Ditch network maintenance in peatland forest as a private investment: short- and long-term effects on financial performance at stand level

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SUMMARY

In Finland, most of the suitable peatland has now been ditched for forestry purposes, and ditch network maintenance (DNM) is carried out on 70,000–80,000 hectares of land each year. We examined the financial performance of DNM operations on 44 sample plots representing two medium-quality site types located within two different climatic regions in northern Finland. We applied a simulation approach in which actual measurements of trees growing on sample plots were fed into a stand simulator (MOTTI) which predicted stand development with and without DNM. The financial assessments involved calculating short-term and long-term effects of DNM by applying, respectively, ROI (return on investment) and NPV (net present value) analyses. The results indicated that the financial performance of DNM, particularly in the short term, was highly dependent on the availability of government subsidies. Without the DNM subsidy, the return on investment was between 1.6% and 3.7%; whereas with government subsidy it ranged from 3.8% to 8.4%. In the long run, the net present value was *ca*. 4–14% higher for stands with DNM than for those without.

KEY WORDS: forestry economics, MOTTI stand simulator, net present value (NPV), return on investment (ROI), SINKA plots.

INTRODUCTION

Peatland is extensive in Finland, covering at least 29% (Montanarella *et al*. 2006) and originally some 34% (10.4 million ha) of the country. The natural peatland vegetation includes Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and silver birch (*Betula pendula* Roth) which currently account, respectively, for 48%, 24% and 26% of the 21.2 million m^3 annual growth increment of peatland forest (Tomppo 2005).

The practice of draining peatland to improve the growth of forest has been common across the whole of Fennoscandia (e.g. von Arnold *et al*. 2005), the intention being to increase roundwood production (Päivänen 2007). The productivity of trees growing on wet soils is usually limited by waterlogging, so that altering the hydrological regime by excavating networks of ditches releases the innate potential of the land for timber production. Benefits are realised as both enhanced growth in height and girth of existing trees (e.g. Seppälä 1969, McDonald & Yin 1999) and increased density of sapling establishment (e.g. Hökkä & Laine 1988).

In Finland, according to the Ninth National Forest Inventory (NFI9), approximately 6.1 million hectares of peatland and paludified forest have been drained for forestry (Tomppo 2005). During the last 15 years, however, the area of new ditching has declined from appoximately 41,000 hectares per year to practically zero because almost all of the suitable peatland has already been drained. Over the same period, the area of land where ditch network maintenance (DNM) operations have been carried out has varied between 70,000 and 80,000 hectares annually (FFRI 2005). This arises because, in boreal conditions, the ditch networks deteriorate at such a rate that maintenance is generally required after 20–30 years in order to sustain their beneficial effect on tree growth (Ahti 2005). Much of the area that is subject to DNM is dominated by stands of Scots pine (Nuutinen *et al*. 2000) on medium-quality or poor-quality sites.

Changing the focus from new ditching to DNM operations has generated two new challenges for peatland forest management. The first is to quantify the benefits of DNM in terms of enhanced tree growth and the second is, more importantly, to determine whether the growth enhancement achieved justifies the financial outlay. Research on the former issue has led to the development of a growth response model (Hökkä & Kojola 2002, Hökkä & Salminen 2006). The latter can be addressed by determining the conditions under which the increased growth due to DNM will provide a financially positive outcome.

Recent literature in forestry economics has focused on optimal stand management (e.g. Brazee & Bulte 1997, Hyytiäinen & Tahvonen 2001, Pohjola & Valsta 2006). Significantly less attention has been paid to the financial performance of alternative management regimes and individual forestry operations (e.g. Raunikar *et al*. 2000, Ashton *et al.* 2001, Valkonen & Valsta 2001). Nevertheless, the question of how profitable a single forestry measure such as DNM can actually be is of great relevance from a practical as well as from a socio-economic point of view. Private forest owners (assuming that they act rationally) and private companies increasingly seek and implement only the most profitable of the forestry measures that are available to them. Furthermore, the public sector tends to finance only forestry measures which are assumed or proven to be "best" in terms of generating the highest value-added input to the economy.

The aim of our study was to evaluate the financial performance of ditch network maintenance (DNM) operations for two representative stand types. Financial performance corresponds to profitability, and was calculated separately for short-term and long-term time perspectives using ROI (return on investment) and NPV (net present value) methods respectively.

METHODS

Data acquisition

Our study employed existing SINKA data. SINKA is an acronym for the Finnish "**S**uometsien **IN**ventointi**K**oe**A**lat", which translates roughly as "permanent peatland inventory plots". SINKA plots are forested plots on peatland which are used for recurrent inventories of tree growth and timber yield. They were originally selected by stratified systematic sampling from the subset of the Seventh National Forest Inventory (NFI7) plots that were situated on drained peatland, and established in 1984–1988 in order to produce data for models of stand- and tree-level growth in such locations (Penttilä & Honkanen 1986, Hökkä *et al*. 1997). The first measurements were made during the period 1988–1994 and they were repeated for each plot when five growing seasons had elapsed. The sampling units were stands which were homogeneous with respect to site and stand development stage, and in satisfactory silvicultural condition. Each SINKA plot was made up of three circular sub-plots located 40 m apart, and the whole plot contained *ca.* 100 tally trees with minimum diameter at breast height (d.b.h.) 2.5 cm, or 4.5 cm if the stand had passed the pole stage (Hökkä *et al*. 1997). Numerous measurements were made to describe the trees, the stands and the sites.

For this study we selected 44 SINKA stands in northern Finland. Two different peatland forest site types (distinguished on the basis of vegetation) were represented. Sites of Type Mtkg II are relatively good mesotrophic sites at an advanced stage of transformation through drainage ('in transformed phase'), where productivity approaches that of stands on mineral soil and the ground layer consists of *Vaccinium myrtillus* L. and other dwarf shrubs with some herbs. Sites of Type Ptkg II are moderately productive oligotrophic sites, with *Vaccinium vitis-idaea* L. and other dwarf shrubs dominating the ground layer. The tree layer of both types is generally pine-dominated, but pubescent birch (*Betula pubescens* Ehrh.) may compose a significant proportion of this layer, being more vigorous in Mtkg II sites (Laine 1989). Exclusively juvenile (younger than half-rotation) stands were selected for this study - either young pole or thinning stands with average d.b.h. less than 12 cm. Average stand characteristics are given in Table 1.

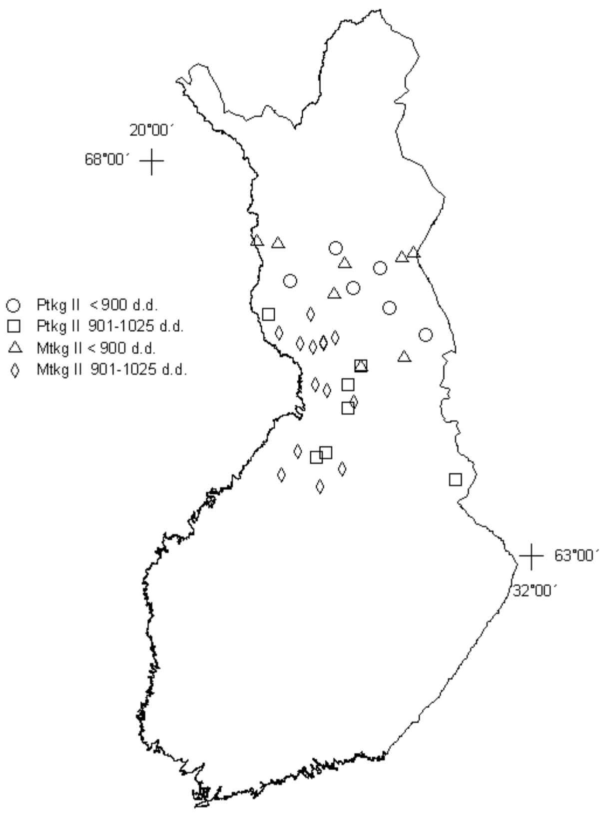

Figure 1. Map of Finland showing the locations of SINKA plots used in the analysis. The plots are divided into four categories according to site type and climatic region (see text for details).

Table 1. Average stand characteristics of SINKA plots included in the simulation, categorised according to peatland forest site type and climatic region. Standard deviations in parentheses.

Site Type	Climatic Region (d.d. °C)	Number of plots *n*	Stem number[1]	Weighted diameter[2] (cm)	Basal area (m^2 ha^{-1})	Dominant height (m)
Ptkg II	< 900	8	1122 (607)	8.4 (1.4)	3.8 (2.4)	6.4 (1.6)
Mtkg II	< 900	10	1087 (439)	11.3 (2.8)	6.7 (3.0)	8.0 (1.2)
Ptkg II	901–1025	11	1811 (863)	6.4 (1.3)	11.9 (5.3)	7.0 (0.9)
Mtkg II	901–1025	15	1505 (469)	9.9 (1.4)	15.0 (4.7)	9.6 (1.6)

[1] Stem number includes both hardwood and coniferous species. All sample plots were pine dominated, i.e. at least 70% of the total number of stems were pine.
[2] Average diameter weighted according to basal area.

Climate was described in terms of the temperature sum (in day degrees, abbreviated to 'd.d.'), which was calculated from information contained in the SINKA database as the annual sum of the number of degrees by which each daily mean temperature exceeded +5 °C. The climatic range encompassed by the suite of site locations included in the study was divided into two regions (< 900 day degrees, and 901–1025 day degrees).

Growth predictions

Growth predictions were generated using the MOTTI stand simulator. This is a stand-level growth simulation model incorporating growth and yield models based on assumptions that are consistent with generally accepted principles of empirical tree growth modelling as described by Wykoff (1990). It is designed to simulate stand development in Finland under alternative management regimes and growth conditions (Hynynen *et al*. 2002, Matala *et al*. 2003, Salminen *et al*. 2005), and offers separate models for peatland trees (Hökkä 1997, Hynynen *et al*. 2002, Hökkä & Salminen 2006). It incorporates distance-independent tree-level models for predicting, e.g., natural regeneration, growth and mortality in addition to the effects of management on tree growth (Hynynen *et al*. 2002). Specifically relevant in the present context are the logistic regression models for identifying DNM requirements and the model for predicting the growth responses of stands to DNM implementation under different conditions, which can be used to estimate the effects of drainage and DNM on stand-level growth forecasts (Hökkä & Salminen 2006). Management operations such as ditching can be applied during a simulation, or the stand management regime for the entire simulation period can be defined at the outset. For financial analyses, the MOTTI accepts several user-defined variables such as the cost of management practices, timber prices and interest rate (Hynynen *et al*. 2005).

Tree tally data for individual plots were fed into the MOTTI stand simulator to obtain predicted growth and yield with and without DNM. The management options applied were combinations of DNM and thinning operations. Where implemented, the DNM operation was simulated at the beginning (Year t_0) of the run.

Short-term financial performance

Corporate finance theory offers many alternative methods for evaluating the financial desirability of an investment, depending how risk is taken into account (e.g. Luenberger 1997, Meggison 1997). One of the commonest (and simplest) approaches is to calculate the 'return on investment' or ROI (Friedlob & Plewa 1996). The ROI method is an application of Fisher's Interest Theory (Fisher 1930, Hyder *et al*. 1999) that measures the rate of financial return on a single activity. This is the deterministic return, risk being taken into account indirectly by e.g. calculating separate ROIs for each bundle of investments and further applying e.g. volatility calculations.

The ROI method is applicable when we are interested in the investment as a whole rather than just the shareholder's perspective, for which ROE (return on equity) is usually calculated. ROE differs from ROI because companies typically borrow part of their capital (Friedlob & Plewa 1996). In Finland, private non-industrial forest owners tend not to apply for loans to finance forestry operations, but rather use their own assets and government subsidies (Ollonqvist 2004, FFRI 2005, Aarnio & Uotila 2006). The government subsidy system for DNM (Anonymous 1996) is based on a very broad three-zone classification based on climate (all of our sample plots were located within a single DNM subsidy zone), and the subsidies are widely available. Thus ROI is more appropriate than ROE for the Finnish situation.

In order to assess the short-term effects of DNM on financial performance, ROI was calculated using the equation:

$$\left[COST_{DNM} * (1+ROI)^{t}\right] - COST_{DNM} = \Delta CI_{t} \qquad [1]$$

re-arranged as:

$$(1+ROI)^{t} = \frac{\Delta CI_{t} + COST_{DNM}}{COST_{DNM}} \qquad [2]$$

where $COST_{DNM}$ = DNM operation cost in € ha^{-1} ($COST_{DNM}$ = 240 € ha^{-1} without government subsidy and = 84 € ha^{-1} with the appropriate subsidy); *ROI* = return on investment (%); ΔCI_t = difference in felling income or monetary value of growing stock (€ ha^{-1}) between alternatives with and without DNM at time *t*; and *t* = time in years since DNM was carried out (note that *t* can have three different values for a single stand, depending on the method applied; see below).

ROI was calculated by iterating in a spreadsheet program (Microsoft Excel 2000) with accuracy set to two decimal places. The term ΔCI_t was calculated as the monthly average stumpage price for authentic timber assortments reflecting the pattern of extraction from forests in northern Finland during the period January to October 2006 (FFRI 2006).

We calculated theoretical ROIs at two time points for each stand. ROI_1 was based on the assumption that we could fully capitalise on the accumulated additional growth due to DNM at the time when annual growth increment was at its peak (Figure 2). ROI_2 was calculated by assuming that we could fully capitalise on the increase in growing stock when this was at its peak (Figure 3). These ROIs are regarded as theoretical because no opportunity to realise financial return (by extracting thinnings) was exploited. Finnish silvicultural recommendations provide guideline thresholds for thinning which are specified separately for each tree species and soil type by a curve relating basal area to dominant height (Anonymous 2006). As the prescribed thinning threshold was not necessarily exceeded in all stands at the time points chosen for calculating ROI_1 and ROI_2, no thinning at all was simulated and these ROIs are purely theoretical.

We also calculated actual ROI (ROI_3) for the earliest time point after DNM implementation at which the thinning threshold was exceeded. Thinning was simulated by adjusting the post-thinning basal area to the same level for cases with and without DNM. After thinning, the remaining basal area corresponded to the lower end of the post-thinning range defined by current silvicultural recommendations (Anonymous 2006).

In some sample plots the thinning threshold was not exceeded within 20 years, after which the growth response to DNM disappears. To explore possible causes we carried out a statistical analysis of differences in stand characteristics between sample plots in which the thinning threshold was exceeded and those in which it was not. This tested whether basal area, weighted diameter and dominant height had differed significantly between the two plot categories at the beginning of the simulation.

Long-term financial performance

For long-term effects of ditch network maintenance on financial performance we calculated the net present value, NPV (e.g. Tiernan & Nieuwenhuis 2005, Naim 2006, Siregar *et al*. 2007) for each stand. NPV is a standard metric in economics for the financial appraisal of long-term projects. It measures the excess or shortfall of cash flows in present value terms, once financing charges have been met, and is an indicator of how much value an investment or project adds to the total value of a company. The rate that is used to discount future cash flows to their present values is a key variable (see e.g. Santhakumar & Chakraborty 2003).

The NPVs were calculated according to the following equation:

$$NPV_{diff} = \left[\sum_{n=1}^{N} \frac{CI_n^{DNM}}{(1.0p)^n} - COST_{n=0}^{DNM}\right] - \sum_{t=1}^{T} \frac{CI_t^{NO}}{(1.0p)^t} \qquad [3]$$

where NPV_{diff} = difference in NPV between alternatives with and without DNM in € ha^{-1}; CI_n^{DNM} = cutting income at year *n* in cases with DNM, valued at stumpage in € ha^{-1} (cutting income derived from thinnings when $n \neq N$ and from final cut when $n = N$; $COST_{n=0}^{DNM}$ = DNM operation cost at year 0 (without subsidy this cost is 240 € ha^{-1} and with subsidy it is 84 € ha^{-1}); CI_t^{NO} = cutting income at year *t* in cases with DNM, valued at stumpage in € ha^{-1} (for thinnings $t \neq T$ and for the final cut $t = T$); *n,t* = thinning times for alternative scenarios with (*n*) and without (*t*) DNM; and *p* = discount rate, which ranges here from 2% to 5% in steps of 1%.

We calculated NPV only for sample plots where the thinning threshold was exceeded within the 20 year period of the DNM cycle and for which, therefore, intermediate thinning could be simulated.

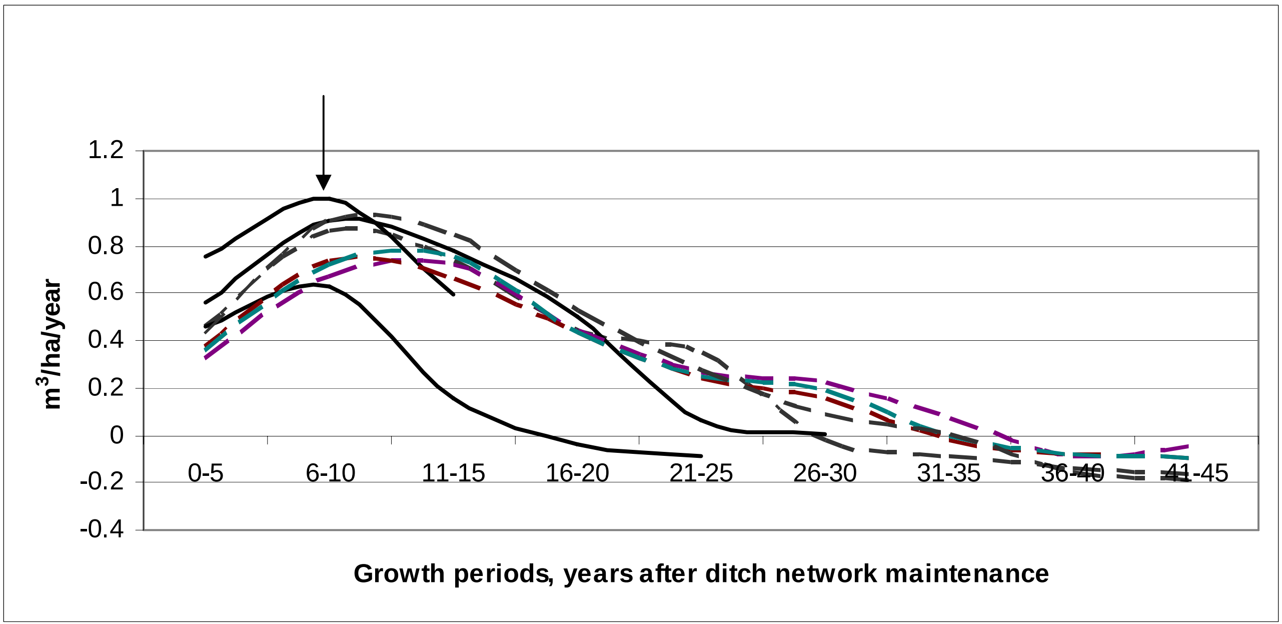

Figure 2. Development of the effect of ditch network maintenance on annual stand volume increment, based on 5-year growth periods, for Site Type PtkgII and Climatic Region 901–1025 d.d. Solid lines represent the SINKA plots where thinning took place within 20 years of the DNM operation, and dotted lines indicate plots where the thinning threshold was not exceeded within the 20 years following DNM. The arrow indicates the peak for an individual plot, which defines the time point (*t*) for calculation of ROI_1.

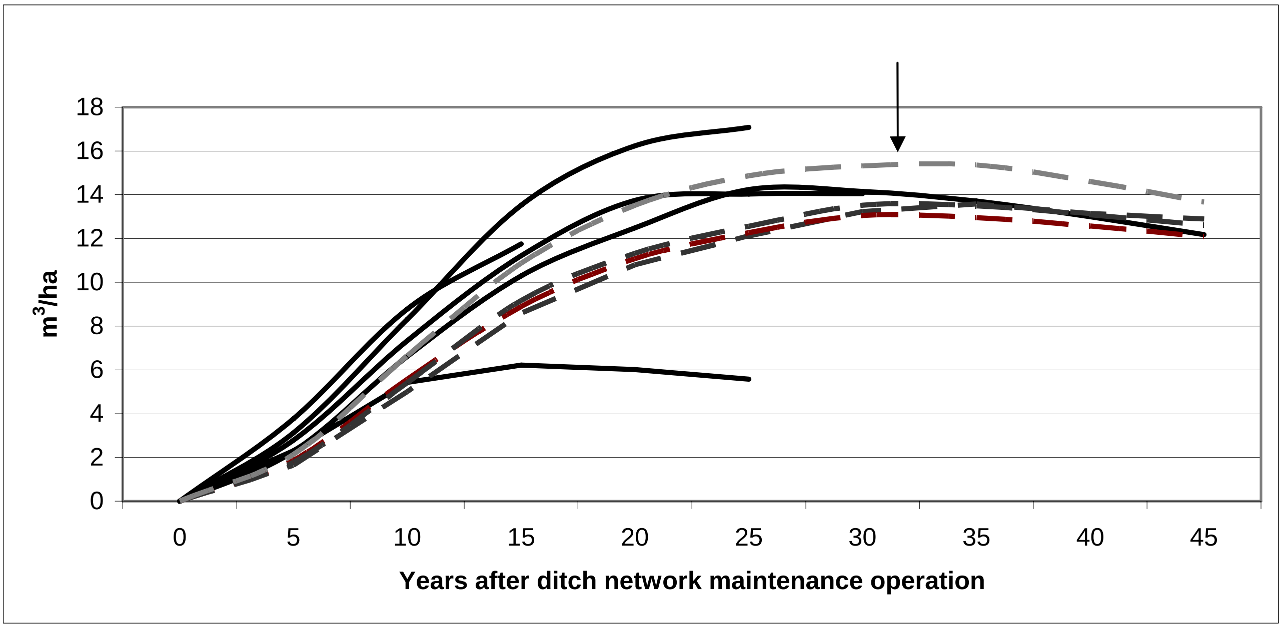

Figure 3. Additional volume of growing stock as a function of years after application of DNM for Site Type PtkgII and Climatic Region 901–1025 d.d. Solid lines represent the SINKA plots where thinning took place within 20 years of the DNM operation, and dotted lines indicate plots where the thinning threshold was not exceeded within 20 years following DNM. The arrow indicates the peak for an individual plot, which defines the time point (*t*) for calculation of ROI_2.

RESULTS

Growth predictions

The mean annual increment (MAI) without DNM for the 45-year period simulated ranged from 1.9 m^3 ha^{-1} (Ptkg II, Climatic Region < 900 d.d.) to 4.0 m^3 ha^{-1} (Mtkg II, Climatic Region 901–1025 d.d.). Applying DNM increased the MAIs by 0.24 m^3 ha^{-1} and 0.42 m^3 ha^{-1} respectively. Average values of time points and income differences (t and ΔCI_t in Equations 1 and 2) with their standard deviations are presented in Table 2. These data show that, for example, in Site Type Ptkg II and Climatic Region 901–1025 d.d., annual growth increment peaked on average 11.1 years after the DNM operation, when the mean enhancement in monetary value of the tree crop (ΔCI_t) due to DNM, fully capitalised, would be 91.4 € ha^{-1}. Without government subsidy for DNM, Equation 2 gives *ca*. 2.9% return on investment per annum (ROI_1) for this example.

Short-term financial performance

Without government subsidy, ROIs were highest for the more productive Mtkg II peatland site type in Climatic Region 901–1025 d.d. Even these values were relatively low, at only 3.7% for theoretical ROI (taken as the greater of ROI_1 and ROI_2) and 3.0% for actual ROI (ROI_3). When government subsidy was applied, the theoretical ROI increased to 8.4% and the actual ROI to 6.7%. The effects of peatland site type and climatic region on ROI were substantially smaller than the effect of government subsidy. For Site Type Mtkg II and Climatic Region 901–1025 d.d., the theoretical ROI was *ca*. 2.2 times that for the poorer Site Type Ptkg II and Climatic Region < 900 d.d., regardless of whether or not the DNM operation was subsidised (Table 3).

Table 2. Average time points (t in years after application of DNM) and the corresponding average values of the term ΔCI_t (the value/income difference due to DNM in € ha^{-1}) that were used to calculate the three different ROI values (Equation 2) for each of the four site type/climatic region combinations. Standard deviations in parentheses.

Site Type	Climatic Region, d.d. °C	ROI_1 (peak annual growth increment)		ROI_2 (peak growing stock)		ROI_3 (actual ROI)	
		t	ΔCI_t	t	ΔCI_t	t	ΔCI_t
Ptkg II	< 900	18.8 (7.6)	67.8 (24.2)	40.0 (10.6)	113.9 (21.0)	*	*
Ptkg II	901–1025	11.1 (2.2)	91.4 (18.4)	26.7 (7.5)	160.9 (36.7)	23.3 (7.6)	148.3 (43.7)
Mtkg II	< 900	10.0 (0.0)	56.7 (13.4)	33.0 (11.6)	125.3 (16.6)	20.0 (0.0)	106.0 (26.5)
Mtkg II	901–1025	10.0 (0.0)	104.1 (15.5)	22.1 (9.9)	162.4 (26.0)	13.6 (2.4)	118.1 (20.0)

* For Site Type Ptkg II in Climatic Region < 900 d.d., the thinning threshold was not attained in any sample plot within 20 years of the DNM operation. Therefore thinning was not simulated and actual ROI could not be calculated.

Table 3. Mean values of theoretical (the greater of ROI_1 and ROI_2) and actual (ROI_3) returns on investment in ditch network maintenance (DNM) for the four combinations of site type and climatic region, without and with government subsidy. Standard deviations in parentheses.

Site Type	Climatic Region d.d. °C	ROI (%) without government subsidy		ROI (%) with government subsidy	
		theoretical	actual	theoretical	actual
Ptkg II	< 900	1.6 (0.64)	*	3.8 (1.65)	*
Ptkg II	901–1025	3.0 (0.58)	2.2 (0.59)	6.9 (1.2)	4.6 (1.22)
Mtkg II	< 900	2.1 (0.46)	1.8 (0.36)	5.3 (1.05)	4.1 (0.67)
Mtkg II	901–1025	3.7 (0.45)	3.0 (0.22)	8.4 (0.89)	6.7 (0.63)

* For Site Type Ptkg II in Climatic Region < 900 d.d., the thinning threshold was not attained in any sample plot within 20 years of the DNM operation. Therefore thinning was not simulated and actual ROI could not be calculated.

Long-term financial performance

The statistical analysis of stands showed that stand basal area at the beginning of the simulation period was the most crucial factor in determining whether or not the thinning threshold would be exceeded (Table 4). Furthermore, the stands with higher stocking at the beginning of the simulations performed best with regard to profitability. NPVs were not calculated for Site Type Ptkg II in Climatic Region < 900 d.d. because the thinning threshold was not exceeded within 20 years of the DNM operation. For other sites and regions, the NPVs were *ca*. 4–14% higher with DNM depending upon climatic region, peatland site type and discount rate (Figure 4). For instance, for Site Type Mtkg II in Climatic Region 901–1025 d.d., applying a discount rate of 5%, NPV was *ca*. 10% higher with DNM than without it. Furthermore, the higher the discount rate that was applied, the greater was the difference in NPV between cases with and without DNM. This is illustrated in Figure 4 by the rising trend in bar height as discount rate increases. In terms of NPV, all individual stands with DNM out-performed all cases without DNM.

Table 4. Results of the statistical comparison of stands according to thinning potential. The sample plots were divided into categories that would ("thinning") and would not ("no thinning") exceed the thinning threshold within 20 years, and average tree characteristics at the start of the simulation period were compared between the two categories using the Mann Whitney U Test ($p < 0.05$) (SPSS 14.0 for Windows, Release 14.0.2). Asterisks indicate statistically significant differences between the two categories.

Site Type	Climatic Region	variable	thinning	no thinning
Ptkg II	901–1025 d.d.	basal area (m^2 ha^{-1})	10.8	4.8*
		weighted diameter (cm)	9.3	8.3
		dominant height (m)	9.5	7.4
Mtkg II	< 900 d.d.	basal area (m^2 ha^{-1})	9.8	4.6*
		weighted diameter (cm)	12.3	10.3
		dominant height (m)	10.6	8.1*
Mtkg II	901–1025 d.d.	basal area (m^2 ha^{-1})	17.0	10.0*
		weighted diameter (cm)	12.4	12.2
		dominant height (m)	12.4	10.9

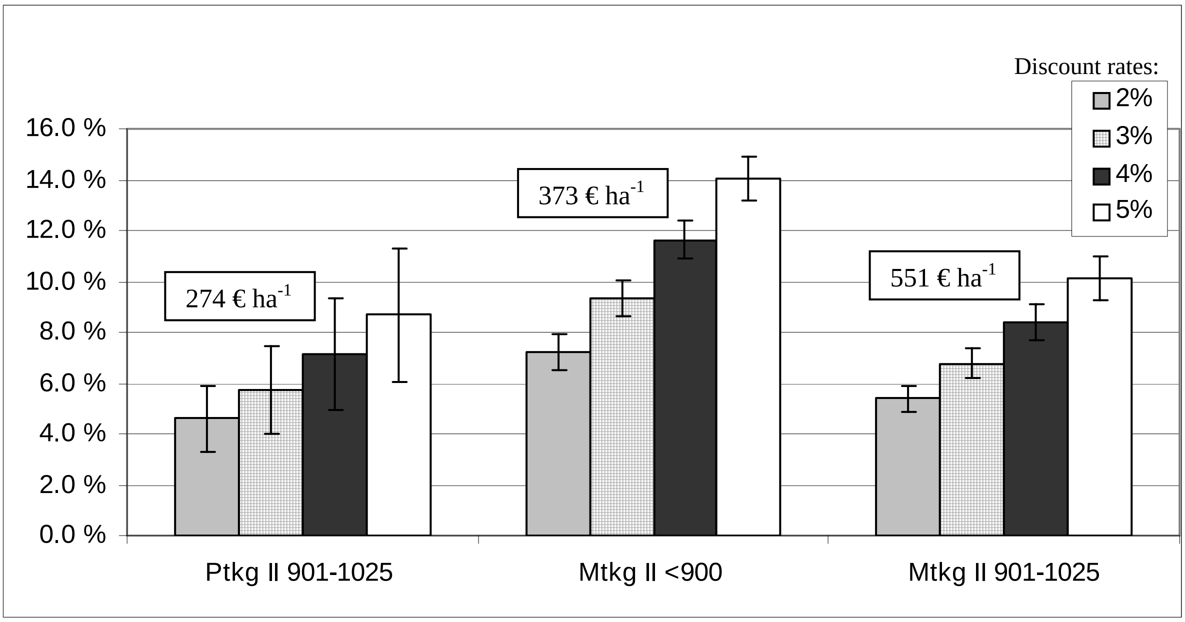

Figure 4. Summary of enhancement of net present value (ordinate is NPV_{diff} in Equation 3) by DNM for the three combinations of site type and climatic region where intermediate thinning was simulated, showing the effect of altering the discount rate (p in Equation 3). The values in boxes above the bars are the absolute values of NPV (discount rate 3%) for each of the three site type/climatic region combinations without DNM.

DISCUSSION

The biological basis of forest drainage is straightforward; ditching improves the soil water conditions and nutrient availability and this is expressed as considerably faster growth of existing trees (Seppälä 1969) and simultaneously enhanced establishment of new trees (Hökkä & Laine 1988). As a result, the naturally sparse peatland forest stands become more densely stocked and so attain higher commercial value (Uuttera *et al*. 1997, Sarkkola *et al*. 2005), which is the financially desired outcome.

Previous work on the profitability of ditching in Finland suggests that, on average, 5% internal rates of return can be achieved from oligotrophic sites with medium productivity (e.g. those belonging to Site Type Ptkg II) in southern Finland (Mikkola *et al*. 2002, Aarnio 2004); but that for the same site type in northern Finland, the achievable internal rate of return is only 3% (Aarnio 2004). Another previous attempt to calculate the profitability associated with DNM operations (Hytönen & Aarnio 1998) focused solely on overall profitability, expressed as an internal rate of return for the whole management schedule. Thus these earlier studies left unanswered the question of how profitable a single ditch network maintenance operation might be. Our study addressed this question with the help of modern corporate finance theory (e.g. Friedlob & Plewa 1996). In tandem with the main question we compared net present value (NPV) for the whole rotation between cases where ditch network maintenance had and had not been carried out. Furthermore, by basing our work on real peatland forest stands in Finland, we have provided new information on the effect of real-life variability on financial performance.

In order to produce growth and yield projections for long-rotation tree species we need reliable software. In this study we applied the MOTTI stand simulator, which was designed specifically for Finnish growth conditions and includes models for peatland (Hynynen *et al*. 2002, Salminen *et al*. 2005, Hökkä & Salminen 2006). However, the use of actual measured data as input to a stand simulator is not without drawbacks. The outcome depends primarily on how well the data setting corresponds to the growth models incorporated within the simulator. In this study the two were considered to correspond adequately because the study material was a sub-sample of the original modelling data that were used to construct peatland growth models for the MOTTI stand simulator (e.g. Hökkä *et al*. 2000, Hökkä & Salminen 2006). Furthermore, earlier MOTTI studies conducted on peatland plot data indicate that combining measured data with MOTTI stand projections yields acceptably accurate estimates of actual tree growth on peatland (Ahtikoski *et al*. 2004, Kojola *et al*. 2004).

This study provides two main results. First, given constant costs, the stands with higher initial stocking, better site type and higher temperature sum showed higher profitability. Although there were large differences in ROI values between site types and climatic regions, the influence of initial stand stocking on financial performance appeared to be more important than that of site quality or geological location. This emphasises the fact that investment in DNM is worthwhile only for stands with a certain minimum stocking level. However, the profitability limit appears to be relatively low in terms of stand basal area (4–6 m^2 ha^{-1}). The second main result is that the government subsidy is an important influence on financial performance, particularly in the short term. With government subsidy for DNM, the theoretical return on investment may be as high as 8.4% for the best site type, whereas without government subsidy it can be as low as 3.7%. Thus the government subsidy seems to favour private forest owners by augmenting the financial effect of DNM. The actual ROIs with government subsidy ranged from 4.1% to 6.7%, depending on the site type and climatic region. Without government subsidy the actual ROI ranged from 1.8% to 3.0%. Thus, even without the government subsidy, some DNM operations appeared to be rather good investments.

The reason for calculating and comparing theoretical and actual ROIs was to inform the process of re-allocation of government subsidies between different activities. For instance, if the theoretical ROI had been as high as 15% and the actual ROI only 2%, the difference between the theoretical and actual ability to recover investments would be too large for economic viability and all DNM activity would have been compromised. This question is closely related to the availability of intermediate thinnings during the 15–20 year period for which the growth response to DNM is effective. The sale of thinnings generates income before the end of the rotation, and thus influences financial performance substantially. Our results show that if the monetary value of accumulated growth cannot be realised until the final felling, the effect of ditch network maintenance on profitability remains marginal.

Before exploring further potential implications of this research for practical forestry, it is necessary to emphasise that our results are applicable only to forests that resemble the stands included in this study with adequate accuracy - namely peatland stands which have been managed according to silvicultural recommendations and where first-time ditching has been carried out.

Given this caveat, our main results could be used to indicate the forest characteristics and conditions which meet *a priori* criteria associated with financial performance, such as a target ROI for the DNM operation expressed as an annual percentage value. This could assist decision-makers in classifying peatland forest stands according to whether or not DNM would be a profitable management operation. This raises the larger question of the level at which a target ROI should be set, to which our results are also relevant. This question may be of interest to state authorities setting overall guidelines for public investment.

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