View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Jukuri

Pools and Fluxes of Key Elements in a Forest Stand in Olkiluoto with a Sensitivity Analysis and an Evaluation of the Knowledge Base

Haapanen, R[1]., Aro, L.[2], Ikonen A. T. K.[3] & Hjerpe, T.[4]

[1]*Haapanen Forest Consulting, Kärjenkoskentie 38, 64810 Finland, reija.haapanen@haapanenforestconsulting.fi*
[2]*Finnish Forest Research Institute, Parkano Research Unit, Kaironiementie 54, 39700 Parkano, Finland, lasse.aro@metla.fi*
[3]*Posiva Oy, Olkiluoto, 27160 Eurajoki, Finland, ari.ikonen@posiva.fi*
[4] *Saanio & Riekkola Oy, Laulukuja 4, 00420 Helsinki, Finland, thomas.hjerpe@sroy.fi*

INTRODUCTION

Olkiluoto Island on the Finnish coast of Baltic Sea has been selected as the repository site for spent nuclear fuel produced in Finland. Olkiluoto Island is ecologically interesting, because it is located on a land up-lift shore, meaning that the soils are young (0 – 2,500 years) and the physical, chemical and hydrological properties are gradually changing. To provide the radioecological models with site-specific data, a monitoring plot applying the concept used in the Pan-European programme for intensive monitoring of forest ecosystems (Raitio *et al*. 2001) was established on Olkiluoto in 2003. This study reports the pools and fluxes of some key elements in the monitored stand based on the site data, supplemented with generic data and assumptions.

MATERIAL AND METHODS

Study site and monitoring system

The monitored stand consists of 40-year-old planted Scots pines growing on a herb-rich site (density 956 stems/ha, mean height 17.1 m, mean DBH 21.4 cm and stem volume 268.1 m^3/ha). The previous tree generation consisted of Norway spruce. The soil is fine-textured till covered by a 3 cm thick organic layer. The site has emerged from the sea ca. 1000 years ago. The monitoring activities are presented in Table 1.

Table 1. Activities performed on study site after establishment in 2003. → = continuous monitoring.

Target of monitoring	Schedule
Coverage of understorey plant species	2003, 04, 05
Basic tree attributes	2004, 2009
Crown condition	2006 → [1)]
Bulk precipitation and stand throughfall, soil water	2003 →
Litterfall	2004 →
Needle chemistry	2003 → [1)]
Micrometeorology, diameter growth	2004 →
Sap flow (evapotranspiration)	2007 →
Soil profile description	2007
Soil analysis	2008

[1)] Measurements or sampling annually

Studied elements and construction of material flow models

The elements considered here are carbon (C) and primary nutrients (nitrogen; N, phosphorus; P and potassium; K). From the point of view of spent nuclear fuel disposal, their most important radioisotope analogues are: C-14 (a radioactive isotope of C) and Cs-137 (chemical analogue of K). As Sr-90 (chemical analogue of calcium) and Cl-36 (behaves like stable chlorine) are important radionuclides as well, Ca and Cl were added to the analysis.

A nitrogen model according to Helmisaari (1998) is presented in Fig. 1. Nitrogen differs from other mineral nutrients in its origin: from atmospheric N bacteria fix it in the form of ammonium (NH_4), which is further changed to NO_3 via nitrification. Nitrogen present in the organic matter detritus is changed into ammonium through mineralization. P, K and Ca originate from minerals via weathering. C is taken from airborne CO_2.

Year 2005 was selected as the basis of calculations. The missing stocks and fluxes were estimated using data from other measurement campaigns from Olkiluoto or from literature.

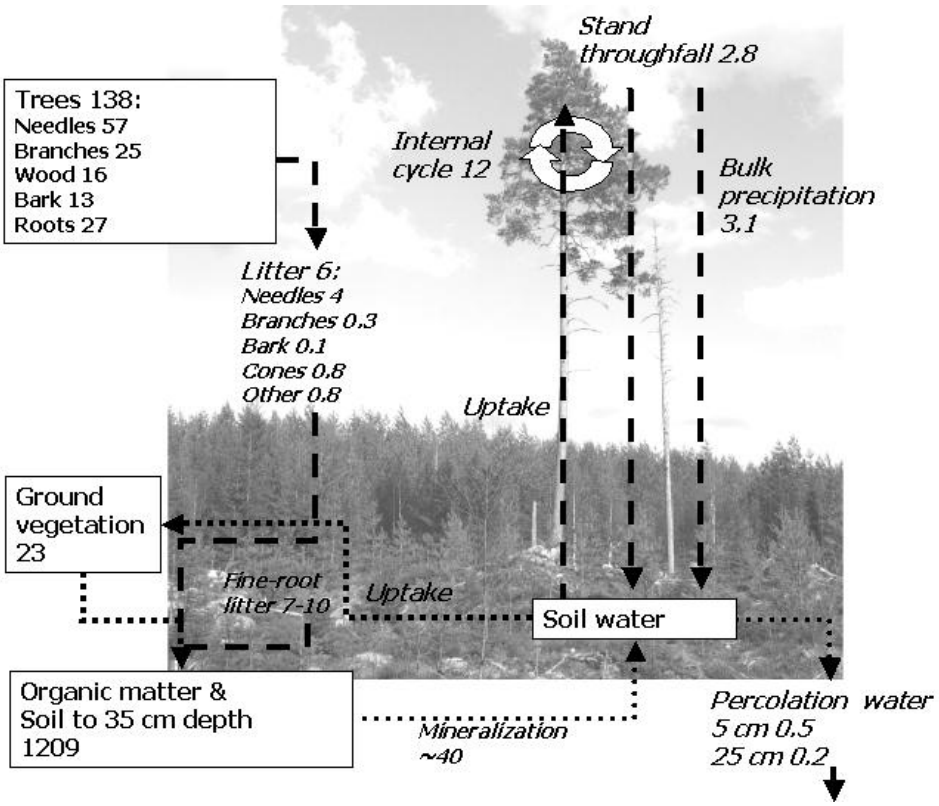

Figure 1. Major pools and fluxes of nitrogen in a forest stand according to Helmisaari (1998). Figures are pools (kg/ha) or fluxes (italics, kg/ha/a) in a 35-year-old pole stage pine stand growing on dryish soil in Eastern Finland. Human and animal interactions are not considered.

RESULTS AND CONCLUSIONS

The results are presented in Table 2. The amounts of nutrients taken from soil, C intake from air, biological N fixation, N mineralization or weathering of other nutrients were not estimated at this stage.

The target stand has a relatively simple structure: there is only one tree species (Scots pine) and the trees are of the same age. However, the fertile site supports a larger stock of tree biomass compared with nutrient studies of pine stands by Mälkönen (1974) and Helmisaari (1998): the stem volumes are 268, 149 and 58 m^3/ha, respectively. This is reflected in the differing nutrient amounts of trees, litterfall and organic layer (Fig. 1 and Table 2). Furthermore, the previous generation of spruces has affected the soil in a different way than a pine stand would have done.

Table 2. Stocks and fluxes estimated for the study site. C in italics is DOC (leaching = TOC), P in italics is PO_4-P. For N, P, K and Ca reference values from Mälkönen (1974) are given in parentheses. These values are from a pine stand growing on fresh soil in Southern Finland (prescribed burning applied before planting, study time precipitation at the same level as in Olkiluoto in 2005). Leaching is based solely on literature.

	C	N	P	K	Ca	Cl	Note
Deposition g/m²/a							
Open areas	*0.8*	0.3 (0.7)	*0.0*	0.1 (0.4)	0.2 (0.5)	0.3	1
Stand throughfall	*4.0*	0.3 (0.5)	*0.0*	0.5 (0.6)	0.2 (0.7)	0.7	2
Soil g/m²							
Organic layer	2360.0	77.6 (37.4)	5.6 (2.2)	6.0 (3.8)	25.9 (14.7)	-	2
Organic layer	2774.2	133.5		4.7	26.6	-	3
Mineral soil, 0-30 cm	2151.3	129.6 (130.0)	- (3.8)	4.5 (9.0)	33.4 (29.7)	-	3
Soil solution g/m²/a							
5 cm	*7.1*	0.2	*0.0*	0.1	0.4	0.2	2
Leaching g/m²/a	*6.7*	0.2	0.0	-	-	-	4
Trees g/m²							
Needles	293.6	9.6 (5.5)	1.0 (0.6)	3.5 (2.6)	2.4 (1.6)	-	5,6
Branches	1163.0	7.4 (3.8)	1.0 (0.4)	4.4 (1.6)	5.6 (2.3)	-	5,7
Stemwood	4945.5	6.6 (3.7)	0.4 (0.2)	3.3 (1.8)	6.1 (3.4)	-	5,7
Bark	373.3	2.8 (2.0)	0.4 (0.3)	1.7 (1.2)	3.7 (2.6)	-	5,7
Stump and roots	1487.2	3.9 (3.6)	0.6 (0.6)	2.7 (2.3)	2.4 (2.3)	-	5,7
Understorey vegetation g/m²	104.2	3.4 (5.9)	0.3 (0.7)	3.0 (2.9)	0.9 (2.2)	-	8
Litterfall from trees g/m²/a	152.4	2.3 (1.0)	0.0 (0.1)	0.0 (0.2)	0.0 (0.7)	-	2

Notes: 1) Average from 3 open area sites in Olkiluoto (Haapanen, 2007), 2) Study site results (Haapanen, 2007; Potila *et al*. 2007), 3) Average of 2 nearby plots: same stand, same site type (Tamminen *et al*., 2007), 4) Kortelainen & Saukkonen (1998); South-Finnish sites with peatland % < 35, 5) Tree measurements from study site fed into Marklund's (1988) models, 6) nutrient concentrations from study site, 7) nutrient concentrations from Mälkönen (1974: pine stand on fresh soil), 8) Biomass from 2 nearby plots, nutrient concentration averages for several same site type plots (Tamminen *et al*. 2007).

The stand was clear-cut in late 1960's, which means that part of the nutrients has been removed in the tree stems. Furthermore, clear-cuttings cause a peak in the leaching of nutrients from the site. There has been a saw in a nearby island until 1923. This indicates, that the site has been subject to tree harvests for a long time. While long-term and intensive management of forests is typical of Finland in general, there are some site-specific features in the nutrient stocks and flows of this site. The young age and fertility of the soils on Olkiluoto contribute to greater amounts of N, P and Ca in the mineral soil layers (Tamminen *et al*., 2007).The Cl levels in deposition and soil solution are higher on Olkiluoto than on a comparison site in mainland due to the surrounding sea areas. K and Ca show higher values in deposition due to ongoing construction works and intense traffic (Haapanen, 2007). The K and Ca deposition results in Mälkönen's (1974) study are explained by the decreasing trend of base cation deposition in Finland since the 1970's.

The results will be completed with sensitivity analysis and quality evaluation of the knowledge base (pedigree analysis) in the final paper.

REFERENCES

Haapanen, R. 2007 (ed.). Results of Monitoring at Olkiluoto in 2006 - Environment. Posiva Oy, Working Report 2007-52. 99 p.

Helmisaari, H-S. 1998. Metsäekosysteemin toiminta ympäristömuutosten ilmentäjänä. (The functioning of forest ecosystem as the indicator of environmental changes). In: Mälkönen, E. (ed). Ympäristömuutos ja metsien kunto. Metsien terveydentilan tutkimusohjelman loppuraportti. The Finnish Forest Research Institute. Research papers 691: 170-174.

Kortelainen, P. & Saukkonen, S. 1998. Leaching of nutrients, organic carbon and iron from Finnish forestry land. Water, Air, and Soil Pollution 105: 239-250

Mälkönen, E. 1974. Annual primary production and nutrient cycle in some Scots pine stands. Comm. Inst. For. Fenn. 84.5. 87 p.

Marklund, L.G. 1988. Biomassafunktioner för tall, gran och björk i Sverige. Sveriges Lantbruksuniversitet, Institutionen för skogstaxering. Rapport 45. 73 p.

Potila, H., Sarjala, T. & Aro, L. 2007. Dissolved nitrogen transformations and microbial community structure in the organic layer of forest soils in Olkiluoto in 2006. Posiva Oy, Working Report 2007-08. 36 p.

Raitio, H., Hamari, A., Merilä, P., Mäkinen, J. & Nöjd, P. 2001. Forest condition monitoring under the UN/ECE and EC programmes in Finland. In: Ukonmaanaho, L. & Raitio, H. (eds.). Forest Condition Monitoring in Finland. National report 2000. Finnish Forest Research Institute, Research Papers 824: 10-33.

Roivainen, P. 2006. Stable elements and radionuclides in shoreline alder stands at Olkiluoto in 2005. Posiva Oy, Working Report 2006-70. 103 p.

Tamminen, P., Aro, L. & Salemaa, M. 2007. Forest soil survey and mapping of vegetation nutrition on Olkiluoto Island. Results from the first inventory on FEH plots. Posiva Oy, Working Report 2007-78. 109 p.