen et al. 2013). Sulphate concentrations were also approximately the same or slightly higher on FIP10 than those for the corresponding reference site at a 5 cm depth (Nieminen et al. 2013). There was a clear overall increase in sulphate concentrations with increasing depth on FIP4 and 10. Similar trends in sulphate concentration have been reported at all the ICP Forests Level II plots in Finland (Derome et al. 2007). No clear trends have been found in the SO_4-S concentrations during 2004-2014 on the FIP plots 4 and 11 at a depth of 5 cm (Figure 18). However, on the plots FIP10 and FIP14 the SO_4-S concentrations were the highest in 2014 at a depth of 5 cm of the whole monitoring period (Figure 18).

Chloride concentrations were extremely high at all depths on all 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).

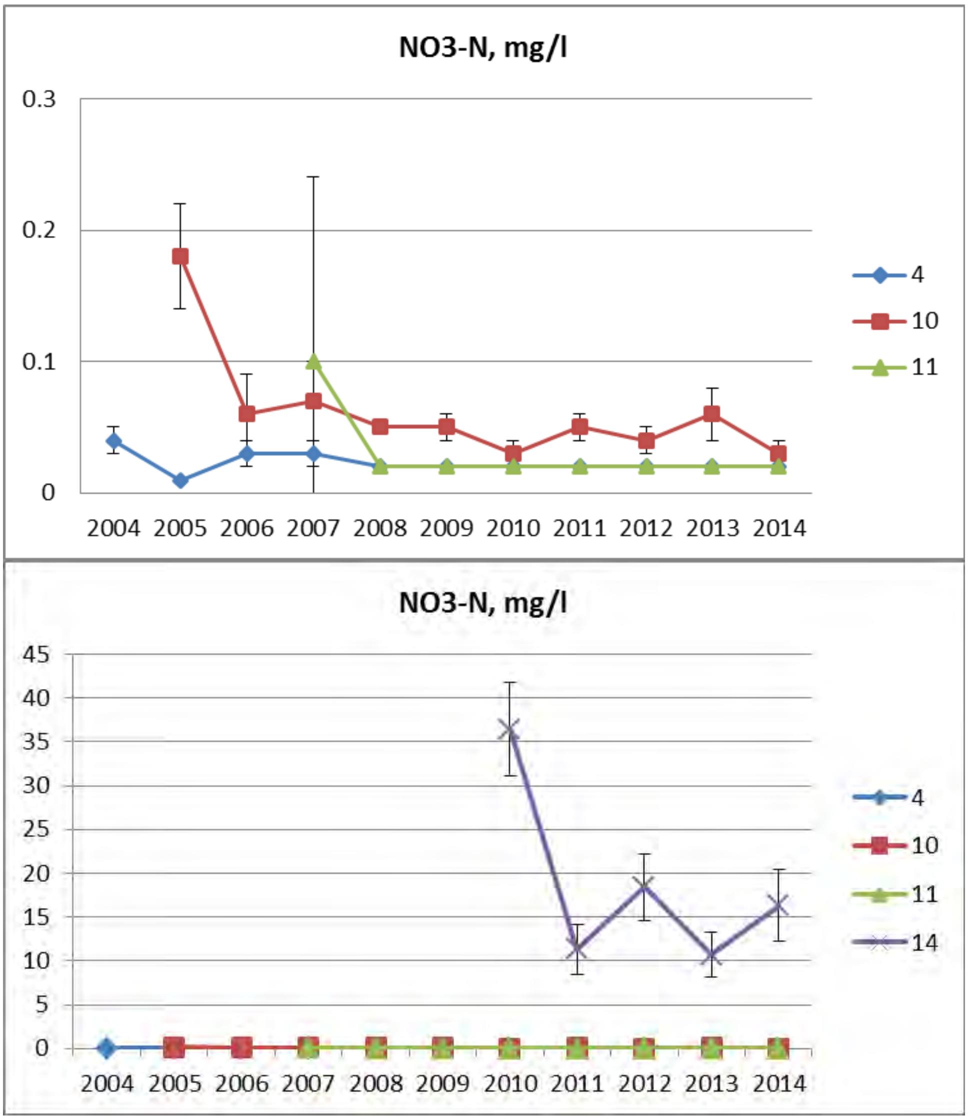

Figure 17. *Annual mean nitrate (NO_3-N) concentrations at a depth of 5 cm on plots FIP4 (pine stand, NO_3-N below the respective limit of quantification 2008-2014), FIP10 (spruce stand), FIP11 (birch dominated stand, NO_3-N below the respective limit of quantification 2008-2014) and FIP14 (alder stand) at Olkiluoto during the snow-free period in 2004-2013. The bars denote the standard error of the mean. NO_3-N concentrations are presented in two different scales due to the high values of NO_3-N at FIP14.*

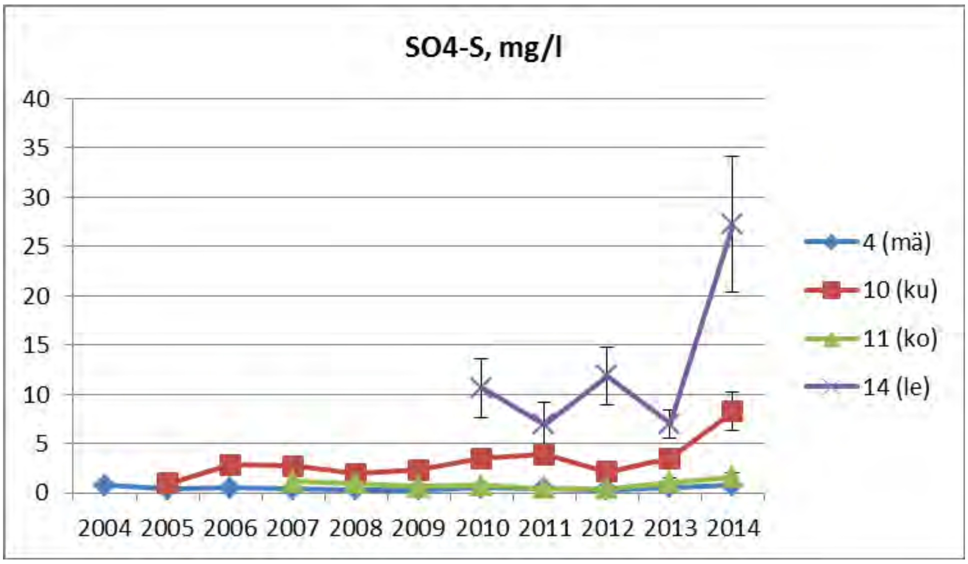

Figure 18. *Annual mean sulphate (SO_4-S) concentrations at a depth of 5 cm on plots FIP4 (pine stand), FIP10 (spruce stand), FIP11 (birch dominated stand) and FIP14 (alder stand) at Olkiluoto during the snow-free period in 2004-2014. The bars denote the standard error of the mean.*

The concentrations of the three important plant nutrients (Ca, Mg and K) on FIP4, FIP10 and FIP11 were comparable in 2014 to the values measured in earlier years at all depths. The soil on the plots at Olkiluoto is very young, and the 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 all of the plots and at all depths, the concentrations of total Al in 2014 were relatively similar to those in earlier years. The concentrations of Al^{3+} were lower than the widely accepted toxicity level of 2 mg/l on all the plots. The Fe, Mn and Si concentrations at all depths were comparable in 2014 to the values measured in earlier years. The concentrations of heavy metals (Cd, Cr, Ni, Pb) at all depths at Olkiluoto during 2004-2013 continued in many cases to be quite low. In 2014, the concentrations of Ba, Nb, Pd, Sn, Sr, Ta, Te, V and W were also determined from the soil solution samples. The concentrations were generally below the respective limits of quantification for all parameters except Ba, Sr and V.

The Sr concentrations in bulk deposition (BD) and stand throughfall (TF) were clearly lower than the Sr concentrations in soil solution at depths of 5-30 cm (Figure 19). This was probably a natural phenomenon and due to weathering input of Sr from the soil minerals. There were also variations in the Sr concentrations between the plots; in 2014 the mean Sr concentrations varied from 16-19 µg/l on the plot FIP4 at depths of 5-30 cm while the corresponding concentrations varied from 52-61 µg/l on the plot FIP10. The role of the natural weathering processes of soil minerals is probably important for these patterns in Sr concentrations, but the role of weathering rates should be determined as they provide a basis for background levels of elements such as Sr.

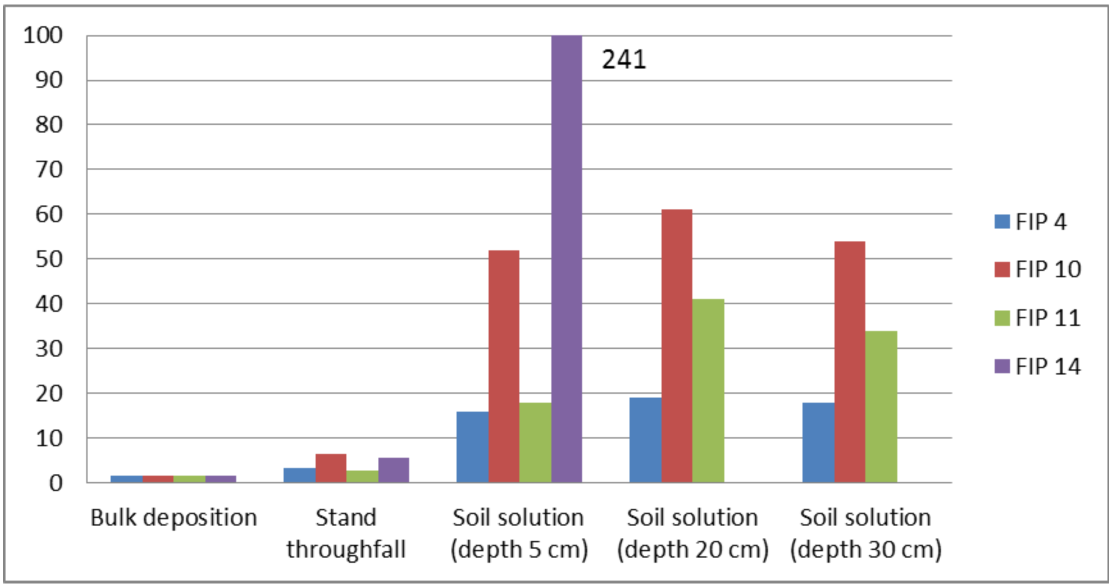

Figure 19. *Sr concentration (mg/l) in bulk deposition, in stand throughfall and in soil solution on the plots FIP4, FIP10, FIP11 and FIP14 (value 241 mg/l at the depth of 5 cm is not in the scale) in 2014.*

4.3 Tree stand transpiration

The monthly stand level transpiration of the Scots pine (FIP4) dominated stand is presented in Figure 20. In 2014 the monthly level of transpiration on the plot FIP4 was lower during May to July than during previous years (2008-2012, Figure 21). In 2013 a similar low level of transpiration was observed for the period of May to August.

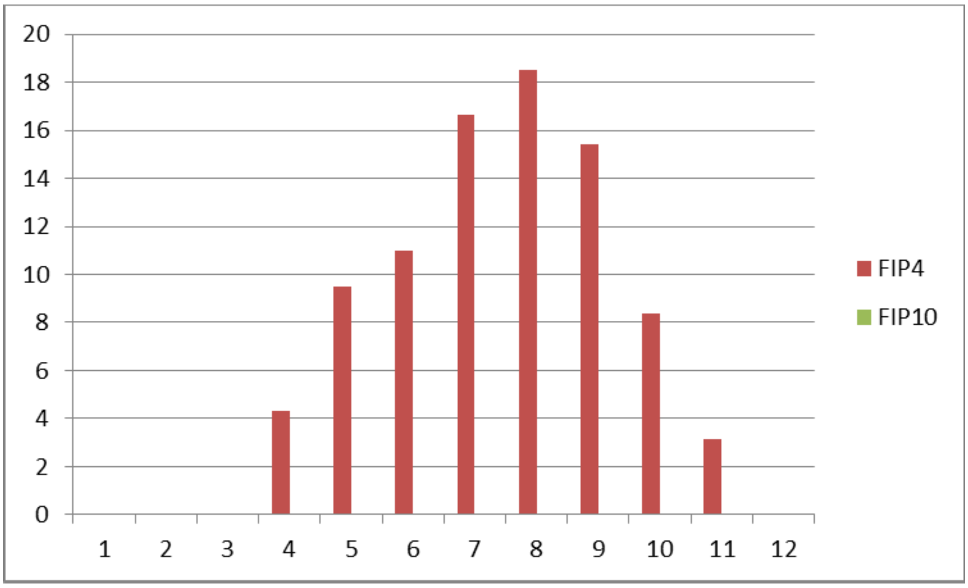

Figure 20. *Monthly stand level transpiration (mm) on the FIP4 (Scots pine stand) sample plot in 2014. Data for the Norway spruce stand (FIP10) is missing due to measurement problems during 2014.*

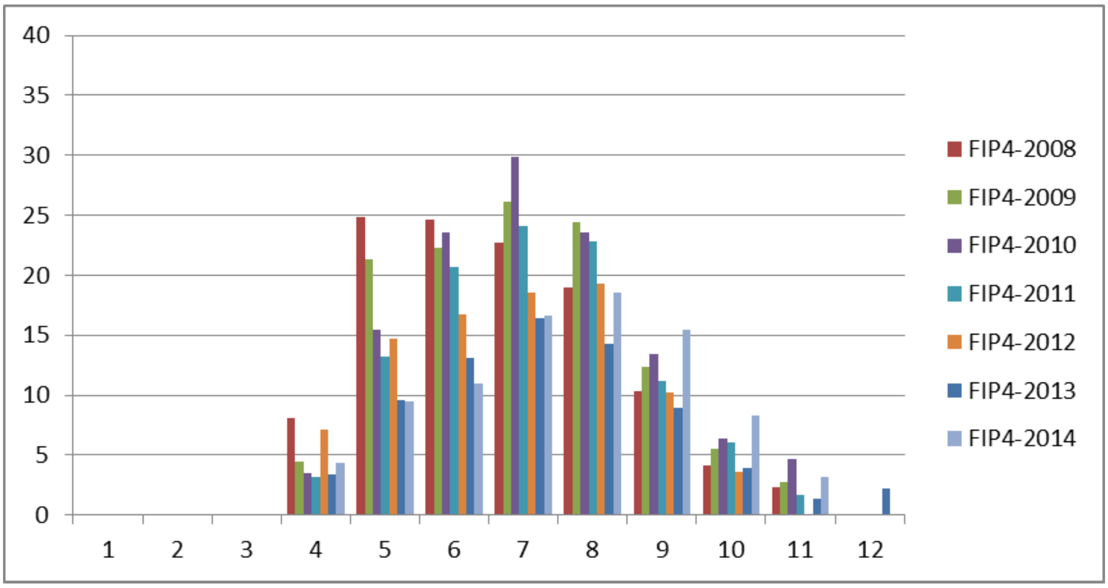

Figure 21. *Monthly stand level transpiration (mm) on the FIP4 sample plot during 2008-2014. Results are only reliable for the period of April-November (2008-2011 and 2014), April-October (2012) and April-December (2013).*

4.4 Litterfall production and element return to the forest floor

Total annual litterfall production on coniferous plots (FIP4 and 10) and on the birch plot (FIP11) was lower in 2013 compared to 2012 (Figure 22). The within-year temporal trends, however, were more or less the same as during the previous collection period (Table 10; see Aro et al. 2015, Figures 17a-d).

As a reference Ukonmaanaho et al. (2008) reported annual litterfall production (without large branches, i.e. fraction 7 here) of 226 g_{dw}/m^2 for Scots pine and 350 g_{dw}/m^2 for Norway spruce in 13 Finnish ICP Forests plots (mainly in southern Finland) during 1996-2003. The corresponding values for the FIP plots were 434 g_{dw}/m^2 (Scots pine stand), 212 (Norway spruce stand), 173 (birch-dominated stand) and 343 (alder stand) during 2013. Values (higher or lower than in the Finnish ICP Forests plots) recorded on Olkiluoto Island are due to natural annual variation. The Scots pine stand (FIP4) is too dense because the stand has not been thinned for a long time, and additionally Scots pine blister rust (caused by fungi *Cronartium flaccidum* (Alb. et Schw.) Wint. and *Peridermium pini* (Pers.) Lev.) are causing trees to shed more and more needles each year. The spruce stand (FIP10), located in the nature protection area of old growth forests, is deteriorating because no silvicultural measures are allowed to be done there, hence the litter production varies from year to year due to natural reasons. On the birch plot, a large proportion of the trees are just getting tall enough to shed leaves to the collectors, and hence the amount of litter has been increasing more or less linearly since the beginning of litter collection (Figure 22).

The most notable differences in element concentrations between the plots are those of Al and N concentrations (Tables 11 and 12). Al is commonly higher in living pine needles than in spruce needles and this can also be seen in the Al concentration (Table 11) in litterfall on the pine plot (FIP4) compared to the spruce plot (FIP10). High Al

(Table 11) and Fe (Table 13) concentrations in fraction 5 (remaining litter) are most likely due to soil dust. The highest N concentrations were generally detected in fraction 4 (leaves) or 5 (remaining litter). The remaining litter can include e.g. seeds and flowers (i.e. living biological material) or insect faeces that are naturally high in N. Hence the remaining litter can in some cases have an equal or even higher N concentration than alder leaves (Table 12, FIP14) which are known to have a high N concentration even after senescence. On the birch dominated plot (FIP11) the highest N concentrations in leaves occurred during summer (i.e. non-senescent leaves) but also senescent leaves (i.e. those collected during autumn) contained more N than green pine needles (Table 12).

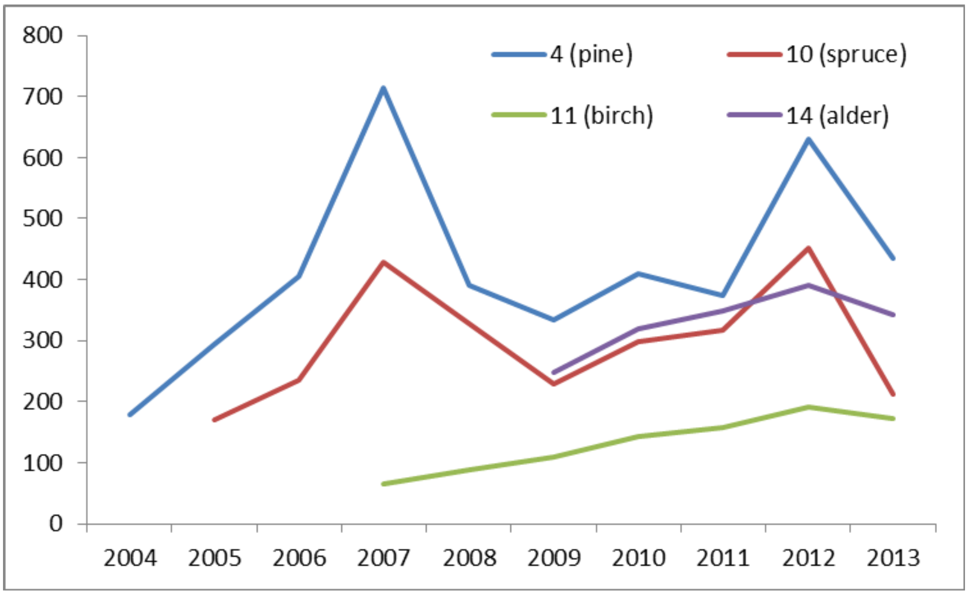

Figure 22. *Annual total litterfall production (g_{dw}/m2) without large branches in heath forests (FIP plots 4-11) and in a grove forest (FIP14) during 2004-2013. All branches excluded in 2004-2005.*

Table 10. *Mass (g_{dw}/m^2) of different litterfall fractions at different collection dates (and annual total) on the FIP plots (FIP4=pine, 10=spruce, 11=birch and 14=alder) during 2013.*

		Litter fraction*								**Sum**
Plot	Date	1	2	3	4	5	6	7	12	**1-6**
4	22.5.	5.6	1.9	0.3	0.0	15.6	8.7	10.8	28.1	**32.1**
	19.6.	12.0	0.6	0.2	0.0	25.5	3.9	2.7	37.6	**42.1**
	15.7.	9.5	1.5	0.1	0.0	32.8	2.1	4.0	31.9	**46.0**
	12.8.	8.2	1.6	0.0	0.0	25.5	2.5	11.1	30.0	**37.8**
	17.9.	107.2	1.3	0.0	0.0	18.1	1.8	1.0	115.7	**128.4**
	15.10.	119.8	1.4	0.1	0.0	24.5	1.7	2.0	122.5	**147.5**
Annual total		**262.3**	**8.3**	**0.7**	**0.1**	**142.1**	**20.7**	**31.6**	**365.8**	**434.0**
10	22.5.	0.0	0.0	45.2	0.3	22.0	8.0	6.7	50.8	**75.9**
	19.6.	0.0	0.0	15.6	0.3	9.8	2.9	2.2	31.2	**28.7**
	15.7.	0.0	0.0	7.4	0.6	8.2	1.4	2.3	15.4	**17.5**
	12.8.	0.0	0.0	3.4	0.7	3.7	1.4	3.0	5.2	**9.3**
	17.9.	0.0	0.0	4.2	6.3	12.4	0.8	0.6	15.5	**23.6**
	15.10.	0.0	0.0	10.8	27.3	16.8	2.3	2.9	53.4	**57.2**
Annual total		**0.0**	**0.0**	**87.0**	**35.4**	**72.9**	**16.9**	**17.7**	**171.4**	**212.2**
11	22.5.	0.0	0.0	2.6	0.3	6.5	1.8			**11.1**
	19.6.	0.0	0.0	2.1	0.7	4.5	1.9			**9.2**
	15.7.	0.0	0.0	1.5	2.3	2.1	2.9			**8.9**
	12.8.	0.0	0.0	1.1	5.3	1.2	1.5			**9.1**
	17.9.	0.0	0.0	0.9	75.4	2.0	0.2			**78.5**
	15.10.	0.0	0.0	1.8	53.2	0.8	0.4			**56.2**
Annual total		**0.0**	**0.0**	**10.0**	**137.1**	**17.2**	**8.7**			**173.0**
14	22.5.	0.0	0.0	0.3	1.7	24.2	6.0	6.4	28.0	**32.2**
	20.6.	0.0	0.0	0.0	1.4	9.2	2.8	2.4	8.1	**13.4**
	15.7.	0.0	0.0	0.0	17.4	7.9	11.9	4.6	21.9	**37.2**
	13.8.	0.0	0.0	0.0	33.5	4.0	4.3	2.5	38.7	**41.7**
	17.9.	0.0	0.0	0.0	84.7	13.7	4.1	2.0	104.2	**102.6**
	15.10.	0.0	0.0	0.0	105.9	6.8	3.4	3.7	106.8	**116.2**
Annual total		**0.0**	**0.0**	**0.3**	**244.6**	**66.0**	**32.5**	**21.5**	**307.6**	**343.4**

* Litter fraction numbers refer to: 1= dead pine needles, 2= living (green) pine 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 11. *Aluminium concentration (Al, mg/kg$_{dw}$) in the seven fractions of litterfall on the FIP plots during 2013. The annual total is given if there has not been enough material for chemical analysis in individual collection periods.*

		Litter fraction*						
Plot	Date	1	2	3	4	5	6	7
FIP 4	22.5.2013	633	490	267		1960	482	368
	19.6.2013	367	318			467	448	350
	15.7.2013	320	205			564	461	323
	12.8.2013	334	211			596	405	354
	17.9.2013	284	202			438	415	393
	15.10.2013	300	190			434	482	355
	Annual total 2013			165				
FIP 10	22.5.2013			72.6	620	833	288	181
	19.6.2013			66.5	165	698	265	230
	15.7.2013			49	105	1120	204	172
	12.8.2013			61.4	195	2060	243	102
	17.9.2013			40.1	36.5	338	232	190
	15.10.2013			53.8	67.7	320	230	236
FIP 11	22.5.2013			116	1570	1220	132	
	19.6.2013			48.6	229	482	26.6	
	15.7.2013			29.4	77.2	1000	18	
	12.8.2013			44.4	112	676	44.4	
	17.9.2013			30.6	37.4	234	41	
	15.10.2013			39.7	50.3	306	23.9	
FIP 14	22.5.2013				996	347	42.4	27.4
	20.6.2013				235	309	51	24.2
	15.7.2013				57.2	220	19	26.5
	13.8.2013				90.9	151	29.5	65.9
	17.9.2013				45.1	80	22.6	20.3
	15.10.2013				47.9	108	24.9	22.7
	Annual total 2013			51.3				

* 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 12. *Nitrogen concentration (N, %) in the seven fractions of litterfall on the FIP plots during 2013. The annual total is given if there hasn't been enough material for chemical analysis in individual collection periods.*

		Litter fraction*						
Plot	Date	1	2	3	4	5	6	7
FIP 4	22.5.2013	1.08	1.52	0.87		1.08	0.78	0.65
	19.6.2013	1.31	1.66			1.16	0.74	0.70
	15.7.2013	1.00	1.61			0.72	0.75	0.64
	12.8.2013	0.94	1.55			0.70	0.82	0.56
	17.9.2013	0.54	1.40			0.76	1.00	0.73
	15.10.2013	0.61	1.43			0.65	1.11	0.75
	Annual total 2013			1.13				
FIP 10	22.5.2013			1.00	1.79	1.59	0.82	1.00
	19.6.2013			1.12	3.12	1.78	1.03	0.97
	15.7.2013			1.09	2.32	1.63	0.94	1.09
	12.8.2013			1.12	1.83	2.08	1.15	0.91
	17.9.2013			1.02	0.98	0.86	1.10	0.93
	15.10.2013			0.93	0.88	0.79	1.02	0.95
FIP 11	22.5.2013			1.29	2.70	1.44	0.98	
	19.6.2013			1.59	3.62	2.13	0.81	
	15.7.2013			1.61	2.18	2.58	0.57	
	12.8.2013			1.53	1.50	2.46	0.76	
	17.9.2013			1.39	1.18	1.98	0.95	
	15.10.2013			1.27	1.16	2.37	1.05	
FIP 14	22.5.2013				3.48	2.55	1.64	1.46
	20.6.2013				3.71	3.04	1.95	1.76
	15.7.2013				2.60	2.72	1.31	1.67
	13.8.2013				2.93	2.85	1.53	1.88
	17.9.2013				2.25	2.05	1.69	1.94
	15.10.2013				2.19	2.54	1.72	1.73
	Annual total 2013			1.19				

* 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 13. *Iron concentration (Fe, mg/kg$_{dw}$) in the seven fractions of litterfall on the FIP plots during 2013. The annual total is given if there hasn't been enough material for chemical analysis in individual collection periods.*

		Litter fraction*						
Plot	Date	1	2	3	4	5	6	7
FIP 4	22.5.2013	627	400	260		2690	479	310
	19.6.2013	137	90.6			468	416	293
	15.7.2013	92.9	56.9			551	438	232
	12.8.2013	141	92.5			550	385	314
	17.9.2013	87.5	50.9			415	379	301
	15.10.2013	103	45.7			388	403	273
	Annual total 2013			88.6				
FIP 10	22.5.2013			96.6	1090	1210	451	272
	19.6.2013			83.4	288	971	397	358
	15.7.2013			54	189	1440	299	266
	12.8.2013			72.4	324	2870	371	145
	17.9.2013			43.4	85.3	447	344	304
	15.10.2013			62.3	140	438	342	353
FIP 11	22.5.2013			184	2790	2020	190	
	19.6.2013			77.5	394	730	45.9	
	15.7.2013			47.4	144	1330	32.4	
	12.8.2013			71.8	202	1070	68	
	17.9.2013			51.8	87.5	382	70.8	
	15.10.2013			80.4	115	501	47.7	
FIP 14	22.5.2013				1730	491	87.8	69.6
	20.6.2013				380	420	90.3	77.2
	15.7.2013				126	491	47.7	66.2
	13.8.2013				179	233	62.8	193
	17.9.2013				100	129	63.4	69.6
	15.10.2013				100	173	68	68.6
	Annual total 2013			71				

* 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"

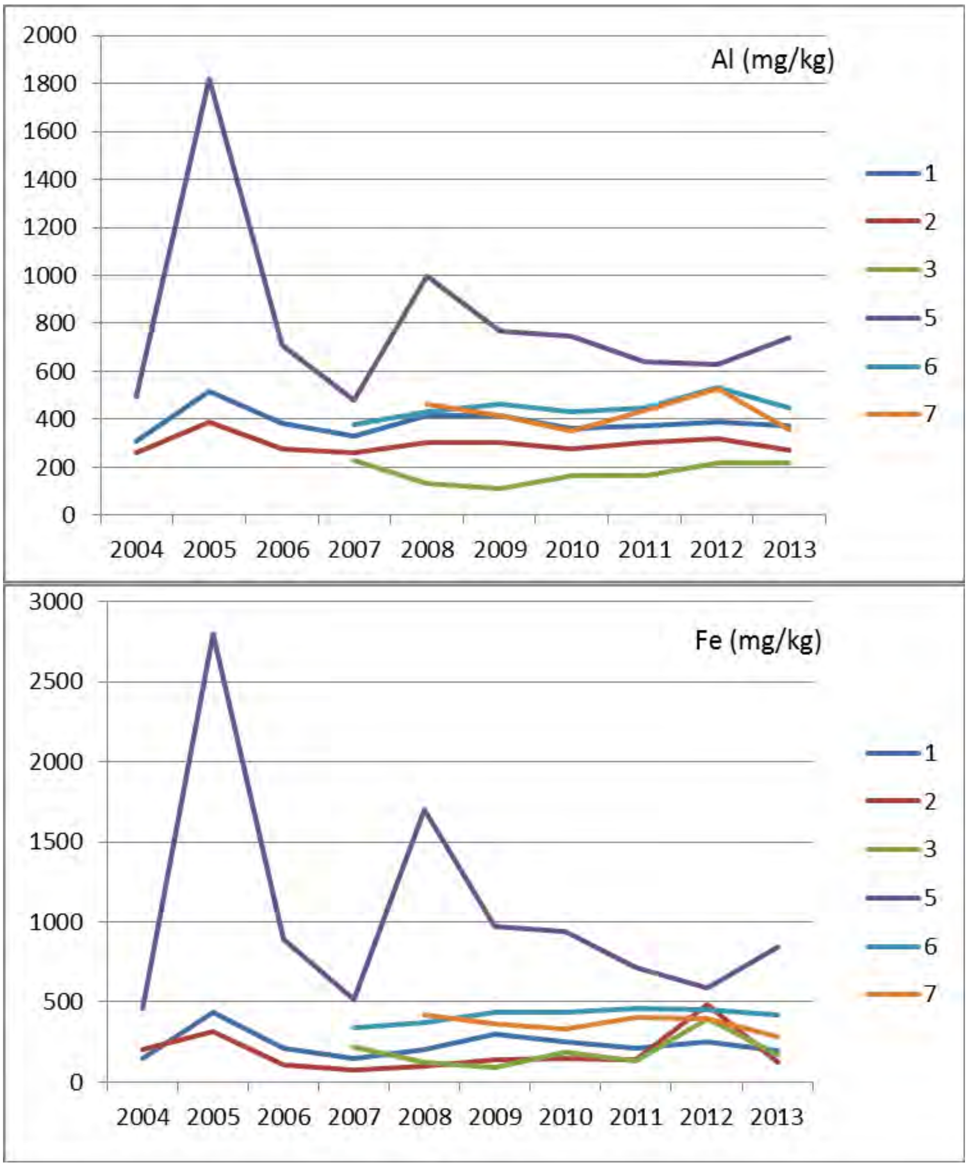

Figure 23. *Concentrations (mg/kg) of Al and Fe in litterfall (fractions: 1= dead pine needles, 2=living pine needles , 3=spruce needles, 5=remaining litter,6=small branches and 7=branches) on plot FIP4 during the monitoring period.*

4.5 Defoliation of trees

The degree of defoliation of Scots pine and Norway spruce was determined on the FIP plots during 1.–2.7.2014. The average defoliation level of the pines was 5.0% (±0.8, sd) and of the spruces 28.6% (±2.3). The pines were classified as non-defoliated indicating good crown condition of the trees. The spruces were classified as moderately defoliated (defoliation degree >25%, Table 14), similarly to 2010 and 2012. Previously (2006-2009) the spruces were classified as slightly defoliated. The defoliation degree level of Scots pine correlated strongly with the results for the ICP Level II plots in Tammela (Nevalainen & Lindgren 2013). 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.

4.6 Tree stand characteristics on the FIP plots

Basic characteristics of tree stands on FIP plots are presented in Table 15. The total stem volume of tree stands was 361, 447, 83, 172, 64 and 85 m^3/ha on the plots FIP4, FIP10, FIP11, FIP14, FIP15 and FIP16 in 2014, respectively (Table 15, Figure 24). The current annual increment (CAI) was very high, 14.2 $m^{3/}$ha/a, in the Scots pine stand on FIP4 during the last five years. On the other hand, the high basal area (37.5 m^2) in the pine dominated FIP4 showed clearly that thinning will be necessary in the near future (Table 15). CAI was also high in Norway spruce (FIP10, 9.7 $m^{3/}$ha/a during the last five years) and birch (FIP11, 9.3 $m^{3/}$ha/a during the last six years) dominated stands. In the spruce stand (FIP10) the birches have reached their mature age (Table 15). Plant competition-caused self-thinning is a normal age-related phenomenon in natural stands and will continue during the following monitoring period. Based on the basal area and stem volume, silver birch has become the dominating tree species on the FIP11 plot. Instead, CAI was exceptionally low, 4.9 $m^{3/}$ha/a, in the black alder stand (FIP14) during the last five years. The black alder stand is growing in a very fertile site (grove) but in extremely harsh conditions (wind, flooding and ice load from the sea) beside the sea shoreline.

Table 14. *Number of assessed trees (Nr.) and defoliation degree (DEF, %) of the trees on the FIP plots by sub-plot during 2006-2014.*

Plot	Sub-plot	Species	Nr.	DEF 2006	2007	2008	2009	2010	2012	2014
4	1	Scots pine	20	3.2	3.4	5.2	4.5	3.5	3.8	4.8
	2	Scots pine	20	3.2	7.7	4.9	5.7	4.9	5.3	6.1
	3	Scots pine	20	4.2	2.9	3.7	3.3	4.0	3.1	4.3
	4	Scots pine	20	4.5	3.3	3.8	4.9	5.2	3.5	5.0
	Mean			3.7	4.3	4.4	4.6	4.4	3.9	5.0
	SD			0.7	2.2	0.8	1.0	0.8	0.9	0.8
10	1	Norway spruce	20	15.8	19.8	17.5	21.0	23.8	23.8	25.8
	2	Norway spruce	20	18.8	18.8	19.3	26.0	27.5	28.0	31.5
	3	Norway spruce	20	15.5	20.8	18.5	23.3	27.3	26.0	28.8
	4	Norway spruce	20	21.3	17.8	18.3	26.3	28.8	27.3	28.5
	Mean			17.8	19.3	18.4	24.1	26.8	26.3	28.6
	SD			2.7	1.3	0.7	2.5	2.1	1.9	2.3

Table 15. *The basic stand characteristics of Scots pine (FIP4, last inventory in March 2014), Norway spruce (FIP10, October 2014), birch (FIP11, March 2014), black alder (FIP14, October 2014) and Scots pine (FIP15 and FIP16, March 2014) dominated plots during 2004-2014.*

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	4	1	Scots pine	878	28.65	21.1	16.85	8.95	17.86	237.5
2009	4	1	Scots pine	867	32.82	22.7	18.18	10.86	19.13	290.4
2014	4	1	Scots pine	856	37.48	24.4	20.06	12.67	21.04	361.4
2005	10	1	Norway spruce	722	30.03	29.8	18.34	8.25	27.58	341.5
2009	10	1	Norway spruce	667	30.59	31.4	18.50	8.17	27.31	340.5
2014	10	1	Norway spruce	678	33.58	32.6	19.20	8.10	28.36	388.8
2005	10	1	Birch	189	7.42	25.2	23.68	15.44	25.02	83.2
2009	10	1	Birch	133	5.63	25.8	23.77	13.97	24.29	63.8
2014	10	1	Birch	111	5.06	26.7	24.06	14.69	24.67	58.4
2008	11	1	Scots pine	0	0	0	0	0	0	0
	11	1	Norway spruce	1150	1.92	5.9	3.63	0.35	5.75	5.8
	11	1	Silver birch	4779	2.74	4.0	3.78	1.26	6.28	8.6
	11	1	Downy birch	11239	4.12	3.5	3.19	1.14	6.03	12.9
2014	11	1	Scots pine	89	0.07	3.1	5.73	1.88	5.73	0.2
	11	1	Norway spruce	1327	5.13	9.2	6.14	1.15	9.12	23.6
	11	1	Silver birch	5664	9.43	6.8	5.98	2.03	10.83	41.6
	11	1	Downy birch	10619	4.74	4.6	3.98	1.28	9.65	17.6
2009	14	2	Black alder	1200	23.51	19.6	10.31	5.21	17.08	142.8
	14	2	Norway spruce	11	0.33	19.6	12.00	1.30	12.00	1.9
	14	2	Other broadl.	44	0.59	14.3	8.00	2.08	8.00	2.5
2014	14	2	Black alder	1100	24.66	20.6	11.72	6.56	19.02	165.8
	14	2	Norway spruce	11	0.40	21.5	13.30	1.40	13.30	2.5
	14	2	Other broadl.	44	0.73	15.6	9.48	2.08	9.47	3.5
2014	15	2	Scots pine	2029	15.00	15.0	5.14	2.77	8.86	63.6
2014	16	2	Scots pine	1467	18.26	17.5	6.31	3.13	10.17	84.5
	16	2	Norway spruce	33	0.09	7.6	4.47	1.23	4.47	0.3
	16	2	Birch	22	0.01	3.4	2.80	1.35	2.80	0.03

4.7 Thickness of the organic layers on the FET plots

The thickness of the litter layer was 2.2 cm (sd ±0.9 cm) in rocky forests, 4.3 cm (±1.9) in heath forests, 3.9 cm (±2.6) in herb-rich forests and 4.8 cm (±1.8) in mires (Table 16). Mor and peat formed the organic layer in rocky forests, and the thickness of the layer was 3.5 cm (sd ±1.5 cm) on average (Table 16). Mull and peat were the most common types of organic layer in heath forests with a mean layer thickness of 8.7 cm (±4.5). Moder and mull types of organic layer were found in groves, and its mean thickness was 8.5 cm (±4.8). The mean thickness of the organic layer was 25.6 cm (±28.6) in mires, and peat was the most common type.

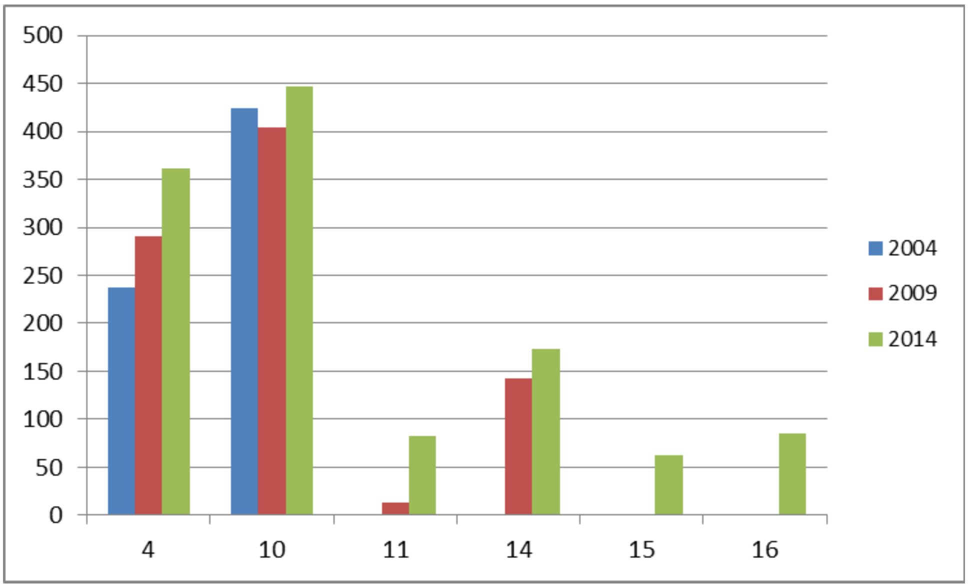

Figure 24. *Total stem volume (m^3 ha^{-1}) of living trees on the plots FIP4, FIP10, FIP11, FIP14, FIP15 and FIP16 during 2004-2014.*

Table 16. *Thickness (cm) of the litter (L) and organic (H) layers by the organic layer types of biotopes in 2014.*

	Biotopes									
	Rocky forest		Heath forest		Grove		Mire		All	
Type of organic layer[1]	L	H	L	H	L	H	L	H	L	H
0			1.3	0.0	0.0	0.0			1.0	0.0
1	2.1	3.0	4.1	7.9			3.7	7.7	3.9	7.4
2			4.4	9.7	3.5	8.3	4.0	16.5	4.2	10.3
3			5.7	14.3	5.5	11.3			5.6	13.1
4	2.5	5.5	7.5	14.3			5.8	39.2	5.8	29.9
5			5.0	6.0					5.0	6.0
All	2.2	3.5	4.3	8.7	3.9	8.5	4.8	25.6	4.2	10.8

[1] Type of organic layer (H): 0=missing or very thin, 1=mor, 2=moder, 3=mull, 4=peat, 5=raw humus

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 2014, excluding litterfall production, results of which cover the previous year, 2013. All the data have been stored in the POTTI database (Posiva research result database) and only the main findings are presented in this report. There were no essential changes in current monitoring networks during 2014. Monitoring of deposition and litterfall production were started on two new intensive monitoring plots FIP15 and FIP16.

In general, the level of precipitation was relatively low in 2014. The NH_4-N deposition that decreased in 2012 compared to the situation in 2011 remained relatively low also in 2013 and 2014. The NO_3-N deposition values increased in 2012 and were the highest for the whole monitoring period during 2004-2012. However, in 2013 the NO_3-N deposition decreased and remained at a similar level also in 2014. The increase in NO_3-N in bulk deposition in 2012 was probably due to the construction activities in the area (e.g. rock detonations). 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 and utilization by the mosses, lichens and microflora on the needle surfaces). Nitrogen retention in the tree canopies is a well-documented phenomenon in coniferous stands in Finland. The SO_4-S and Ca depositions were clearly elevated in 2014 on the plot MRK13 which is located close to the construction activities. Elevated concentrations of these elements were detected in BD especially in June 2014, and this fact was reflected also in the annual deposition. A possible reason for this observation could be the $CaSO_4$ used in the construction activities.

The major problem in collecting deposition is the avoidance of contamination caused by bird droppings in the rainfall collection equipment. So far, contaminated samples from individual collectors have been excluded if there has been evidence of bird droppings. However, these contaminated samples might be valuable in determining elemental cycles in relation to birds. Thus, the question of whether those samples could be collected and analysed separately, instead of destroying them, should be considered.

The soil solution quality in 2014 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 4, 10 and 11. This indicates that available nitrogen mineralized from the organic layer is rapidly taken up by the roots of the trees and ground vegetation on these plots. However, nitrate concentrations were high in the soil solution on FIP14. There appeared to be a clear overall increase in sulphate concentrations with increasing depth on FIP4 and FIP10. In addition, the sulphate concentrations were the highest in 2014 at a depth of 5 cm of the whole monitoring period on the plots FIP10 and FIP14. Chloride concentrations in the soil solution were extremely high at all depths on all FIP plots throughout the monitoring period; it is clear that there is a considerable input of NaCl in the deposition derived from the sea. The concentrations of heavy metals (Cd, Cr, Ni, Pb) in the soil solution at all depths at Olkiluoto during 2004-2014 continued in many cases to be relatively low.

The biogeochemical studies in Olkiluoto including element concentrations and fluxes in deposition, stand throughfall and soil solution would benefit from the information of element fluxes related to mineral weathering in the forest soil. Estimation of weathering fluxes would complete the picture of input and output flows of nutrients and elements through the forest ecosystems. This would be especially important when considering key elements in biosphere assessment, such as Sr.

Due to technical problems we were not able to report the transpiration of the Norway spruce stand (FIP10) in 2011–2014. Finally, sap flow measurements were finished on the FIP10 plot in 2014. Severe technical problems occurred also in sap flow measurements in the Scots pine stand during 2014. It is probable that technical problems will stop transpiration rate calculations also in the pine stand in the near future. If stand transpiration is still needed in model validations, for example, new sap flow measurement systems should be built.

In general, annual total litterfall production was lower in coniferous plots in 2013 compared to the previous collection period 2012. Total annual litterfall production (without larger branches) was 434 g_{dw}/m^2 (Scots pine stand), 212 (Norway spruce stand), 173 (young birch-dominated stand) and 343 (alder stand). Annual variations recorded on Olkiluoto Island are due to natural reasons. The Scots pine stand (FIP4) is too dense because the stand has not been thinned for a long time, and additionally Scots pine blister rust is causing trees to occasionally shed more needles. The spruce stand (FIP10), located in the nature protection area of old growth forests, is deteriorating because no silvicultural measures are allowed to be done there. On the birch plot, trees have grown high enough to shed leaves into the collectors, and hence the amount of litter has been increasing more or less linearly since the beginning of litter collection. 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 the remaining litter, and were most likely due to soil dust.

The average defoliation level of the pines was 5.0% (±0.8, sd) and of the spruces 28.6% (±2.3) in July 2014. The pines were classified as non-defoliated indicating good crown condition of the trees. The spruces were classified as moderately defoliated.

Current annual increment (CAI) was very high, 14.2 $m^{3/}$ha/a, in the Scots pine stand on FIP4 during the last five years. On the other hand, the high basal area (37.5 m^2) in the pine dominated FIP4 showed clearly that thinning will be necessary in the near future. CAI was also high in Norway spruce (FIP10, 9.7 $m^{3/}$ha/a during the last five years) and birch (FIP11, 9.3 $m^{3/}$ha/a during the last six years) dominated stands. Instead, CAI was exceptionally low, 4.9 $m^{3/}$ha/a, in the black alder stand (FIP14) during the last five years. In the spruce stand (FIP10) the birches have reached their mature age. Based on the basal area and stem volume, silver birch has become the dominating tree species on the FIP11 plot.

In connection with the forest inventory in 2014, the thickness of litter (4.2 cm, on average) and organic layers (10.8 cm) were measured from the set of FET plots and the results were presented by biotopes. The thickness of the litter layer was 2.2, 4.3, 3.9 and 4.8 cm in rocky forests, heath forests, herb-rich forests and mires, respectively.

Corresponding values for the organic layer (mostly mor, moder or peat) were 3.5, 8.7, 8.5 and 25.6 cm.

No harmful effects of human activities on the forest condition were observed in the nature conservation area.

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APPENDICES

APPENDIX 1. Data definition in the POTTI database.

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 (not in use 2012-) 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 (not in use since 3.10.2013) 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, 2 m hPa Channel22 Soil temperature -30 cm °C (since 3.5.2012) Channel25 PAR-radiation, 24 m (mean) $\mu mol\ s^{-1}\ m^{-2}$ 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 Channel22 Soil temperature -30 cm °C
Method parameters	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 parameters	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 moisture –20 cm 1 (%) Channel8B Soil moisture –20 cm 2 (%) Channel1C Temperature, 2 m (°C) Channel6C Soil moisture –20 cm 3 (%) (since 10.6.2009) Channel7C Proportional humidity, 2 m (%) Channel8C Rain (mm)
Method parameters	Document reference

WOM5

Science	ENVI
Method Categories	Vegetation inventories
Method	WOM5, Weather Observation Mast 5
Description	Posiva WR 2009-45
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 moisture -20 cm 1 (%) Channel8B Soil moisture -20 cm 2 (%) Channel1C Temperature, 2 m (°C) Channel7C Proportional humidity, 2 m (%)
Method parameters	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 B (mg/l) B_ctrl Cd (mg/l) Cd_ctrl Cr (mg/l) Cr_ctrl Ni (mg/l) Ni_ctrl P (mg/l) P_ctrl Pb (mg/l) Pb_ctrl S (mg/l) S_ctrl Ba (mg/l) Ba_ctrl Nb (mg/l) Nb_ctrl Pd (mg/l) Pd_ctrl Sn (mg/l) Sn_ctrl Sr (mg/l) Sr_ctrl Ta (mg/l) Ta_ctrl Te (mg/l) Te_ctrl V (mg/l) V_ctrl W (mg/l) W_ctrl
Method parameters	

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 centre distance m New centre direction 0-360 Degrees Tree distance cm (from new centre) Tree direction 0-360 Degrees (from new centre) 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 parameters	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 centre) Tree direction 0-360 Degrees (from centre) (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 parameters	Classification system Document reference Measured by Time

Science	ENVI
Method Categories	Vegetation inventories
Method	Forest inventory: tree measurements (WOM1)
Description	WOMpuustoinv_ohje2011.doc / 16.3.2011 / L. Aro
Target type	Weather mast
Target	WOM1
Processing stage	MEAS
Subtext files	VMI9.pdf, MT257
Method variables	OBS ID Measurement line Line direction (from WOM1, /360°)

	Plot Tree species Tree species in Finnish Height (dm) Plot mean height (dm) Surveyor Date of inventory Comments Photo
Method parameters	Classification system

DATA. Forest inventory by plots: plot characteristics

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 parameters	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, living 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 parameters	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) Lab ID 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 parameters	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 parameters	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)* Ba (mg/kg) Nb (mg/kg) Pd (mg/kg) Sn (mg/kg) Sr (mg/kg) Ta (mg/kg) Te (mg/kg) V (mg/kg) W (mg/kg)
Method parameters	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 parameters	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 parameters	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) Remarks Ba (mg/l) Nb (mg/l) Pd (mg/l) Sn (mg/l) Sr (mg/l) Ta (mg/l) Te (mg/l) V (mg/l) W (mg/l)
Method parameters	

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) Sap flow signal_tree 5 (mV) Sap flow signal_tree 6 (mV)
Method parameters	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 parameters	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 parameters	

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 Ba (mg/kg) Nb (mg/kg) Pd (mg/kg) Sn (mg/kg) Sr (mg/kg) Ta (mg/kg) Te (mg/kg) V (mg/kg) W (mg/kg)
Method parameters	

APPENDIX 2. List of data in the POTTI database (site=Olkiluoto, science= environment).

Target	Method	Time	Proc stage	Activity ID
OL-TK4	Forest soil water analysis	15.11.2011	MEAS	67888
OL-TK4	Forest soil water analysis	16.8.2011	MEAS	60263
OL-TK4	Forest soil water analysis	30.5.2011	MEAS	60262
OL-TK4	Forest soil water analysis	9.12.2008	MEAS	54677
OL-TK4	Forest soil water analysis	12.10.2010	MEAS	54702
OL-TK4	Forest soil water analysis	26.7.2010	MEAS	54754
OL-TK4	Forest soil water analysis	19.5.2010	MEAS	54695
OL-TK4	Forest soil water analysis	26.11.2009	MEAS	36573
OL-TK4	Forest soil water analysis	11.12.2009	MEAS	36760
OL-TK4	Forest soil water analysis	16.6.2009	MEAS	36367
OL-FIP04	Sap flow measurement	1.1.2009	PROC	67719
OL-FIP04	Sap flow measurement	1.1.2008	PROC	67718
OL-FIP04	Sap flow measurement	8.5.2007	PROC	67717
OL-FIP04	Sap flow measurement: tree stand transpiration	1.4.2014	PROC	85592
OL-FIP04	Sap flow measurement: tree stand transpiration	1.4.2013	PROC	85591
OL-FIP04	Sap flow measurement: tree stand transpiration	1.4.2012	PROC	73378
OL-FIP04	Sap flow measurement: tree stand transpiration	1.4.2011	PROC	73374
OL-FIP04	Sap flow measurement: tree stand transpiration	1.4.2010	PROC	63421
OL-FIP04	Sap flow measurement: tree stand transpiration	1.1.2009	PROC	35128
OL-FIP04	Sap flow measurement: tree stand transpiration	1.1.2008	PROC	34035
OL-FIP04	Sap flow measurement: tree stand transpiration	8.5.2007	PROC	35335
OL-FIP04	Nutrient analysis of litter fractions	1.1.2013	MEAS	88532
OL-FIP04	Nutrient analysis of litter fractions	1.1.2012	MEAS	78454
OL-FIP04	Nutrient analysis of litter fractions	1.1.2011	MEAS	73457
OL-FIP04	Nutrient analysis of litter fractions	6.5.2010	MEAS	67802
OL-FIP04	Nutrient analysis of litter fractions	14.5.2009	MEAS	56255
OL-FIP04	Nutrient analysis of litter fractions	1.4.2008	MEAS	56939
OL-FIP04	Nutrient analysis of litter fractions	8.5.2007	MEAS	56938
OL-FIP04	Nutrient analysis of litter fractions	25.4.2006	MEAS	56937

OL-FIP04	Nutrient analysis of litter fractions	13.4.2005	MEAS	56936
OL-FIP04	Nutrient analysis of litter fractions	29.6.2004	MEAS	56935
OL-FIP04	Forest inventory: tree measurements (FIP/MRK)	10.3.2014	MEAS	88534
OL-FIP04	Forest inventory: tree measurements (FIP/MRK)	26.3.2009	MEAS	32953
OL-FIP04	Forest inventory: tree measurements (FIP/MRK)	30.6.2004	MEAS	26356
OL-FIP04	Soil chemical analysis (Metla)	24.5.2007	MEAS	28236
OL-FIP04	Sampler and sensor locations	1.1.2007	MEAS	26127
OL-FIP10	Sap flow measurement	1.1.2009	PROC	67722
OL-FIP10	Sap flow measurement	1.1.2008	PROC	67720
OL-FIP10	Sap flow measurement	6.6.2007	PROC	67720
OL-FIP10	Sap flow measurement: tree stand transpiration	1.4.2010	PROC	63422
OL-FIP10	Sap flow measurement: tree stand transpiration	1.1.2009	PROC	35129
OL-FIP10	Sap flow measurement: tree stand transpiration	1.1.2008	PROC	35127
OL-FIP10	Sap flow measurement: tree stand transpiration	6.6.2007	PROC	35334
OL-FIP10	Nutrient analysis of litter fractions	1.1.2013	MEAS	88512
OL-FIP10	Nutrient analysis of litter fractions	1.1.2012	MEAS	85426
OL-FIP10	Nutrient analysis of litter fractions	1.1.2011	MEAS	78294
OL-FIP10	Nutrient analysis of litter fractions	6.5.2010	MEAS	67821
OL-FIP10	Nutrient analysis of litter fractions	15.5.2009	MEAS	56256
OL-FIP10	Nutrient analysis of litter fractions	1.4.2008	MEAS	56943
OL-FIP10	Nutrient analysis of litter fractions	8.5.2007	MEAS	56942
OL-FIP10	Nutrient analysis of litter fractions	25.4.2006	MEAS	56941
OL-FIP10	Nutrient analysis of litter fractions	7.6.2005	MEAS	56940
OL-FIP10	Forest inventory: tree measurements (FIP/MRK)	27.10.2014	MEAS	88535
OL-FIP10	Forest inventory: tree measurements (FIP/MRK)	29.9.2009	MEAS	32952
OL-FIP10	Soil chemical analysis(Metla)	24.5.2007	MEAS	28237
OL-FIP10	Forest inventory: tree measurements (FIP/MRK)	16.6.2005	MEAS	26382
OL-FIP10	Sampler and sensor locations	1.9.2003	MEAS	22004
OL-FIP11	Nutrient analysis of litter fractions	1.1.2013	MEAS	88513
OL-FIP11	Nutrient analysis of litter fractions	1.1.2012	MEAS	85589
OL-FIP11	Nutrient analysis of litter fractions	1.1.2011	MEAS	73459

OL-FIP11	Nutrient analysis of litter fractions	6.5.2010	MEAS	67822
OL-FIP11	Nutrient analysis of litter fractions	14.5.2009	MEAS	56257
OL-FIP11	Nutrient analysis of litter fractions	1.4.2008	MEAS	56945
OL-FIP11	Nutrient analysis of litter fractions	28.5.2007	MEAS	56944
OL-FIP11	Forest inventory: tree measurements (FIP/MRK)	11.3.2014	MEAS	90198
OL-FIP11	Forest inventory: tree measurements (FIP/MRK)	4.6.2008	MEAS	26378
OL-FIP11	Sampler and sensor locations	1.1.2007	MEAS	22009
OL-FIP14	Nutrient analysis of litter fractions	1.1.2013	MEAS	88533
OL-FIP14	Nutrient analysis of litter fractions	1.1.2012	MEAS	85590
OL-FIP14	Nutrient analysis of litter fractions	1.1.2011	MEAS	73460
OL-FIP14	Nutrient analysis of litter fractions	6.5.2010	MEAS	67823
OL-FIP14	Nutrient analysis of litter fractions	4.8.2009	MEAS	56258
OL-FIP14	Forest inventory: tree measurements (FIP/MRK)	28.10.2014	MEAS	90197
OL-FIP14	Forest inventory: tree measurements (FIP/MRK)	30.9.2009	MEAS	90196
OL-FIP15	Forest inventory: tree measurements (FIP/MRK)	14.3.2014	MEAS	90287
OL-FIP16	Forest inventory: tree measurements (FIP/MRK)	13.3.2014	MEAS	90288
OL-FETgroup	Vegetation nutrition analysis	11.8.2010	MEAS	57255
OL-FETgroup	Vegetation nutrition analysis	29.7.2005	MEAS	20922
OL-FETgroup	Soil chemical analysis (Metla)	29.10.2008	MEAS	38745
OL-FETgroup	Soil chemical analysis (Metla)	29.10.2008	PROC	46447
OL-FETgroup	Soil chemical analysis (Metla)	17.5.2005	MEAS	27976
OL-FETgroup	Soil chemical analysis (Metla)	17.5.2005	PROC	28437
OL-FETgroup	Foliage chemical analysis	24.8.2009	MEAS	33734
OL-FETgroup	Foliage chemical analysis	7.3.2006	MEAS	26365
OL-FETgroup	Forest inventory by plots: plot characteristics	14.5.2004	MEAS	42797
OL-FETgroup	Forest inventory: tree measurements (FET)	14.5.2004	MEAS	28056
OL-FETgroup	FET plot locations	1.5.2003	MEAS	21929
OL-MRK01	Sampler and sensor locations	2.6.2003	MEAS	26115
OL-MRK03	Sampler and sensor locations	2.6.2003	MEAS	26116
OL-MRK05	Sampler and sensor locations	26.8.2003	MEAS	26117
OL-MRK06	Sampler and sensor locations	26.8.2003	MEAS	26118
OL-MRK08	Sampler and sensor locations	2.6.2003	MEAS	26119

OL-WOM1	Forest inventory: tree measurements (WOM1)	30.3.2011	MEAS	55570
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2014	PROC	85649
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2014	MEAS	85667
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2013	PROC	82650
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2013	MEAS	78054
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2012	PROC	82630
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2011	PROC	73465
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2010	PROC	67662
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2009	PROC	67229
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2008	PROC	67228
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2007	PROC	67227
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2006	PROC	67226
OL-WOM2	WOM2,Weather Observation Mast 2	1.1.2005	PROC	67225
OL-WOM2	WOM2,Weather Observation Mast 2	1.9.2004	PROC	67224
OL-WOM3	WOM3,Weather Observation Mast 3	23.5.2005	PROC	67664
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2006	PROC	67666
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2007	PROC	67668
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2008	PROC	67669
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2009	PROC	67670
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2010	PROC	67671
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2011	PROC	67672
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2012	PROC	77998
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2013	MEAS	78074
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2013	PROC	77999
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2014	MEAS	85668
OL-WOM3	WOM3,Weather Observation Mast 3	1.1.2014	PROC	85650
OL-WOM4	WOM4,Weather Observation Mast 4	28.6.2007	PROC	67674
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2008	PROC	67675
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2009	PROC	67676
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2010	PROC	67677
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2011	PROC	67678
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2012	PROC	78014
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2013	MEAS	78075
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2013	PROC	78015
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2014	MEAS	85669
OL-WOM4	WOM4,Weather Observation Mast 4	1.1.2014	PROC	85651
OL-WOM5	WOM5,Weather Observation Mast 5	3.11.2009	PROC	67682

OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2010	PROC	67683
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2011	PROC	67684
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2012	PROC	78016
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2013	MEAS	78076
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2013	PROC	82611
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2014	MEAS	85670
OL-WOM5	WOM5,Weather Observation Mast 5	1.1.2014	PROC	85652
OL-MRKgroup	Foliage chemical analysis	29.3.2010	MEAS	73463
OL-MRKgroup	Foliage chemical analysis	19.12.2003	MEAS	66082
OL-MRKgroup	Wet deposition analysis	1.1.2014	MEAS	85546
OL-MRKgroup	Wet deposition analysis	1.1.2013	MEAS	85347
OL-MRKgroup	Wet deposition analysis	1.1.2012	MEAS	85345
OL-MRKgroup	Wet deposition analysis	14.2.2011	MEAS	67764
OL-MRKgroup	Wet deposition analysis	2.2.2010	MEAS	56946
OL-MRKgroup	Wet deposition analysis	2.2.2009	MEAS	53456
OL-MRKgroup	Wet deposition analysis	1.1.2008	MEAS	26153
OL-MRKgroup	Wet deposition analysis	1.1.2007	MEAS	26157
OL-MRKgroup	Wet deposition analysis	1.1.2006	MEAS	26159
OL-MRKgroup	Wet deposition analysis (2003-2005)	1.1.2003	MEAS	26161
OL-TMAspring	Spring and ditch water chemical analysis	30.10.2009	MEAS	36299
OL-TMAspring	Spring and ditch water chemical analysis	28.4.2010	MEAS	42224
OL-TMAspring	Spring and ditch water chemical analysis	16.6.2009	MEAS	36300
OL-TMAspring	Spring and ditch water chemical analysis	23.9.2008	MEAS	26386
OL-TMAspring	Spring and ditch water chemical analysis	13.2.2008	MEAS	26385
OL-KK17	Forest soil water analysis	15.11.2011	MEAS	67884
OL-KK17	Forest soil water analysis	30.5.2011	MEAS	60255

OL-KK17	Forest soil water analysis	9.12.2008	MEAS	54674
OL-KK17	Forest soil water analysis	12.10.2010	MEAS	54697
OL-KK17	Forest soil water analysis	19.5.2010	MEAS	54691
OL-KK17	Forest soil water analysis	7.12.2009	MEAS	36762
OL-KK17	Forest soil water analysis	2.6.2009	MEAS	36382
OL-DI10	Spring and ditch water analysis	20.7.2010	MEAS	54755
OL-DI10	Spring and ditch water analysis	30.10.2009	MEAS	49889
OL-DI10	Spring and ditch water analysis	28.4.2010	MEAS	50573
OL-KK21	Forest soil water analysis	15.11.2011	MEAS	67886
OL-KK21	Forest soil water analysis	16.8.2011	MEAS	60259
OL-KK21	Forest soil water analysis	30.5.2011	MEAS	60258
OL-KK21	Forest soil water analysis	12.10.2010	MEAS	54700
OL-KK14	Forest soil water analysis	15.11.2011	MEAS	67885
OL-KK14	Forest soil water analysis	16.8.2011	MEAS	60254
OL-KK14	Forest soil water analysis	30.5.2011	MEAS	60253
OL-KK14	Forest soil water analysis	12.10.2010	MEAS	54696
OL-KK14	Forest soil water analysis	26.7.2010	MEAS	54750
OL-KK14	Forest soil water analysis	19.5.2010	MEAS	54690
OL-KK14	Forest soil water analysis	2.6.2009	MEAS	36359
OL-KK14	Forest soil water analysis	17.9.2008	MEAS	36580
OL-KK14	Forest soil water analysis	16.11.2009	MEAS	36574
OL-KK14	Forest soil water analysis	7.12.2009	MEAS	36761
OL-KK18	Forest soil water analysis	30.5.2011	MEAS	60256
OL-KK18	Forest soil water analysis	9.12.2008	MEAS	54675
OL-KK18	Forest soil water analysis	12.10.2010	MEAS	54698
OL-KK18	Forest soil water analysis	26.7.2010	MEAS	54751
OL-KK18	Forest soil water analysis	19.5.2010	MEAS	54692
OL-KK18	Forest soil water analysis	16.11.2009	MEAS	36575
OL-KK18	Forest soil water analysis	2.6.2009	MEAS	36389
OL-KK18	Forest soil water analysis	7.12.2009	MEAS	36763
OL-KK19	Forest soil water analysis	30.5.2011	MEAS	60257
OL-KK19	Forest soil water analysis	9.12.2008	MEAS	54676
OL-KK19	Forest soil water analysis	12.10.2010	MEAS	54699
OL-KK19	Forest soil water analysis	26.7.2010	MEAS	54752
OL-KK19	Forest soil water analysis	19.5.2010	MEAS	54693
OL-KK19	Forest soil water analysis	16.11.2009	MEAS	36576
OL-KK19	Forest soil water analysis	7.12.2009	MEAS	36764
OL-KK19	Forest soil water analysis	2.6.2009	MEAS	36392

OL-TK15	Forest soil water analysis	15.11.2011	MEAS	67887
OL-TK15	Forest soil water analysis	16.8.2011	MEAS	60261
OL-TK15	Forest soil water analysis	30.5.2011	MEAS	60260
OL-TK15	Forest soil water analysis	12.10.2010	MEAS	54701
OL-TK15	Forest soil water analysis	26.7.2010	MEAS	54753
OL-TK15	Forest soil water analysis	19.5.2010	MEAS	54694
OL-TMA01	Spring and ditch water analysis	20.7.2010	MEAS	54756
OL-TMA01	Spring and ditch water analysis	13.2.2008	MEAS	50574
OL-TMA01	Spring and ditch water analysis	30.10.2009	MEAS	49890
OL-TMA01	Spring and ditch water analysis	23.9.2008	MEAS	50576
OL-TMA01	Spring and ditch water analysis	16.6.2009	MEAS	50586
OL-TMA01	Spring and ditch water analysis	28.4.2010	MEAS	50577
OL-TMA02	Spring and ditch water analysis	20.7.2010	MEAS	54757
OL-TMA02	Spring and ditch water analysis	30.10.2009	MEAS	49893
OL-TMA02	Spring and ditch water analysis	28.4.2010	MEAS	50582
OL-TMA02	Spring and ditch water analysis	23.9.2008	MEAS	50580
OL-TMA02	Spring and ditch water analysis	16.6.2009	MEAS	50579
OL-TMA02	Spring and ditch water analysis	13.2.2008	MEAS	50578
OL-TMA07	Spring and ditch water analysis	20.7.2010	MEAS	54758
OL-TMA07	Spring and ditch water analysis	30.10.2009	MEAS	49892
OL-TMA07	Spring and ditch water analysis	28.4.2010	MEAS	50585
OL-TMA07	Spring and ditch water analysis	23.9.2008	MEAS	50584
OL-TMA07	Spring and ditch water analysis	16.6.2009	MEAS	50583
OL-TMA07	Spring and ditch water analysis	13.2.2008	MEAS	50581

APPENDIX 3. Material related to forest monitoring on Olkiluoto island stored in Kronodoc during 2003–2014.

Description	Kronodoc no.
Results of forest monitoring on Olkiluoto Island in 2014	PRJ-006997
Results of forest monitoring on Olkiluoto Island in 2013	PRJ-006996
Results of forest monitoring on Olkiluoto Island in 2012	PRJ-006334
Results of forest monitoring on Olkiluoto Island in 2011	PRJ-005226
Results of forest monitoring on Olkiluoto Island in 2010	PRJ-003997
Results of forest monitoring on Olkiluoto Island in 2009	PRJ-003033
Intensive monitoring of forests on Olkiluoto Island	PRJ-002959
Stand meteorology (FIP plots, WOM2-WOM5)	PRJ-006090
Corrected and calculated weather data 1993–2012	PRJ-006408
Lysimeter studies at intensive forest monitoring plot IP4	PRJ-006683
Sampling of soil water on the FIP plots in 2011	PRJ-004267
Results of soil solution chemistry from lysimeters elsewhere than at the FIP plots	PRJ-006173
Metsikkö- ja vapaan sadannan seuranta vuonna 2003	PRJ-006682
Sampling of deposition on MRK and FIP plots in 2008	PRJ-008873
Sampling of deposition on MRK and FIP plots in 2009	PRJ-008872
Sampling of deposition on MRK and FIP plots in 2010	PRJ-003261
Sampling of deposition on MRK and FIP plots in 2011	PRJ-003708
Sampling of deposition on MRK and FIP plots in 2012	PRJ-005054
Results of deposition monitoring at MRK and FIP plots	PRJ-004074
Lindroos, A.-J., Derome, J. & Aro, L. 2008. Annual precipitation, interception by the tree canopies, and the mean pH and amounts of cations, anions and other elements in bulk deposition and stand throughfall on Olkiluoto during 2007, and a comparison with the results for 2004–2006. 13 p.	POS-003852
Sampling of litterfall in 2010	PRJ-003296
Sampling of litterfall in 2011	PRJ-004076
Sampling of litterfall in 2012	PRJ-005222
Results of litter nutrient analyses in FIP plots	PRJ-006085
Puuston runkohaihdunnan laskeminen (Estimating tree stand transpiration)	POS-003795
Hökkä, H. 2008. Tree stand transpiration in forest intensive monitoring	POS-005147

plots (FIP4 and FIP10) on Olkiluoto Island – estimates of annual transpiration June 2007 – June 2008. 5 p.	
Aluskasvillisuuden inventointi 2003, IP4 ja IP9	PRJ-006681
Aluskasvillisuuden inventointi 2004, IP4 ja IP10	PRJ-006684
OL-FIP4:n puuston taustatietoja (jalostuskoe)	PRJ-006685
Tamminen, P. & Aro, L. 2008. Forest soil properties of the FIP plots on Olkiluoto in 2007. 11 p.	POS-005571
juurikuvat FIP-aloilta 2008–2011	PRJ-002679
Results of foliage washing analyses in MRK plots (2004–2009)	PRJ-006084
Aro, L., Ylinen, A. & Rautio, P. 2007. The effect of dust emissions on the needle element concentrations of Scots pine and Norway spruce on the wet deposition monitoring plots in Olkiluoto during 2005 and 2006. 22 p.	POS-003528
Pölypäästöjen seuranta MRK-verkoston neulasanalyysillä (Rautio, P., Aro, L. & Ylinen, A. 2008. The effect of dust emissions on the needle element concentrations of Scots pine and Norway spruce on the wet deposition monitoring plots in Olkiluoto during 2003–2007. 30 p.)	POS-005536
Biomassakoepuiden otto ja esikäsittely (Sampling and pre-treatment of biomass sample trees)	POS-007889
Chemical analysis of sample trees	PRJ-004499
ALS Scandinavia AB:n analysoimat kasvillisuus- ja maaperänäytteet 2008	PRJ-004067
MRK-alojen maaperänäytteet 2011 (Soil sampling on MRK plots in 2011)	PRJ-004303
MRK-alojen maaperä- ja neulasanalyysit	PRJ-004544
MRK-alojen neulasten ja maaperän siirtokertoimet (Transfer factors from soil to needles on the MRK plots)	PRJ-004957
Paljakkaan toimitetut Metlan arkistonäytteet (Archive samples stored in the Environmental Specimen Bank of the Finnish Forest Research Institute, Paljakka)	PRJ-005707
Olkiluodon hakkuut (Thinnings on Olkiluoto Island)	PRJ-002838
Miettinen ja Haapanen 2002. Kuvioittainen kasvillisuuskartoitus	PRJ-006922
Seuranta-alojen kartoitus, Ilavainen ja Tyrniemi 6.6.2013	PRJ-006313
Ympäristötutkimuksen havaintopaikkakoodit ja numerointi	POS-000523
Seurantatutkimukset metsän intensiivihavaintoaloilla (toiminta kenttätutkimusten yhteydessä) (Monitoring studies on Forest intensive plots, field instructions)	POS-000659
Tietojen tarkastus ja hyväksyntä POTTI-järjestelmässä	POS-002807