COSTS OF WATER POLLUTION ABATEMENT IN FORESTRY

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ABSTRACT

Several research projects have found that forest management practices cause changes in water hydrology and quality. To reduce the negative effects of forestry on water-based values, various actions have been suggested for water pollution abatement. In this study the private costs and social profitability of abatement were evaluated in Finland. Adjustment costs for a representative private forest holding were determined by MELA simulation and linear programming system. The length of various shoreline types on forest land was assessed by stratified random sampling. The results suggest regional and local variation in the extent to which abatement actions should be adopted.

Keywords: Environmental impact, forestry, cost-efficiency, water pollution.

INTRODUCTION

In Finland regulation of the forest sector's emissions into watercourses has concentrated on industrial plants. For example, in the pulp and paper industry every plant is regulated with respect to the substances it discharges into watercourses (e.g. Hetemäki, 1994). Consequently, the proportion of diffuse loading in the total emissions has increased.

Several research projects have found that forest management practices cause changes in water hydrology and quality, thus affecting water-based values (see e.g. Saukkonen & Kenttämies, 1993, Matero & Saastamoinen, 1994). In order to reduce the negative effects of forestry on water-based values, various actions have been suggested for water pollution abatement. The main actions include 1) various adjustments in buffer strips along watercourses and 2) sedimentation ponds and other defensive measures in maintenance ditching.

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The actions suggested will result in adjustment costs for private forest owners. On the other hand, forest owners may themselves be willing to accept some losses in timber sales revenues to increase, for example, the value of amenity services in their forest holding (e.g. Kangas, 1992). However, the major part of the benefits of the water pollution abatement will be directed to people other than forest owners, although in Finland land ownership is related to property rights to watercourses. Information about private adjustment costs is necessary for both private and public decision making.

Little research has been done on the private costs of water pollution abatement in forestry. Most research has focused on general environmental restrictions. For example, several studies in Sweden have examined the effects on timber production of the various adjustments and restrictions of the Forestry Act. By applying a Hugin system, Wilhelmsson (1989) showed that in the area studied restrictions related to recreational values decreased harvesting volumes by about 2 %.

Carlén (1994) studied the private costs of environmental protection by asking a number of entrepreneurs to estimate the additional costs due to various adjustments made in the logging process. The results indicated considerable variation in costs (the average cost amounting to 8 %), but buffer strips along watercourses did not explain the variation in costs.

The aims of this study were to determine costs and to assess regional incidence of water pollution abatement in forestry in the southern half of Finland.

EMPIRICAL CALCULATIONS

Adjustments in Buffer Strips

The effects of alternative adjustments in buffer strips were analysed for the representative nonindustrial private forest holding constructed by Aarnio (1990). The (productive) forest land area of this holding was 35.6 hectares and there were 22 forest stands. The mean volume of the growing stock was 107.5 m^3 /ha and the annual volume growth (calculated by MELA-models; see Ojansuu *et al.*, 1991) was 5.9

m^3/ha/a (for a more detailed description, see Aarnio, 1990, p. 23). According to the seventh Nationwide Forest Inventory (NFI), the corresponding figures for the southern half of Finland were 106.8 m^3/ha and 4.9 m^3/ha/a.

Alternative management schedules for the representative forest holding were simulated by the MELA system (for outlines of the system, see Siitonen, 1993). Simulations were done for a planning period of 60 years, divided into six 10-year periods. Simulations resulted in a total of about 2,100 stand treatment schedules for 22 stands over the planning period. The optimal management schedule was selected by a linear programming system where some of the constraints can be specified to subsets of stands (see Lappi, 1992).

Firstly, the representative forest holding was placed in two alternative locations with respect to a watercourse, i.e. at a lakeside and beside a small brook (Appendix 1). Different management schedules (four schedules for water pollution abatement and two basic schedules in each location) were then simulated in order to evaluate the relative effect of location, price level and discount rate on private adjustment costs of water pollution abatement on the forest holding level. Two alternative stumpage-price scenarios (average prices in the 1980s or the 1992 prices; see e.g. Aarne, 1994) and three different discount rates (1, 3 or 5 %) were applied in simulations. Silvicultural expenses were assumed to remain at the 1992 level.

The expected net present value of future timber revenues was maximised in all management schedules.[1] In one basic schedule (Max) no constraints were set. Thus perfect capital markets (e.g. Johansson & Löfgren, 1985) and perfect forest land markets or alternatively "a tinge of altruism" (Hultkrantz, 1992) was assumed. In another basic schedule (Base) "sustainability" and income constraints were introduced. Ownership periods of 20 and 30 years were

[1] The expected net present value of future timber revenues was calculated according to a modified Faustmann rotation. The development of the stands was projected beyond the planning horizon until an exogeneously defined rotation age was reached. In addition, the value of a steady state rotation, repeated indefinitely, was calculated for each stand. Thus, the value of the forest land for perpetual rotations, evaluated at the end of the 60-year planning period, was included in the net present value.

TABLE 1. CALCULATION PRINCIPLE OF NET PROFIT.

Net revenue from timber sales
– Silvicultural expenses
= Gross profit
– Fixed expenses
= Profit before taxes (social cost)
– Silvicultural fee
– Taxes
= Net profit (private cost)

assumed (cf. Ripatti, 1993), and expected net present value of the future timber sales revenues in the year 20 and 50 were constrained to be at least the current one (sustainability assumption). In addition, during each ownership period net revenues from timber sales were constrained to be highest in the first 10-year period and decrease in subsequent 10-year periods. This schedule was assumed to describe more realistically the cutting behaviour of the representative nonindustrial private forest owner (cf. Karppinen & Hänninen, 1990). Various additional constraints were introduced in the schedules for water pollution abatement to reduce the negative impacts of forestry on water-based values (for more detailed description of schedules see Appendix 2).

Private adjustment costs due to water pollution abatement were determined as differences in net profits (Table 1). Fixed expenses were set at 2.9 USD/ha (cf. Holgén & Lind, 1994) and the silvicultural fee at 124.9 USD/year (Aarnio, 1990).[2] Taxes were assumed to be 25 % of the taxable income. Net profits were presented as net present values of the first 60-year period, converted to annual equivalents, annuities. As a result, the relative private adjustment cost per hectare on a forest holding level was assessed. The emphasis was on relative rather than on absolute values.

In the second stage, aggregate private adjustment costs due to adjustments in buffer strips were determined on a regional level, i.e. for three regions in the southern half of Finland (Figure 1). As a point of departure it was assumed

[2] USD = 5.245 FIM exchange rate at the end of 1992 was used.

FIGURE 1. THREE REGIONS IN THE SOUTHERN HALF OF FINLAND

that the structure of timber stock along watercourses (in buffer strips) did not differ from that of the representative forest holding. Consequently, relative effects of adjustments on annual cuttings, harvesting costs and net profits in buffer strips were determined by setting various adjustment constraints for all stands of the representative forest holding.[3] A total of four adjustments for buffer strips were considered, i.e. 1) no clear cuttings, 2) prolonged rotation period (from 80 to 100 years), 3) no regeneration cuttings and 4) no cuttings. The “Base”-schedule was used as a comparison alternative. In this stage, 1992 stumpage prices and 3 % discount rate were applied.

To derive regional net profits for the “Base” schedule, the regional net incomes (USD/ha) presented by Simula (1991) were firstly divided by the ratio of the actual and the allowable cuttings (see also Simula & Keltikangas, 1990). Secondly, the modified “allowable net incomes” were converted to relative ones (by setting the modified “allowable net income” for the southern half of Finland to 1). The net profit for the representative forest holding (87.5 USD/ha,

[3] It was assumed that returns-to-scale in logging in buffer strips do not differ from that in stands of average size.

Appendix 3) was then multiplied by these regional relative figures. As a result, regional net profits for the "Base" schedule were assumed to be 111.2 USD/ha (southern Finland), 86.4 USD/ha (eastern Finland) and 60.4 USD/ha (western Finland).

To evaluate the private net costs due to adjustments, the forest owner's own willingness to accept losses in net profits had to be determined. Results from the earlier studies concerning the difference between the actual and the allowable cut in nonindustrial private forest holdings (Karppinen & Hänninen, 1990; Simula, 1991; Pesonen *et al.*, 1994) were applied in assessing the magnitude of the forest owners' WTA for the adjustments.

Kangas (1992) asked private forest owners living in eastern Finland for their maximum willingness to accept losses in the net present value of timber sales revenues because of other (multiple-use) goals. The average loss (175.0 USD/ha) implies about 5–10 % loss in the net profit applied in this study (the number of forest owners was, however, very small (n=66) and the deviation large (sd=206.9 USD/ha)). In the studies of Karppinen & Hänninen (1990) and of Simula (1991) the proportion of the actual cut in the time period of 3–5 years (during 1975–1988) ranged in different regions in the southern half of Finland from 0.81 to 1. 10 of the allowable cut. Pesonen *et al.* (1994) found that in eastern Finland nonindustrial private forest owners' own timber management strategies accounted, on average, for 91 % of the potential allowable cut (determined by the "sustainability"-strategy).

All the studies dealt with very short time periods. In addition, the potential allowable cut was defined in various ways. Growing stock volumes have, however, increased in all counties in the southern part of Finland over the period of 1952–90 (Aarne, 1994), which exceeds the current mean ownership period of the private forest owners. The results from all these studies therefore suggest that, for some reason, the representative private nonindustrial forest owner is willing to accept some loss in the net profit (from timber production). To conclude, the private forest owners' willingness to accept losses in the net profit (defined as a 3 % annuity) was assumed to be on average 15, 8 and 7 % of the net profit of the "Base" schedule on the southern, eastern and western region, respectively. It is quite possible that forest owners' WTA is not equal in all stands of the forest holdings. Consequently, the WTA, particularly in the stands along watercourses, can be different from that assumed here. Empirical studies concerning this are, however, lacking.

The length of various shoreline types on forest land (and the area of the buffer strips) was assessed by stratified random sampling, in which nine counties composed the strata. The area of sampling units in each county was determined so that the expected area of the forest land in a sampling unit was about 35 ha. In each stratum 60 sampling units were randomly selected from base maps and the length of various shoreline types (lakesides, riversides and brooksides) in each sampling unit was measured by a map measurer to the nearest 100 m (the coastal area of the Baltic Sea was excluded).

In all regional analyses it was assumed that the width of the buffer strips along brooks would be 50 % of that along rivers and lakes. Therefore, the length of the brooks (the length of the brookside divided by two) was used in all analyses where the different types of shoreline were compared. Note that the sampling units did not coincide the private forest holdings. The proportion of summer cottage lots locating along watercourses was finally subtracted from the total length of the shoreline (50 m shoreline per a lot). Thus, it was assumed that no private adjustment costs would occur on the lot areas.

Abatement Actions in Maintenance Ditching

In the beginning of the 1990s the total expenditures used for the defensive actions in the peatland drainage were about 11.4 USD per hectare drained (Matero & Saastamoinen, 1994). According to the Finnish Forest Improvement Law, the additional costs due to environmental concern can be financed by state grants and loans. The private costs of the abatement are then equal to zero. In the beginning of the 1990s the proportion of the forest owners' own financing was, however, about 33 %. This amount, i.e. 3.8 USD/drained hectare, was used in this study as the private cost of water pollution abatement in maintenance ditching.

The Forest Improvement working group (1994) estimated areas where maintenance ditching was suggested for the next 5 years. These estimates were applied in the evaluation of the aggregate costs due to water pollution abatement on the regional level.

To evaluate the social desirability of the abatement, the social cost estimates were compared to the number of fishermen who during the 1980s perceived noticeable damages caused by forest ditching in their main fishing site (see Lappalainen & Hildén, 1993). This comparison resulted in the mean WTP per fisherman required for the abatement to be socially desirable, when no one else was assumed to gain from the abatement.

TABLE 2. DISCOUNT RATES AND NET PROFITS

Effect of discount rate on relative net profits of management schedules (for base schedule, absolute values (USD/ha/a) also given in parentheses).

SCHEDULE	DISCOUNT RATE		
	1.%	3.%	5.%
A. Lake			
Max	101.7	100.7	99.9
Base	100.0 (92.7)	100.0 (87.5)	100.0 (81.9)
Lal	96.8	96.4	95.8
La2	88.1	87.8	86.8
La3	83.6	78.9	74.7
La4	78.9	74.0	69.9
B. Brook			
Max	101.7	100.7	99.9
Base	100.0 (92.7)	100.0 (87.5)	100.0 (81.9)
Brl	98.9	98.2	97.5
Br2	96.4	94.4	92.9
Br3	89.5	86.1	83.4
Br4	85.8	82.6	80.1

RESULTS

Private Adjustment Costs in Buffer Strips on the Forest Holding Level

Two basic schedules were almost identical with respect to annual cuttings, gross profits and net profits (Appendix 3). In the "Base" schedule the annual cuttings were 5.2 m^3/ha and the net profits (3 % annuity) 87.5 USD/ha when the average 1992 stumpage prices were used. Various schedules for water pollution abatement reduced the net profit (3 % annuity) 3 – 26 % when the forest holding was located at a lakeside and 2 – 17 % when the forest holding was located beside a brook (Appendix 3).

Another price scenario (stumpage prices of the 1980s) increased the annual cuttings of the "Base" schedule to 5.6 m^3/ha and the net profits to 119.7 USD/ha. Changes in relative net profits were, however, small in all management schedules. The higher the discount rate the higher the relative adjustment costs of the water pollution abatement (Table 2). Thus, the relative effect of the water pollution abatement (especially restrictions in schedules "La3" and "La4") was the most prominent in the beginning of the calculation period.

Private and Social Costs due to Adjustments in Buffer Strips on the Regional Level

Giving up clear cuttings in buffer strips would result in 17 % reduction in the annual cuttings, whereas logging costs (USD/m^3) would increase 8 % (Table 3). The relative private adjustment cost (i.e. the loss in the net profit, 3 % annuity) would be 14 %, of which the increase in the logging costs accounted for 3 %. The private adjustment costs due to other adjustments were 22 % (prolonging the rotation period from 80 to 100 years), 44 % (no regeneration cuttings) and 100 % (no cuttings). Because of the private forest owners' willingness to accept losses in the assumed net profit, the relative private net costs were smaller. For example, the private net cost of giving up clear cuttings in buffer strips in southern Finland was equal to zero, since the assumed mean WTA (15 % of the net profit) exceeded the adjustment cost (14 % of the net profit).

TABLE 3. EFFECTS OF ADJUSTMENTS IN BUFFER ZONES

Relative changes in annual cuttings (m^3/ha/a), logging costs (USD/m^3) and net profits (3% annuity) due to various adjustments in buffer zones (for base schedule, absolute values are also given in parentheses, 1992 stumpage prices).

SCHEDULE[1]	CHANGE IN ANNUAL CUTTINGS, % (m^3/ha/a)[2]		CHANGE IN LOGGING COST, % (USD/m^3)[2]		CHANGE IN NET PROFIT, % (USD/HA/A)[3,4]	
1	0	(5.2)	0	(8.6)	0	(87.5)
2	– 17		+ 8		– 14	(ll/– 3)
3	– 4		+ 5		– 22	(21/– 1)
4	– 40		+ 23		– 44	(40/– 4)
5	– 100		..		– 100	(– 100/..)

[1] 1 = Sustainable timber production, rotation period 80 years.
2 = No clear cuttings.
3 = Prolonged rotation period (100 years).
4 = No regeneration cuttings.
5 = No cuttings.

[2] Average values for the calculation period of 60 years.

[3] 3 % annuity.

[4] Partial effects due to changes in value of cuttings/logging costs in parentheses.

TABLE 4. LENGTH OF LAKESIDES, RIVERSIDES AND BROOKS

Total length of lakesides, riversides and brooks (1,000 km) on forest land by counties (S=southern Finland, E=eastern Finland, W=western Finland) (95 % confidence limit for total length also given).

COUNTY	LAKESIDES	RIVERSIDES	BROOKS 1,000 KM	TOTAL	(95 % CONFIDENCE LIMITS)
Uudenmaan (S)	1.7	0.7	1.7	4.0	(2.5 – 5.5)
Turun ja Porin (S)	4.5	0.5	5.0	10.1	(6.2 – 13.9)
Hämeen (S)	11.4	0.6	2.6	14.5	(10.0 – 19.0)
Kymen (S)	8.6	0.6	1.1	10.4	(7.0 – 13.8)
Mikkelin (E)	25.9	1.1	3.9	30.9	(24.5 – 37.2)
Pohjois-Karjalan (E)	10.4	1.4	3.8	15.6	(11.3 – 19.9)
Kuopion (E)	15.0	2.5	4.0	21.5	(15.6 – 27.4)
Keski-Suomen (W)	12.7	1.2	4.7	18.6	(13.7 – 23.4)
Vaasan (W)	1.2	2.8	3.1	7.1	(4.2 – 10.0)
Total	91.4	11.2	30.0	132.6	(119.7–145.5)

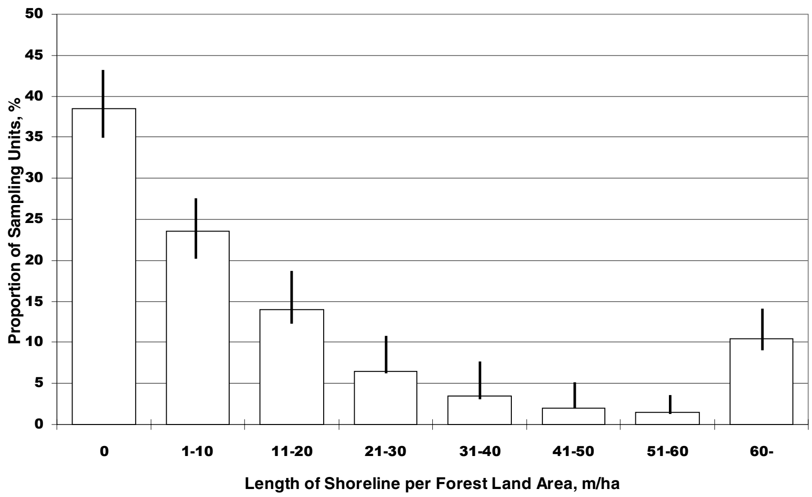

FIGURE 2. DISTRIBUTION OF SAMPLING UNITS

Distribution of sampling Units (% ± 2. standard error, SE) by length of the shoreline per forest land area (all regions included).

The length of lakesides, riversides and brooks on forest land differed greatly by counties (Table 4). The area of the buffer strips of which width is 30 m along lakes and rivers, and 15 m along brooks (summer cottage lots excluded) would comprise 2.7 % of the total forest land area in southern Finland, 4.8 % in eastern Finland and 2.4 % in western Finland. The mean shoreline length per forest land area in the sampling units was 23 m/ha (median 5 m/ha).[4] About 38 % of the sampling units had no shoreline at all (Figure 2). Thus, no adjustments (and costs) occurred in these sampling units. On the other hand, about 10 % of the sampling units had at least 60 meters shoreline per forest land area (i.e. the area of buffer strips (width 30 m) would comprise 18 % of the forest land area in the sampling unit).

The shoreline length per forest land area (i.e. the relative share of the buffer strip area) in the sampling units differed significantly between counties (Kruskal-Wallis H-test, p=0.000). It also differed significantly according to a sampling unit area (Kruskal-Wallis H-test, p=0.000; four

[4] In the representative forest holding the shoreline length per forest land area was 22 m/ha when located the lakeside and 8 m/ha when located the brookside.

area categories). Because the area distribution of the sampling units differed significantly from that of nonindustrial private forest holdings (that pay silvicultural fee; see Aarne, 1994) (χ^2-test, $p< 0.001$), the proportions presented (Figure 2) apply only tentatively to private forest holdings.

The aggregate private costs due to certain adjustment were highest in eastern Finland (Table 5). The costs increased linearly with respect to the buffer strip width because no spatial differences were assumed in the structure of the growing stock (and the forest owners' WTA). Also the social costs (expressed as USD per household living on a region i.e. the mean WTP per household required for the abatement to be socially profitable in each region) were highest in eastern Finland (Table 6).

TABLE 5. ANNUAL PRIVATE COSTS OF ADJUSTMENTS IN BUFFER STRIPS

Annual private costs of various adjustments in buffer strips by regions and width of the buffer strip along lakes and rivers (width along brooks 50 %) (million USD/a).

ADJUSTMENT	WIDTH OF THE BUFFER STRIP ALONG LAKES AND RIVERS (50 % ALONG BROOKS)		
	10m	30m	50m
Southern Finland			
No cuttings	3.30	9.90	16.49
No regeneration cuttings	1.12	3.37	5.62
Prolonged rotation period	0.27	0.80	1.33
No clear cuttings	0	0	0
Eastern Finland			
No cuttings	5.09	15.27	25.45
No regeneration cuttings	1.96	5.89	9.82
Prolonged rotation period	0.72	2.17	3.62
No clear cuttings	0.29	0.86	1.43
Western Finland			
No cuttings	1.35	4.06	6.77
No regeneration cuttings	0.53	1.60	2.67
Prolonged rotation period	0.19	0.57	0.95
No clear cuttings	0.08	0.23	0.38

TABLE 6. ANNUAL SOCIAL COSTS OF ADJUSTMENTS IN BUFFER STRIPS

Social costs (USD per household, 3 % annuity) of various adjustments in buffer strips by regions and width of the buffer strip along lakes and rivers (width along brooks 50 %) (million USD/a).

ADJUSTMENT	WIDTH OF THE BUFFER STRIP ALONG LAKES AND RIVERS (50 % ALONG BROOKS)		
	10m	30m	50m
Southern Finland			
No cuttings	3.6	10.9	18.1
No regeneration cuttings	1.1	3.4	5.7
Prolonged rotation period	0.4	1.1	1.9
No clear cuttings	0	0	0
Eastern Finland			
No cuttings	26.9	80.7	134.4
No regeneration cuttings	10.3	30.9	*51.5*
Prolonged rotation period	3.8	11.4	19.1
No clear cuttings	1.5	4.6	7.6
Western Finland			
No cuttings	6.9	20.6	34.3
No regeneration cuttings	2.7	8.0	13.4
Prolonged rotation period	1.0	2.9	4.8
No clear cuttings	0.4	1.1	1.9

Regional Abatement Costs in Maintenance Ditching

The regional private costs due to the abatement actions in maintenance ditching ranged from 0.08 million USD per year (southern Finland) to 0. 12 million USD per year (western Finland) during the next 5 years. Thus, they were almost negligible compared to the private costs due to various adjustments in buffer strips. The annual social costs (expressed as USD per fisherman that during the 1980s perceived noticeable damages caused by forest ditching) ranged from 8.6 USD (southern Finland) to 22.7 USD (western Finland) (Figure 3).

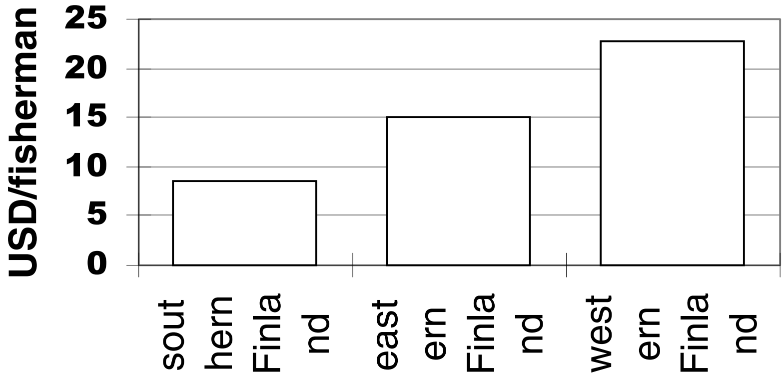

FIGURE 3. ANNUAL SOCIAL ABATEMENT COSTS IN DITCHING

Estimated annual social abatement costs (FIM per fisherman who perceived damages caused by ditching during the 1980s) in maintenance ditching during the next 5 years by Region.

DISCUSSION

When evaluating the effects of various adjustments on timber revenues, the choice of the comparison alternative is essential. Because of the uncertainty concerning the future development of stands, estimated effects are conditional to simulation models and price scenarios applied. For example, the annual mean cuttings in the both basic management schedules were greater than those in the management alternatives simulated by Aarnio (1990) for the same forest holding. The reason for the difference was in growth models and unit prices applied. It can be assumed, however, that the relative effects of the adjustments are more stable and easier to predict.

In the representative forest holding various abatement actions reduced the net profits 2–32 % depending on the location, price level and discount rate. The timber revenues comprise, however, only 10 % on average of the forest owners' total gross income in the southern half of Finland (Ihalainen, 1992). Consequently, the reductions in the total disposable income (i.e. the real private cost) were considerably smaller on average.

The effect of discount rate on the relative adjustment costs is presumably very sensitive to the differences in the age distribution between stands locating along watercources and elsewhere. The adjustments (i.e. the buffer strips) in the representative forest holding were applied in stands where the growing stock was older than on average. Therefore, the relative effect on the net profit was the most prominent in the beginning of the calculation period. Prolonging the rotation period delayed also timber revenues; the effects of prolonging are thus the more remarkable the higher the discount rate.

The increase in logging costs contributed only marginally to the total adjustment cost whereas the reduction in the value of cuttings was the most important factor in the adjustment cost. Carlén (1994) found similar results in his study. The cost models applied in this study probably underestimated the real logging costs, because the mean logging cost in the "Base"-schedule was only 8.6 USD/m^3 whereas the average unit costs in the logging of roundwood by the forest industries and the Finnish Forest and Park Service were 10.9 USD/m^3 in 1992 (Aarne, 1994).

The simulation models of the adjustments may need further calibaration. For example, simulating only the thinnings (i.e. no regeneration cuttings) may imply the transition of stands in buffer strips to uneven-aged stands. The lack of knowledge about the natural regeneration and the initial development of a new cohort in uneven-aged stands is substantial at the present (e.g. Kolström, 1992). Thus, the results presented cover only a kind of transition period, after which effects can be substantially different.

It was assumed that the private forest owners will be willing to accept some losses in the net profit. This is not a self-evident assumption. Reasons for the past difference between the actual and potential allowable cut with non-industrial private forest owners in Finland are imperfectly known, and different explanations have been presented (e.g. Pesonen *et al.*, 1994). Methods for integrating amenity values to the private forest planning that have been developed recently are now available for assessing the private forest owners' own willingness to pay for the amenity services (e.g. Kangas *et al.*, 1993; Pukkala & Kangas, 1994).

The strongly skewed distribution of the shoreline length per forest land area suggests that the private costs due to adjustments in buffer strips vary considerably between the private forest holdings. In Sweden Carlén (1994) found also that about 6 % of the private forest owners met costs of environmental protection more than 10 %, whereas about 16 % actually earned money from protecting the environment.

The polluter pays -principle, which is quite widely accepted in Finnish society, would imply that the water users have the (property) right to the best water quality attainable. In the Finnish Water Court some damages in water-based values caused especially by the diffuse loading remain, however, uncompensated because of the duty of the water users to tolerate modest damages. On the other hand, the forest owners also have to apply the adjustments attainable with reasonable cost ("the principle of minimising damages"). The main difficulty remains in determining the reasonable cost level and localising the forest holdings where the tolerance level will be exceeded due to adjustments. The regulation becomes even more difficult if we take into account the spatial and inter-temporal variation in the private forest owners' own willingness to accept losses.

The total shoreline length in the forest land is so great in the southern half of Finland that the buffer strips when extensively applied will probably reduce the timber supply (i.e. have negative effects on forest industrial firms). Thus, the marginal cost curve with respect to the buffer strip width is likely to be nonlinear rather than linear. Presumably, the incidence of the costs will also change. For example, Montgomery *et al*. (1994) found that due to the reduction in the stumpage supply and the resulting increase in local stumpage prices, private stumpage suppliers both within and outside the owl region were expected to gain from the northern spotted owl conservation as long as the owl conservation was concentrated on the public land. Respectively, in the case of Finnish water pollution abatement, the private forest owners having no shoreline may gain from the abatement due to increase in stumpage prices if the forest industry cannot substitute the reduction in the timber supply by, e.g. increasing the import of timber.[5] Determining impacts on forest industrial firms is, however, impossible without applying some forest sector model.

Evaluation of the social profitability of the adjustments in buffer strips is an extremely difficult task, because the spatially and (intertemporarily) varying marginal damage function is not known exactly. The effect on water quality of the abatement in forestry is very marginal because of many other polluters. If the unmanaged narrow buffer strips (width 5-10 m) and the actions in ditching, together, reduced the total nutrient load of forestry by 50 %, the reduction in total phosphorous load would equal to about 2 % of the current total load when all the other polluters are included. This "marginality" highlights the difficulty of the benefit valuation. Boyle *et al*. (1994) concluded that "the most striking implication from our study is the extremely difficult task of valuing marginal changes in a natural resources, when those changes represent small proportions of the total environmental assets in question".

According to regional estimates in this study, unmanaged buffer strips (width 10 m) would result in annual social costs of about 13.3 million USD in the southern half of Finland. In addition, annual social costs of the abatement actions in maintenance ditching were estimated to be about 0.95 million USD. To evaluate the social desirability of the abatement actions we have to compare these costs to aggregated benefits. In benefit estimation we must include also the beneficial effects on biodiversity and amenity values on shoreareas which may comprise the most part of the benefits from adjustments. For example, some shoreareas (along small brooks and lakes) have been suggested to be conserved as "key habitats" in maintaining the biodiversity. Note, however, that the amenity benefits to forest owners are partly included in the present private net cost estimates.

The abatement actions in maintenance ditching are likely to be socially desirable in the southern half of Finland, because the required annual willingness to pay per fisher-

[5] Possible increase in stumpage prices would also increase the revenues of forest owners affected by a water pollution abatement thus alleviating the adverse impacts of the abatement on private forest owners.

man who during the 1980s perceived noticeable damages caused by forest ditching were quite low. In addition, ditching have caused also other damages; thus, more households will gain from the adjustment.

Regional cost estimates imply that more extensive adjustment actions are cost-efficient in southern Finland than in eastern Finland, if the demand for the water quality (and thus, the aggregate benefits) are positively related to the number of households living on a region (although the private adjustment cost per hectare is highest in southern Finland).

Other spatial differences in the demand for the water quality are, however, also possible, thus making the regional comparison more complicated. In any case, it can be argued that the spatial variation in the social profitability of timber management practices will be changing when various local and regional environmental effects are taken into account.

Acknowledgements

I am grateful to Associate Professor Olli Saastamoinen, Mr. Kaarle Kenttämies, Mr. Jari Jämsä and Mr. Jukka Aarnio for their invaluable help during the study. Constructive comments made by an anonymous referee were also helpful. The usual disclaimer applies. The study was financially supported by Ministry of Agriculture and Forestry, Ministry of Environment and The Society of Forestry in Finland. The Faculty of Forestry at the University of Joensuu provided the facilities.

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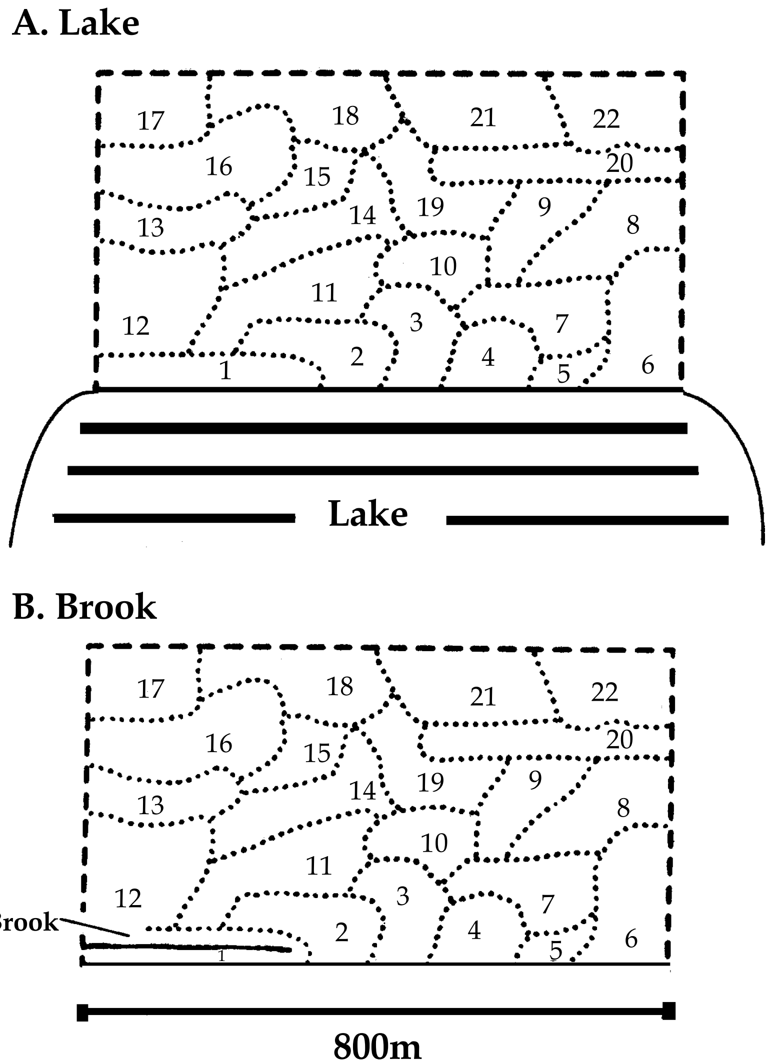
APPENDIX 1.

Alternative locations of the representative private forest holding.



APPENDIX 2.

Different management schedules in a private forest holding.

Basic Schedules

Max Maximization of net present value without constraints.

Base Constrained maximization of net present value. Constraints: expected net present value of the forest holding in a year 20 and 50 at least that of the current value (assumed ownership periods 20 and 30 years). In addition, net timber sales constrained to decrease during each ownership period.

Water Pollution Abatement Schedules [1]

A. Lake

Lal No regeneration cuttings in buffer strip (width 20 m).

La2 No cuttings in the inner part of buffer strip (width 20 m); no regeneration cuttings in the outer part of buffer strip (width 30 m).

La3 As in La2 but, in addition, maximum regeneration area in each 10-year period constrained to 3 hectares, i. e. rotation period outside the buffer strip at least 105 years.

La4 As in La2 but, in addition, maximum regeneration area in each 10-year period constrained to 2.6 hectares, i. e. rotation period outside the buffer strip at least 122 years.

B. Brook

Brl No regeneration cuttings in buffer strip (width 10 m on each side of the brook).

Br2 No cuttings in the inner part of buffer stip (width 10 m on each side of the brook); no regeneration cuttings in the outer part of buffer strip (width 15 m on each side of the brook).

Br3 No cuttings in buffer strip (width 25 m on each side of the brook). In addition, maximum regeneration area in each 10-year period in a watershed of the brook (area 7.2 ha outside the buffer strip) constrained to 0.8 hectares, i. e. rotation period outside the buffer strip at least 90 years.

Br4 As in Br3 but maximum regeneration area in each 10-year period in a watershed of brook constrained to 0.6 hectares, i. e. rotation period outside the buffer strip at least 120 years.

[1] Adjustments for water pollution abatement described; otherwise as in the "Base" schedule.

Appendix 3.

Relative annual cuttings, gross profits (3 % annuity) and net profits (3 %,annuity) in different schedules in a calculation period of 60 years (for base schedule, absolute values also given in parentheses) (1992 prices).

	Annual Cuttings % (m^3/ha)		Gross Profit %(usd/ha)		Net Profit % (usd/ha)	
A. Lake						
Max	102		101		101	
Base	100	(5.2)	100	(123.2)	100	(87.5)
La1	97		97		96	
La2	89		88		88	
La3	86		80		79	
La4	82		75		74	
B. Brook						
Max	102		101		101	
Base	100	(5.2)	100	(123.2)	100	(87.5)
Br1	99		98		98	
Br2	97		95		94	
Br3	92		87		86	
Br4	88		83		83	