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EFFECT OF HARVESTING METHOD ON THE AMOUNT AND NUTRIENT CONTENT OF LOGGING RESIDUES OF SCOTS PINE IN FIRST THINNINGS ON DRAINED PEATLANDS

Jyrki Hytönen[1] and Mikko Moilanen[2]

[1)] Finnish Forest Research Institute, Silmäjärventie 2, FI-69100 Kannus, phone: +358 50 391 3405, email: jyrki.hytonen@metla.fi
[2)] Finnish Forest Research Institute, P.O. Box 413, FI90014 University of Oulu

SUMMARY

The differences between harvesting intensities as regards to the amount and the nutrient content of logging residues left on site after fist thinning were studied on five mires drained for forestry. Logging residues left on the sites were weighed and peat and foliar samples were taken from remaining trees and their nutrient concentrations were determined. The amount of logging residues was highest after cut-to-length harvesting. In whole tree harvesting the amount of logging residues was 33–66% of that of cut-to-length harvesting. When compared with peat nutrient stores, the highest relative export of nutrients was recorded in the cases of potassium and boron, especially in whole tree harvesting. However, during the first post harvesting years the amount of slash left on site had only minor effect on the nutrition status of trees.

KEYWORDS: whole tree harvesting, peat nutrients, foliar nutrients

INTRODUCTION

Interest in the use of renewable biomass for energy production has increased considerably during the past decade. In forestry, logging residues have great potential as a source for extra bioenergy. The usage of wood from first thinning stands must be intensified, to further increase the proportion of wood as an energy source. Whole tree harvesting (WTH) is rapidly increasing due to high demand for fuel chips. WTH increases the efficiency of forest chip production from small-diameter trees through increased recovery of biomass. The amount of nutrients removed from the site with harvested biomass is larger in whole tree harvesting compared to conventional stem-only harvesting, as branches and foliage account for a significant proportion of the total amount of nutrients bound in trees. Thus concerns have been raised about the negative effects of whole tree harvesting on site productivity, especially on thick-peated nutrient-poor mires drained for forestry.

According to studies carried out on upland soils, whole tree harvesting may decrease tree growth (Jacobson *et al.*, 1996, 2000). In contrast to mineral soils, an increased loss of nitrogen (N) in residue recovery is not a primary concern in peatland forests. Instead, phosphorus (P) and potassium (K) deficiencies are common in Scots pine stands growing on drained peatlands in Finland (Moilanen *et al.*, 2010). Several studies have shown that equal or even higher amounts of K and boron (B) can be bound in the tree stand than in a 20 cm surface peat layer (e.g. Kaunisto and Paavilainen, 1988; Kaunisto and Moilanen, 1998). In this study, we present preliminary results on effects of different harvesting intensities on the amount of logging residues and their nutrient content and on the nutrition of remaining trees after mechanical first-thinning operation. The study period ranged the first 5 years after logging.

MATERIAL AND METHODS

The thinning experiments were set up in Scots pine (*Pinus sylvestris* L.) stands on drained mires in Central Finland (Table 1). The studied mires were mostly classified as *Vaccinium vitis-idea* II site types (Vasander and Laine 2008). The stands were considered to be in need of thinning according to management practices. Mean height of pines varied from 11 m to 14 m. The studied treatments included different intensities of forest residue recovery ranging from conventional cut-to-length method to whole tree harvesting complemented with manual collection of logging residues (Table 2).

Table 1. Information on experiments.

Experiment	Established year	Volume before thinning, m^3ha^{-1}	Thinning removal, m^3ha^{-1}	Number of foliar samples	Numb er of blocks	Size of plots, m^2
Himanka	2003	265	150	5	6	1500-2000
Muhos	2003	160	70	4	4	700-900
Sievi	2008	141	43	3	4	1600
Alajärvi	2009	178	90	2	2	1200-1900
Kinnula	2010	130	55	1	6	1000-1800

Table 2. Harvesting treatments

Treatment	Description
Cut-to-length (CTL)	Tree tops, branches and small sized trees were left at the site. Conventional stem-only method.
Cut-to-length and delimbed tree top (CTL-)	As cut-to-length, but tree was delimbed to the top and small diameter delimbed tree top was collected for energy. Branches and very short tree top left at the site.
Whole tree harvesting (WTH)	Whole trees with branches harvested from the site. Trees were cut for transport at stump level and middle of the trees. No delimbing.
Whole tree harvesting and manual collection (WTH-)	As whole tree harvesting, but harvesting residues still left at the site were collected manually from the sample plots.

The biomass of harvesting residues left on the sample plots after thinning was measured and their nutrient amounts determined. On each plot 5–15 sub plots for weighing the slash were established. Foliar samples from the remaining stand (5–8 trees per plot) were taken 1 – 5 years after cuttings. Also peat samples were collected for determining the topsoil nutrient content. Standard laboratory analyses were done to determine N, P, K, Ca, Mg and B concentrations of the samples. The effect of treatments was tested with ANOVA.

RESULTS

Peat nutrient amounts

There was considerable variation in the peat nutrient amounts between the sites (Table 3). Muhos, Alajärvi and Kinnula sites had considerably lower amounts on N, P, K, and B than

Himanka and Sievi sites. The mean peat depth was over 50 cm in all study areas. At Himanka on some plots, however, even 20 cm peat depths were measured.

Table 3. Peat depth, bulk density and nutrient amounts in the 0–20 cm peat layer.

Experiment	Peat depth, cm	Bulk density, g l^{-1}	Nutrient N	kg ha^{-1} P	K	Ca	Mg	B
Himanka	64	177	7060	398	127	1239	209	1.0
Sievi	56	177	8820	745	118	552	101	0.7
Muhos	>150	104	3750	166	45	383	78	0.3
Alajärvi	70	140	3874	154	63	1381	154	0.6
Kinnula	124	102	4546	144	57	623	73	0.4

Amount of logging residues

The amount of logging residues left at experimental plots varied considerably between the treatments (Fig. 1). The amount was highest at all sites when cut-to-length harvesting was used (at Himanka 15 340 kg ha^{-1} and at other study sites 7 780 - 12 100 kg ha^{-1}).

The amount of logging residues was significantly smaller after whole tree harvesting than after cut-to-length harvesting. However, in the whole tree harvesting still considerable amount of residues were left on the site as broken dead and living branches and needles (Himanka 47%, Sievi 34%, Alajärvi 34%, Kinnula 32 % Muhos 67%). Smallest the amount of residues was when whole tree harvesting was complimented with manual collection of the slash. Even after manual collection considerable amount of logging residues were left on the site: compared with cut-to-length harvesting, the amount varied from 5% (Alajärvi) to 16% (Himanka).

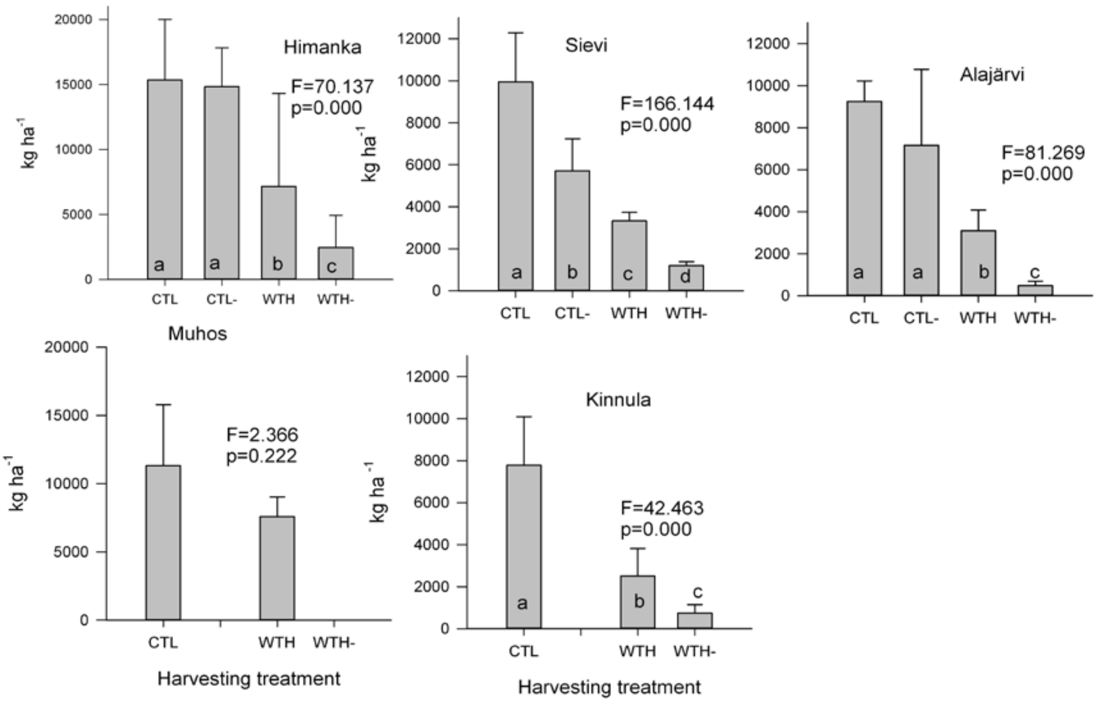

Figure 1. Amount of logging residues (dry-mass) left on site after harvesting. For explanation of treatments see Table 2. At Muhos CTL- and WTH- treatments and at Kinnula CTL- treatment was not included in the study design.

Amount of nutrients in the logging residues

The nutrient content in logging residues was highest at all experiments when cut-to-length harvesting was used (Table 4). Whole-tree harvesting decreased the amount of nutrients left on the site, and especially when it was complemented by manual collection of slash, the removal of nutrients increased considerably.

K has been considered to be one of the critical elements in peatlands. Whole-tree harvesting decreased the amount of K compared with cut-to-length harvesting at Himanka by 12 kg ha^{-1}, at Sievi by 7 kg ha^{-1}, at Alajärvi by 15 kg ha^{-1}, at Muhos by 4 kg ha^{-1}, and at Kinnula by 6 kg ha^{-1}.

Table 4. Amount of nutrients in the logging residues. Means marked with same letter do not differ from each other at 0.05 significance level according to Tukey's test. For explanation of treatments see Table 2.

Experiment	Treatment	Nutrient N	kg ha^{-1} P	K	Ca	Mg	B
Himanka	CTL	85.5[a]	6.7a	20.8a	39.8a	7.3a	0.13a
	CTL-	75.4[a]	6.4a	21.0a	38.4a	6.6a	0.12a
	WTH	34.6[b]	2.7b	9.3b	19.5b	3.0b	0.05b
	WTH-	13.8[c]	1.0c	3.2c	7.2c	1.1c	0.02c
Sievi	CTL	43.1a	4.7a	10.8a	16.9a	4.9a	0.05a
	CTL-	33.4a	3.0b	6.8b	12.6a	3.0b	0.03a
	WTH	20.9b	1.6c	3.5c	5.7b	1.6c	0.02b
	WTH-	9.0c	0.7d	1.5d	3.0c	0.7c	0.01b
Muhos	CTL	51.8	4.3	11.5	18.5	6.2	0.06
	WTH	36.3	3.0	7.8	12.0	4.3	0.03
Alajärvi	CTL	56.0a	6.8a	18.4a	22.8a	5.4a	0.07a
	CTL-	39.2ab	4.3ab	11.6ab	16.0a	3.8ab	0.05ab
	WTH	16.8bc	1.8b	4.3b	7.7b	1.6bc	0.02ab
	WTH-	3.3c	0.4b	0.9c	1.4c	0.3c	0.00b
Kinnula	CTL	39.2a	3.4a	8.9a	18.5a	3.9a	0.04a
	WTH	15.1b	1.1b	2.7b	5.9b	1.3b	0.01b
	WTH-	4.2c	0.3c	0.6c	1.9c	0.3c	0.00c

Foliar nutrient concentrations

N concentrations of Scots pine needles were high and well above deficiency limits at all experiments (nutrient deficiency limits see e.g. Paarlahti *et al.*, 1971). Except to Kannus, on other sites the trees were suffering from a slight to severe shortage of K, whereas P status was mostly adequate. Different thinning treatments—regardless of the amount of harvesting residues removed from the site — had only minor effect on foliar nutrient concentrations. Only at Kannus, during the fourth growing season after logging, K concentration was significantly ($p=0.009$) lower in whole-tree harvesting than in the conventional stem-only harvesting.

DISCUSSION

In this study, we measured the amount of logging residues left on the site after different harvesting treatments. After whole tree harvesting, the amount of logging residues was much smaller than after conventional stem-only harvesting. However, a considerable part (32-67%) of the slash remained on the site after the whole tree harvesting, and even when it was complemented with a manual collection of residual biomass. Thinnings were done mechanically during winter which probably has increased the breaking of small branches. In our experiments more logging residues were left at the site after whole tree harvesting than the current recommendations require (30%) (Äijälä *et al.*, 2010). Also in clear cuttings, the amount of unrecovered biomass has been reported to be 38–50 % of the total residue biomass (Nurmi, 2007).

The amount of remaining biomass in loggings is important for the nutrient reserves of the site. Thus, even after whole tree harvesting, considerable amounts of the nutrients of the tree stand were left in the stand.   During the first one to five years after thinning, intensified recovering of logging residues did not affect the nutrition of the Scots pine. Only at Kannus whole tree method seemed to have lowered foliar K concentration in one study year. Since most of the sites had evident K (and P) deficiencies fertilization of the stands with PK or wood ash would considerable improve the stand growth and is also recommended in recommendations of practical forestry. Following fertilization recovery of logging residues would not cause nutritional risk for the development of the stand. However, the experiments should be followed longer in order to verify the short-term results and study the long-term effects of the treatments on stand growth.

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