Profitability of fertilisation of Scots pine on a drained mire – a case study

Anssi Ahtikoski[1], Mikko Moilanen[2] and Hannu Hökkä[1]

[1] Finnish Forest Research Institute, Eteläranta 55, FIN 96300 Rovaniemi
Phone: + 358 10 211 4416 for Anssi Ahtikoski and +358 10 211 4528 for Hannu Hökkä; fax: + 358 10 211 4401;
e-mails: anssi.ahtikoski@metla.fi, hannu.hokka@metla.fi

[2] Finnish Forest Research Institute, Kirkkosaarentie, FIN-91500 Muhos
Phone: +358 10 211 3743; fax: +358 10 211 3701; e-mail: mikko.moilanen@metla.fi

Summary

Nutrient imbalances and deficiencies have been amended with fertilisation in practical peatland forestry, but studies focusing on the financial aspects of fertilisation are few. In this study, we determined the return on investment (ROI) of fertilisation treatment in a thick-peated minerotrophic mire drained for forestry. The fertilisation treatments were control, PK (phosphorus-potassium) and NPK (nitrogen-phosphorus-potassium), and the annual increases in stem volume during 28 years were 2.0, 7.8 and 7.7 m^3 ha^{-1}, respectively. In the financial analyses we adopted different price combinations of pulpwood and sawlogs real stumpage prices. The results showed that PK-treatment (8.2–13.8% ROI) outperformed NPK-treatment (6.5–10.7% ROI), with fluctuating stumpage prices.

Key index words: peatlands, fertilisation, *Pinus sylvestris* (L.), tree growth, return on investment (ROI)

Introduction

Tree growth on drained mires may often be restricted by a shortage of phosphorus and potassium (Kaunisto and Tukeva, 1984; Moilanen, 1993). Nutritional problems are emphasized on originally treeless or sparsely forested mesotrophic sites. On ombro-oligotrophic sites, also nitrogen limits the growth of trees, especially in the northern climatic conditions (Pietiläinen and Kaunisto, 2003). Nutrient deficiencies and imbalances on peatlands have been amended with fertilisation in practical forest management in Finland: about 1.6 million ha have been fertilised during the last 50 years. Stand growth will increase after phosphorus and potassium fertilisation on nitrogen-rich peatlands (e.g. Silfverberg and Hartman, 1999; Pietiläinen *et al.*, 2005). On nitrogen-poor sites, a clear growth response of N fertilisation has been reported in many studies (e.g. Moilanen, 1993).

In recent forest economic literature, the focus has been on optimal stand management in various forms (e.g. Hyytiäinen and Tahvonen, 2001). The debate on financial performance of alternative management regimes or single forest measures has been significantly less (e.g. Ashton *et al.*, 2001). Nevertheless, the question on how profitable a single forest measure can actually be is of great relevance, especially for practitioners. In earlier studies, it has been found that PK- and NPK fertilisation could turn out to be rather profitable on oligo-mesotrophic sites, even in young pine stands (Rantala and Moilanen, 1993).

The objectives of this study were to evaluate the long-term growth responses to PK and NPK fertilisation in Scots pine stands, the respective foliar responses, and the financial performance of treatments on thick-peated drained mire in the short run. The financial performance was calculated by applying ROI, return on investment method (e.g. Hyder *et al.*, 1999).

Materials and methods

Study site and experiment design

The experimental stand was dominated by Scots pine (*Pinus sylvestris* (L.)) and located on a drained mire on the boreal climate zone in Muhos (64° 53’ N, 26° 05’ E), central Finland. Mean annual temperature sum is 1023 dd (>5 °C), and mean precipitation 506 mm. The site type was classified as moderate fertile tall-sedge pine fen. The basic drainage was carried out in 1939 and a supplementary drainage in 1976 and 1989. Ditch spacing was 30 m and peat thickness between 65 and 90 cm. The total nitrogen concentration in the surface peat was 1.9–2.1 % d.m. (analysis made in 1987).

The fertilisation trial comprising 9 plots was set up in May 1979 (0.06 ha plots) in a design of three randomized blocks. The fertilisers consisted of ‘Urea’ (N 46 %) and ‘PK fertiliser for peatlands’ (P 9 % as raw phosphate, K 17 % as potassium chloride). The experiment included unfertilised control, PK treatment (P 44 kg ha^{-1}, K 83 kg ha^{-1}), and NPK treatment (P 44 kg ha^{-1}, K 83 kg ha^{-1}, N 93 kg ha^{-1}). The stand dominant height was 8–9 m and stem volume 40–50 m^3 ha^{-1} at the time of setup. The stand was thinned in 1994 (removing 36–52 % from stem number depending on the plot) according to the guidelines presented for practical forestry.

Measurements, samples and chemical analyses

The tree stand was measured when 17 and 28 growing seasons had elapsed since the fertilisation. All trees were counted by species and breast-height (1.3 m) diameter. The heights were measured from 20–21 randomly chosen sample pines. Increment cores were extracted from breast height from each sample tree. The development of tree stand characteristics was calculated by using the taper curve and volume functions for Scots pine (Laasasenaho, 1982).

The nutrient status of the stand after fertilisation was monitored by needle samples that were collected during the dormant season in March, when 5, 15 and 22 years had elapsed since fertilisation. Standard laboratory analyses were carried out to determine element (N, P, K, B) concentrations of the samples.

Data analysis

A repeated measures ANOVA model was applied to test the effect of fertilisation treatment on nutrient concentrations. Tree stand measurements indicated remarkable variation between and within the blocks as regards to the timber assortment distribution at establishment of the trial. Therefore, only the most homogeneous block was accepted for the final calculations.

We calculated the return on investment, ROI by adopting the following formula:

$$INV*(1+ROI)^t = \Delta CI_t \text{, where} \qquad [1]$$

INV = initial investment cost on fertilisation, €/ha
ROI = return on investment, %
ΔCI = difference in cutting income at year *t* between the plot which has been fertilised and the control plot (i.e. no fertilisation), €/ha (NOTE: in this study *t* was fixed, i.e. 16 years)

For PK-fertilisation the total cost was 216 €/ha, and for NPK-fertiliser it was 415 €/ha. Both total costs included material and labour costs, reflecting the cost level of year 2007 in Finland. The adopted formula [1] here is a modification from the more general NPV formula (see, e.g. Raunikar et al. 2000).

As a sensitivity analysis, we tested the robustness of ROI with respect to fluctuating stumpage prices. We identified the peaks and bottoms of real stumpage prices of sawlogs and pulp wood (deflating original time series by wholesale price index). Then we applied these into average stumpage prices of Jan 2007–Aug 2007. Finally there were five alternative price combinations for which we determined the ROIs. These five price combinations were: Min sawlogs & Max pulpwood (pine sawlogs price 50.76/ pine pulpwood price 32.21 €/m^3), Min pulpwood & Max sawlogs (74.54/8.17), Min sawlogs & Min pulpwood (50.76/8.17), Max sawlogs & Max pulpwood (74.54/32.21) and Averages of Jan 2007–Aug 2007 (64.81/16.01).

Results

The nutrient status and growth of the stand

Based on the repeated measures ANOVA, the unfertilised trees were suffering from a severe lack of phosphorus and potassium (P concentration < 1.3 mg/g, and K concentration < 4.0 mg/g; see Paarlahti *et al.*, 1971). N status of trees was adequate. PK and NPK treatments significantly increased the foliar phosphorus and potassium concentrations of Scots pine above the deficiency limits.

The stand growth and growth response to PK and NPK fertilisation treatments increased remarkably after the fertilisation during the whole 28-year time period 1979–2006 (Fig. 1). The reaction continued still after the thinning in the end of the time period. The total increases in stem volume in 28 years were 57, 217 and 215 m^3 ha^{-1} (control, PK, and NPK, respectively).

Financial analysis

The ROIs were slightly higher for PK fertiliser than for NPK fertiliser (Fig. 2). This is due to lower total cost of PK fertiliser compared to those of NPK fertiliser: 216 vs. 415 €/ha, respectively. This higher investment cost associated with the NPK fertiliser could not, after all, be compensated by the slightly better growth response of the NPK fertiliser compared to PK fertiliser (Fig. 1). On average, the ROIs were high: if maximum sawlogs and pulpwood prices were applied, the ROI for PK fertilisation was as high as 13.8 %. On the other hand, with fluctuating stumpage prices also the ROI varied distinctively: when the minimum sawlogs and pulpwood prices were applied, the ROI was as low as 8.2% for PK fertiliser and only 6.5 % for NPK fertiliser (Fig. 2).

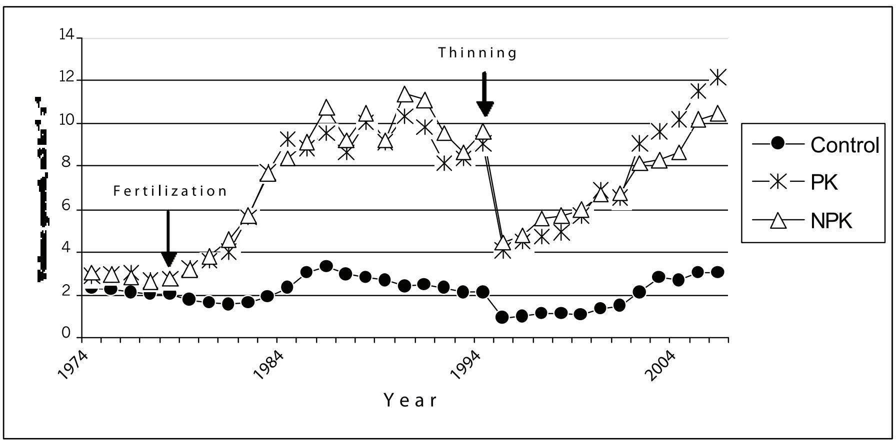

Figure 1. The annual development of stand growth after fertilization and thinning treatments.

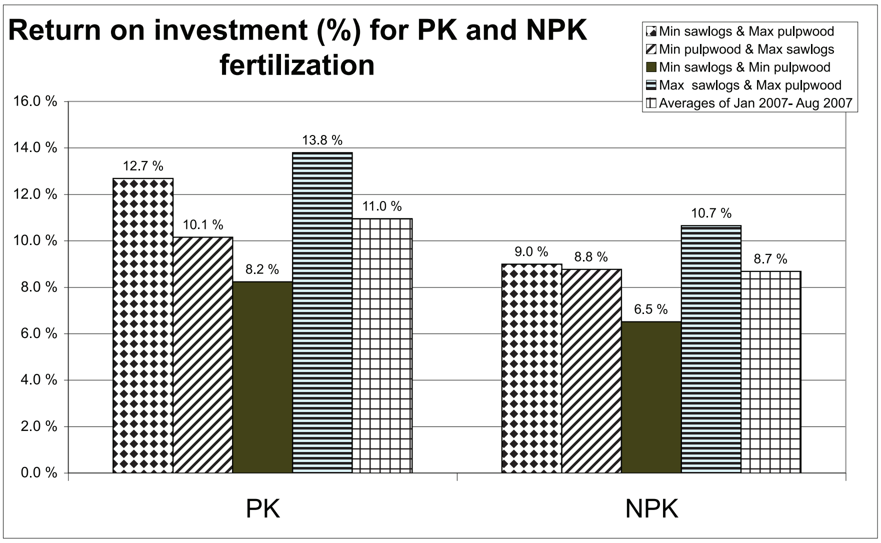

Figure 2. Returns on PK and NPK fertilization (%) with alternative price combinations.

Discussion

In earlier studies, the biggest increases of tree growth after nutrient applications have been gained in nitrogen-rich fens in central Finland. Stand growth increased 2–3 times during 20–30 years compared with unfertilised stands (e.g. Pietiläinen *et al.*, 2005). In this study, the stand response was even more powerful. Two explanations for this can be presented. Firstly, the strong and long lasting response was a consequence of detected severe P and K shortage which probably prevented the normal development of the stand. Secondly, the total N concentration in the peat substrate was adequate (nearby 2 % d.m.) to ensure a good or 'excellent' N status for trees (Pietiläinen and Kaunisto, 2003). Thus, the use of N fertiliser proved to be unnecessary.

The ROIs ranged substantially along the fluctuating stumpage prices. This confirms the fact that good financial performance of the fertilisation is a result of two elements: successful growth response (due to fertilisation) and good timing (ability to roughly forecast peaks and bottoms of stumpage prices).

References

Ashton, M.S., Mendelsohn, R., Singhakumara, B.M.P., Gunatilleke, C.V.S. and Evans, A. (2001). A financial analysis of rain forest silviculture in southwestern Sri Lanka. *Forest ecology and management* **154**, 431-441.

Hyder, A.S., Lönnstedt, L. and Penttinen, M. (1999). Accounting as a management tool for non-industrial private forestry. *Scandinavian journal of management* **15**, 173-191.

Hyytiäinen, K. and Tahvonen, O. (2001). The effects of legal limits and recommendations on timber production: the case of Finland. *Forest Science* **47(4)**, 443-454.

Kaunisto, S. and Tukeva, J. (1984). Kalilannoituksen tarve avosoille perustetuissa riukuvaiheen männiköissä (English summary: need for potassium fertilization in pole stage pine stands established on bogs). *Folia Forestalia* **585**, 40pp.

Laasasenaho, J. (1982). Taper curve and volume functions for pine, spruce and birch. *Communicationes Instituti Forestalis Fenniae* **108**, 74pp.

Moilanen, M. (1993). Lannoituksen vaikutus männyn ravinnetilaan ja kasvuun Pohjois-Pohjanmaan ja Kainuun ojitetuilla soilla (English summary: effect of fertilisation on the nutrient status and growth of Scots pine on drained peatlands in northern Ostrobothnia and Kainuu). *Folia Forestalia* **820**, 37pp.

Paarlahti, K., Reinikainen, A. and Veijalainen, H. (1971). Nutritional diagnosis of Scots pine by needle and peat analysis. *Communicationes Instituti Forestalis Fenniae* **74(5)**, 1-58.

Pietiläinen, P. and Kaunisto, S. (2003). The effect of peat nitrogen concentration and fertilization on the foliar nitrogen concentration of Scots pine (*Pinus sylvestris* L.) in three temperature sum regions. *Suo – Mires and Peat* **54(1)**, 1-13.

Pietiläinen, P., Moilanen, M. and Vesala, H. (2005). Nutrient status and growth of Scots pine (*Pinus sylvestris* L.) on drained peatlands after potassium fertilisation. *Suo – Mires and Peat* **56(3)**, 101-113.

Raunikar, R., Buongiorno, J., Prestemon, J.P. and Abt, K.L. (2000). Financial performance of mixed-age naturally regenerated loblolly-hardwood stands in the south central United States. *Forest policy and economics* **1**, 331-346.

Rantala, T. and Moilanen, M. (1993). Nuorten suomänniköiden lannoituksen kannattavuus Pohjois-Pohjanmaalla (English summary: profitability of fertilisation of young pine stands in northern Ostrobothnia). *Folia Forestalia* **821**, 20pp.

Silfverberg, K. and Hartman, M. (1999). Effects of different phosphorus fertilisers on the nutrient status and growth of Scots pine stands on drained peatlands. *Silva Fennica* **33 (3)**, 187-206.