BOREAL ENVIRONMENT RESEARCH 3: 87–96 ISSN 1239-6095
Helsinki 7 July 1998

Monetary assessment of the impacts of forestry on water-based benefits in Finland

Jukka Matero and Olli Saastamoinen

University of Joensuu, Faculty of Forestry, P.O. Box 111, FIN-80101 Joensuu, Finland

Matero, J. & Saastamoinen, O. 1998. Monetary assessment of the impacts of forestry on water-based benefits in Finland. *Boreal Env. Res.* 3: 87–96. ISSN 1239-6095

This paper identifies the major impacts of forestry on watercourses, introduces methods and calculation approaches for valuing these impacts in monetary terms and presents some preliminary estimates of the economic value (order of magnitude) of damages to different water-based values. Using a variety of calculation approaches, the range of aggregated damages was estimated to be 17–93 million FIM per year if even the more uncertain (guess-estimate type) figures of general recreation, biodiversity and crayfish fisheries were included. The main components in this estimate were the impacts on flood protection and water-based recreation. The range of aggregated damage estimates corresponds to 0.2–1.0% of the GDP of forestry in Finland in 1992. However, due to data and methodological problems in some specific impact estimations, and those related to individual valuation and summation procedure in general, even the total range remains tentative.

Introduction

Hultkrantz (1992), Solberg and Svendsrud (1992) and Seppälä and Siekkinen (1993) have presented "green" national accounting data for forestry related to Swedish, Norwegian and Finnish conditions respectively. Similarly, Saastamoinen (1995) discussed components of the total economic value of forests in Finland. All these studies also included some tentative, but highly aggregated estimates concerning negative environmental impacts of forestry. In reality the environmental impacts of forestry include a great variety of biological, physical and social effects on numerous components of terrestrial and aquatic ecosystems and benefits derived from them. Some of the impacts are very complicated and often marginal compared to other water polluting activities.

When nation-wide impact estimates are sought for, the strategic question arises whether one should evaluate all the effects separately, or whether one should take a more holistic approach. The latter might provide more direct, preference-based (monetary) estimates from people about the aggregated damage caused by forestry on water-based values. Also, it could be based on a more solid methodological approach (e.g. use of one single method such as *contingent valuation* (CV)). While the former approach — often called *individual summation and valuation* (IVS) — suffers from a lack of uniform method, it can be more closely related to causal relationships between forestry source, impact and (derived) benefit change. It does better justice for the complexity of the phenomena, and serves also better the management aspects (e.g. planning and evaluation of mitigation operations). However, due to the variety of methodologies, the IVS approach is more problematic when aggregation (summing up) of the results is concerned.

The purpose of this paper is to identify and determine impacts of forestry practices on different water-based values; to introduce briefly the methods and calculation approaches used for valuing these impacts in monetary terms; and to present some tentative estimates of the economic value of damages caused by forest management practices on water-based values. Despite its well-known problems, an IVS approach was chosen for two main reasons. First, because of budget constraints, it was necessary to rely mainly on secondary data. Second, IVS approach provides suggestive order-of-magnitude estimates and points out issues for more detailed valuation research. Forest management practices refer to silvicultural, forest improvement and harvesting operations. Impacts caused by floating and other long-distance transportation as well as those by forest industries are excluded.

Sources of watercourse pollution

Watercourses are exposed to many forms of pollution: industrial, urban (domestic) and diffuse discharges. With high water protection investments in the past, industrial and urban pollution has been greatly reduced in Finland. Therefore, diffuse discharges have been gradually brought more into focus.

Several research projects in Finland have found that forest management practices cause changes in water hydrology and quality (e.g. Kenttämies 1981, Ahtiainen 1992, Saukkonen & Kenttämies 1995). Since people perceive watercourses according to their characteristics, any forestry operation which changes such characteristics will also change the public's perception. As a consequence, welfare derived from the watercourse will be changed due to the altered characteristics.

Ditching, fertilization, clear-cutting and scarification are the greatest sources of loading to waters due to forest management (Saukkonen & Kenttämies 1995). Drainage increases annual runoff during the first ten years by 0.3 to 0.6% per drainage percentage of the whole catchment (Kenttämies & Saukkonen 1996). A study carried out in the late 1970s showed that forest drainage had increased the maximum streamflow of river basins in northern Finland by 1 to 12%, whereas in southern Finland, maximum streamflow had decreased by a by the same value (Kenttämies & Saukkonen 1996). After 1950, logging over large areas in northern Finland may also have raised the discharges, somewhat, even in large rivers, but no thorough analysis has been made (Hyvärinen 1984).

Due to erosion, sedimentation of suspended solids in watercourses has often been considered as the most common effect of forestry draining (e.g. Kenttämies & Saukkonen 1996). Ditching of forests and wetlands with sand or silt as bottom mineral soils has caused erosion of several tonnes per hectare (Kenttämies & Saukkonen 1996). Leaching of phosphorus from fertilized peatlands has increased phosphorus concentrations in water bodies near these forests. Depending on the proportion of fertilized area in relation to total catchment area, the increase in phosphorus concentration may have been as much as 5 to 15 fold during the first years (Kenttämies & Saukkonen 1996). The addition of extra nutrients and an increase in temperature results in eutrophication by increasing primary productivity (e.g. Holopainen & Huttunen 1992). The probability of occurrence of toxic forms of blue-green algae also increases.

Drainage in watersheds located in acid sulphate soils has a potential acidifying effect during spring and autumn floods 2–3 years after drainage (Palko *et al.* 1988). In some cases, the iron and aluminium content in water have increased after forestry practices (e.g. Kenttämies & Saukkonen 1996). These effects can be especially harmful for salmonids (e.g. brook trout) (Vuorinen *et al.* 1995).

Methods for deriving monetary values for water-based benefits

In the framework of economics the monetary value of *X* (e.g. a characteristics of the environment) is the maximum amount of other goods and services people would give up to get more *X*. Thus, economists view monetary values in the context of trade-offs among different bundles of goods and services. The question is how people trade between other goods and services and *X*, holding the level of utility constant. The definition of monetary value is therefore precise, but narrow. Because personal valuations are bounded by personal income, the monetary values are based on the existing income distribution.

A ranking of projects with both direct economic costs and adverse environmental consequences always implies an economic valuation of the environmental impacts involved, because the trade-off between costs and environmental consequences has to be considered at least implicitly. For instance, Carlsen *et al.* (1993) derived the implicit environmental costs (i.e. willingness to pay to avoid the environmental damage) caused by hydropower development designed by the Norwegian Master Plan for Water Resources. The implicit valuations were quite consistent, although the decision making process was designed at least in part to avoid such a valuation procedure.

Market prices reflect the marginal monetary value for goods and services traded in a well-behaved market. A good, however, has monetary value whenever people are willing to trade their own wealth for more of that good (or also to prevent having less of that good). Monetary values do not depend upon whether people actually must pay for the services received.

During the last twenty years, the techniques for estimating environmental damages in monetary terms have been extensively developed (e.g. Johansson 1993). If the firms acting in competitive markets are affected by the state of watercourses, changes in profits due to changes in the state of watercourses have to be assessed. Ultimately, firms are owned by households and therefore changes in profits have to be accounted for in the assessment of environmental damages on the whole of society.

If environmental impacts affect the demand for non-marketed services or goods, we can derive monetary value for them by estimating the demand for some complementary or substitute market good by the travel cost method or the hedonic price method. In the travel cost method, travel costs are used to reveal the demand for e.g. a recreation site. Smith and Kaoru (1990) used meta analysis to summarize the benefit estimates derived from travel cost recreation demand models. The summary included at least fifteen studies valuing water-based recreation activities. The type of recreation site and primary activities supported by the site had distinctive effects on the estimates of consumer surplus per unit of use. The consumer surplus per unit of use was the highest in water-based recreation activities.

The hedonic price method is used to estimate implicit prices of the characteristics which differentiate closely related products e.g. summer cottages. For example, Garrod and Willis (1994) applied the hedonic price method in estimating the economic benefits which residents gain from a waterside location. We can also simply ask people for their monetary value for environmental change. This survey method is called the contingent valuation method (CVM) since the answers to a valuation question are contingent upon the particular hypothetical market (or "game") described to the respondents. CVM has been widely used also in water resource projects. For example, Navrud and Strand (1992) summarize the results of 17 studies valuing Norwegian freshwater fishing by contingent valuation and travel cost method (*see* also Smith & Desvousges 1986, Desvousges *et al.* 1987).

Some orientation towards the range of related values can be found from implicit valuation. In the beginning of the 1990s, total expenditures used for defensive actions (e.g. sedimentation pools, buffer zones) in peatland drainage of privately owned land were estimated to total 3.9 million FIM per year (60 FIM per hectare drained) or 3% of the total cost of peatland drainage (J. Kokkonen, pers. comm.). This estimate can be considered as the implicit minimum value of damages caused by drainage.

Another used abatement action is leaving unmanaged riparian buffer strips. For buffer strips it is possible to estimate an opportunity cost, i. e. the timber income that would have been foregone if forestry had complied with the buffer strips (Matero & Saastamoinen 1994, Matero 1996). However, adjusting forest management practices in buffer strips also affects carbon storage, biodiversity and amenity values in shore areas. Consequently, abatement costs due to adjustments in buffer strips reflect not only the implicit willingness to pay for the benefits on water-based values, but instead for all the benefits accruing. Presently, it is not possible to allocate the abatement costs for the various benefits concerned. Therefore, in what follows, we attempt to obtain more direct evidence on the magnitude of the damages on water-based values caused by forestry.

Estimating impacts of forestry on different water-based values

Lakes, rivers, ponds, brooks and other water systems constitute a traditional and highly appreciated part of Finland's landscape and nature. There are a multitude of uses and benefits derived from aquatic environments and water resources, of which many are also, to some extent at least, affected by environmental load caused by forestry activities. For the following analysis, the major benefits and uses affected were identified on the basis of existing literature (e.g. Kenttämies 1981, Ministry of the Environment 1991) although some of them are disaggregated for calculation purposes.

Hydrological power generation

As a starting point we assumed that mean discharges due to forestry practices in northern Finland have increased by 2% (cf. Hyvärinen 1984, Kenttämies & Saukkonen 1996). Changes in power generation depend on the timing of discharges and regulation opportunities. Because of the poor regulation opportunities in northern Finland and the discharge increasing mainly in spring, we assumed that the amount of generated energy has increased by only 1%. In the calculation this change has been converted to monetary units by using market prices, i.e. 1% increase in gross value of production which equals 12.0 million FIM in 1990.

Flood protection

Since floods often cause considerable damages downstream, there are also some costs of forestry from increased maximum discharges. The nature of the causal relationships that may be involved are not clear (e.g. Johansson & Seuna 1994), but some approximations can be given.

No estimates of the total damages caused by floods have been presented so far. However, in the 1980s, the state financed flood protection designs by some 80 million FIM on average per year. In an input-output analysis of a flood protection design the estimated increase in maximum discharge due to forest draining corresponded to half of the ability of the design to prevent floods in an Osthrobotnia river (Kattelus 1983). If we assume a linear monotonic relationship between costs and flood prevention ability then also half of the total costs of the design were caused by draining. Here 10–30% (8–24 million FIM) of the total costs used for flood protection designs in the late 1980s has been assumed to arise from forest drainages.

Water supply for communities and industry

In Finland some 50% of the water provided by communal waterworks is groundwater. The area classified as important for ground water is about 1.4% of the total land area (Vesihallitus 1983). Increased nitrate nitrogen concentrations have been found after clear-cutting and nitrogen fertilization on ground water areas but the increases have been almost insignificant when assessing possible health risks (Yrjänä 1983, Kubin 1995). We assumed here that there are no cumulative effects of increased nitrate nitrogen concentration on the quality of ground water because of the long rotation period in forestry.

Instead, we assumed that costs of communal water purification increased by 0.5–2.0% due to eutrophication of surface water caused by forestry. This increase was equivalent to 0.2–0.7 million FIM in 1987. When considering water supply for industry we assumed that costs of chemical and mechanical water purification, alkalization and quality control in some industries (mainly pulp and paper industry) have risen by 0.1–1.0% (0.1–0.6 million FIM in 1990).

Professional fishing

Professional fishing in Finland is mainly concentrated in the Baltic Sea and in larger lakes, where the proportion of total loading from forestry is smaller than average. Therefore, we assume that the impacts of forestry practices on professional fishing are almost negligible. The minimal catch losses (0.1–0.2%) and increases in production costs of professional fishing (0.1%) that we adopted (weak support was found from a case report of a local water authority, cf. Matero and Saastamoinen 1993) gave a reduction of the net value of professional fishing by 0.1–0.2 million FIM per year. However, this can be considered as a conservative estimate because of the uncertainty associated with the possible acidifying effect of the drainage in acid sulphate soils.

Fish farming

The gross value of production in fish farming in Finland has been 500–550 million FIM during recent years (e.g. Riista- ja kalatalouden tutkimuslaitos 1992). Production mainly consists of fish for human consumption whereas the value of fingerling and smolt production for planting is about 70–90 million FIM.

The impact estimate presented here is based on a questionnaire sent to all Finnish fish farms located inland (Tammi & Lappalainen 1993). Farmers were asked to estimate the occurrence of problems in water quality and their resultant cost increases. At the beginning of the 1990s, increased annual production costs were approximately 0.3 million FIM of which 0.14 million FIM was caused by forestry practices according to perceptions made by the fish farmers. Since all the damages were not eliminated (Tammi & Lappalainen 1993) we estimated the total damages due to forestry as equal to 0.2 million FIM.

Crayfish fishery

Radical changes in the natural state of Finnish inland waters in recent decades caused noticeable damage to crayfish fisheries. For example, the highly valuable stock in the river Pyhäjoki, which in the 1950s produced an annual catch of 750 000 to 1 000 000 legal sized specimens, was destroyed in 1960 most probably by engineering operations in the upper course of the river (Niemi 1982). In favourable conditions the yield of crayfish stock exceeds the yield of fish stock. In 1990 the total gross value of crayfish catch was 40–45 million FIM in Finland (Westman 1991).

No estimate of the impact of forestry practices on crayfish fisheries can be given here because of the present disagreement concerning the relative importance of crayfish disease, regulation of watercourses, hydroengineering activities and forestry practices on the observed decline of crayfish stock in many areas. However, if we assume that the total gross value has declined 3–5% (cf. Matero & Saastamoinen 1993) due to forestry practices, the "guess estimate" of the damages would be 1.2–2.4 million FIM per year. It is likely that draining is the most deleterious forestry operation for crayfish fisheries.

Recreational and subsistence fishing

Lappalainen and Hildén (1993) conducted a nationwide questionnaire where fishermen were asked about the occurrence of various damages to their main fishing site due to diffuse loading. Respondents were also asked for their conception concerning the cause of noticeable damages. When extended to the total population results show that during 1980s altogether 17 000 fishermen perceived noticeable damages caused solely by forest draining (occasional fishermen which comprised 22% were excluded). In addition, there were 46 000 cases where draining was mentioned among other causes.

If we multiply the number of damage cases (Lappalainen & Hildén 1993) by some hypothetical annual willingness to pay (WTP) measure for restoring occurred damages, tentative guess estimates of aggregated damages on recreational fishing can be derived. We assume WTP to range from 10 to 50 FIM per single damage per fisherman. For comparison, the total expenses for fishing in 1981 were 1 811 FIM per household and 68–77 FIM per fishing day (1990 prices) (Lehtonen *et al*. 1988). It has to be emphasized that the derived estimate, 0.3–1.6 million FIM (1992), does not include possible changes in fishing sites and related increases in travel costs.

Water-based recreation activities

The major recreational use of watercourses in Finland is based on the use of summer cottages (Siivola 1992). In 1991 a total of 317 000 summer cottages were estimated as being located along watercourses. To estimate the damages on recreational use of summer cottages a method used by the Finnish Water Court was tested. The method is based on differences in real estate prices and resembles the hedonic price method, HPM (for details, *see* Kyber 1981). In this study we estimated the total annual value of water-based recreation activities (including swimming, sauna bathing, boating, recreational fishing and relaxing waterside) to be 4 700–5 100 FIM per summer cottage (1992 prices). The average values being 21–23 FIM per single recreation activity.

Based on six cases where the recreational damages were assessed by Water Court experts in order to determine the amount of compensation to be paid by some polluters (cf. Matero and Saastamoinen 1993), the average damage due to forestry practices was estimated to be 0.5–2% of the total recreation value of summer cottages. In our calculation, the share of dispersed load was based on the six cases referred, including division of dispersed load between agriculture and forestry. The calculation was based on the percentage of cultivated areas. This proportion is equivalent to 7.5–32.3 million FIM of which the share of recreational fishing is 1.6–6.8 million FIM (1992 prices).

The recreational use of watercourses based on the Right of Common Access is not included here. As reliable statistics are lacking concerning water-based recreational activities one might only assume its value being a proportion of activities based on summer cottages. So far, this has not been investigated, but a first "guess estimate" is that it is equal to the recreational value of summer cottage activities.

Water-based biodiversity benefits

Contingent valuation method is the only method applicable for assessing impacts on nonuse (preservation) benefits that water environments provide (e.g. Randall 1991). In Finland, few empirical CV-surveys related to water-based activities were conducted (e.g. Mäntymaa 1993, Hirvonen *et al.* 1994, Tervonen *et al.* 1994), but none of them have been directly connected with biodiversity values. Even public discussion on endangered species in Finland has largely omitted aquatic species, suggesting that the role of aquatic biodiversity is regarded as a minor one.

For valuing biodiversity impacts, we transferred the results from Norwegian and Swedish contingent valuation studies. Unfortunately, none of the studies are directly related to aquatic species threatened by forestry. Strand (1981) (*see* also Navrud 1983) and Hervik *et al.* (1987) presented the only Scandinavian CVM-results on the preservation value of aquatic species (*see* Table 1, footnote 2). These values can be regarded, however, as total values of which the main component may be use-value. Thus, they are not applicable to benefit transfer. Therefore, the benefit transfer experiment was based on studies dealing with a different habitat, i.e. forests. Even though this might seem incompatible, an important similarity is that most of threatened forest species considered in the studies were "unknown" species (e.g. mosses and invertebrates) similarly to the aquatic species in the present study. We can assume that the main motivation for the (marginal) value of biodiversity lies in the vulnerability and perceived importance of species, not in the habitat.

The main assumptions made were: (1) primary effects of forestry on watercourses are the main reasons for 20 species becoming endangered (1.2% of all species classified as threatened and 15.4% of all freshwater species classified as threatened in Finland 1991; Komiteanmietintö 1991, *see* in more detail table 29 and 30 in Matero & Saastamoinen 1993), (2) the mean annual WTP of Finnish households (total of 1.9 million) for preserving all threatened species is equal to the mean WTP of Norwegian households for preserving endangered species living in Norwegian forests, 761 NOK (1992) (Veisten & Hoen 1993), and (3) 0.5–1.2% of total WTP is directed to preserving the above 20 species (most probably less appreciated mosses and invertebrates, consequently this WTP is less than the average).

Summing up all these assumptions gives us a damage estimate of about 6–14.4 million FIM (1992). If assumptions 2 and 3 are derived from the results of Johansson (1989) so that the average WTP of a Finnish person for preserving the above mentioned 20 species is about 3.3% of the WTP of a Swedish person for preserving 300 endangered forest-related animal and plant species ($0.5 \times 20/300 = 3.3\%$), the total aggregated WTP was around 7 million FIM (1990).

The estimates given here are very tentative and we have to be very cautious with results of simple benefit transfers such as this, as monetary measures of environmental changes are affected by the commodity definition and valuation context. A further developed form of transfer is the benefit function transfer, where an estimated benefit function is transferred to a new valuation context. Although it is regarded as an ideal transfer approach (e.g. Loomis 1992) it has also received severe criticism (Downing & Ozuna 1996).

Because species cannot be assessed independently from their habitat, it may seem more natural and justifiable to evaluate the conservation of entire ecosystems instead of single species. For example, about 70–85% of small watercourses in some areas inspected have lost their natural state mainly due to forestry practices (Hämäläinen 1987). Indeed, a national program for preserving the most valuable small watercourses (e.g., springs, brooks and ponds) is at the preparation stage in Finland. Information about the costs of the program might indicate the magnitude of implicit values concerned, although implicit valuation has its own drawbacks (e.g. Navrud 1993).

The aggregated value of impacts of forestry on different water-based values

Uncertainty related to impact-value estimate is treated here by producing a range of values for all (but two) water use or benefit categories instead of a single value. The uncertainty is to some ex-

Table 1. Preliminary estimates of the magnitude of annual impacts of forestry on water-based values in Finland in the late 1980s, by use category (approach used for valuation is presented in parentheses). Recalculated to 1992 FIM using the consumer price index. Benefits are presented as positive (and damages as negative) impacts.

Use category	Impact caused by forestry, million 1992 FIM per year	
Hydrological power generation	+ 12.8	(market value)
Flood protection (agriculture)	– 9.7– – 29.0	(costs)
Water supply for communities and industry	– 0.4– –1.5	(costs)
Professional fishing	– 0.1– – 0.3	(market value)
Fish farming	– 0.2	(costs)
Crayfish fishery	–1.2– – 2.4	(guess estimate)
Sum of the market-based impacts	+ 1.4– – 20.6	
Recreational and subsistence fishing	– 0.3– – 6.8	(CVM/hedonic prices[1])
Water-based recreation activities by users of summer cottages (fishing excluded)	– 5.9– – 25.5	(hedonic prices)
"General" recreational use	– 5.9– – 25.5	(guess estimate)
Water-based biodiversity benefits	– 6.0– –14.4	(CVM-transfer/guess estimate[2])
Sum of the non-market-based impacts	–18.1– – 72.2	
Total of moneterised impacts	–16.9– – 92.8	

[1] Lower and upper values of the range are derived from two, partly overlapping and alternative estimates: (1) assumed WTP for restoring the damages was 0.3–1.6 million FIM (CVM), and (2) assumed damages for recreational fishing activities by users of summer cottages was 1.6–6.8 million FIM (hedonic prices).

[2] Had we assumed that (1) the mean annual WTP per person (over 18 years) for preserving all threatened freshwater species is equal to mean WTP per person in Norway for all freshwater fish species, 500–1 000 FIM (1992) (Strand 1981, the correction presented by Navrud 1983, p. 83 used) or for protecting surviving "virgin" rivers from hydro-electric power development, 250–500 FIM (1992) (Hervik *et al.* 1987), and (2) 5–15% of this WTP is directed to preserving the 20 freshwater species endangered due to forestry (most probably less appreciated mosses and invertebrates, and therefore it is assumed that WTP is less than the average), the value of impact on water-based biodiversity benefits would be – 48.8– – 585 million FIM. The argumentation why we did not adopt this option for a benefit transfer, although it deals with aquatic species, is given in the text.

tent also reflected in the need of two different sub-totals: the first range is market based impacts and equals +1.4– – 20.6 million FIM, and the second sub-total gives a range of the values of non-market based impacts, –18.1– – 72.2 million FIM. The range of impact estimates for non-market benefits is much higher, although more hypothetical than that of market-based impacts (Table 1).

The total magnitude of aggregated impacts was estimated to be – 16.9– – 92.8 million FIM if all the impacts are summed up. These values are uncertain due to the lack of appropriate data, forcing us to use many assumptions and the results should be regarded as educated guesses rather than estimates based on well-argumented documentation.

If the most unsure damage values for "general" recreational use, water-based biodiversity benefits and crayfish fisheries were excluded, the range of remaining values will be – 3.8– – 50.5 million FIM (Table 1). However, in our opinion the higher relevance of the most unsure damage values to some extent outweighs the increased hypotheticality, so we prefer to use the grand total range given earlier.

The impacts of forestry practices on water-based values are composed of numerous small and dispersed flows. Nevertheless, when aggregated they seem to have some economic importance nationwide. In addition, the impacts may have a higher relative significance locally and regionally than these present preliminary national figures suggest. The "marginality" of the impacts makes valuation, however, extremely difficult. For example, 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."

The range of total damages represents 1.3–7.4% of the total costs of silvicultural and forest improvement works and 0.2–1.0% of the GDP of forestry in Finland 1992. Seppälä and Siekkinen (1993) presented a tentative "green" national accounting system for Finnish forestry in 1990 based on a model by Solberg and Svendsrud (1992). They valued negative environmental impacts being 340 million FIM (1990 prices). Their "best guess" judgement was mainly based on Norwegian WTP results.

It has been argued that various practices in peatlands are the main reason for most of the environmental damages of forestry related to water-based values (e.g. OECD 1988). Timber production in peatlands on a large scale is one of the most distinctive features of Finnish forestry. New drainage has almost completely stopped but maintenance ditching is increasing. Environmental impacts (i.e. external effects) of timber production on peatlands are still not well known.

The reservations given above and earlier in the text have mainly been concerned with the lack of appropriate data and consequent need for assumptions as well as restrictions in some of the methods or methodological experiments done.

However, there are also more general problems related to the basic approach that we have applied. Randall (1991), for example, has argued that independent valuation and summation (IVS) can produce misleading estimates of total value and component values, especially when several methods are applied in independent valuation. The problem is that an IVS valuation procedure does not take proper account of resource scarcity and of interactions, such as substitution or complementarity, among various kinds of environmental services.

To avoid these involved summing problems, a potential approach for the valuation of non-marketed water-based benefits, for example, might be to define a programme (programmes) with forest management changes large enough to cancel out the estimated harmful effects of current practices on both recreation and preservation and to estimate its costs. People's willingness to pay for this program could be revealed using CV techniques. In particular, a referendum format could be used where people are directly asked whether they would vote for the program given the estimated cost they would have to bear.

Another important issue for further studies is to ascertain to what extent the internalizing of different environmental impacts will reduce the social (or environmental-economic) profitability of forest drainage, soil scarification and other measures. Economic estimates of the damage impacts of forestry are also needed to determine the economic efficiency of alternative defensive actions (or programs) although a mere cost-effectiviness approach may in practice play a major role in defensive actions concerning the decrease of diffuse loadings. "Green accounting" is also a field of research where more accurate economic estimates of forestry externalities on water resources are needed.

Acknowledgements: We thank Mr. Kaarle Kenttämies, Mr. Veli Hyvärinen, Mr. Antti Lappalainen, Mr. Mikael Hildén, Mr. Juhani Kokkonen, the participants of the METVE-project and the anonymous referees for helpful comments and constructive criticism. We also gratefully acknowledge the financial support of the METVE project as well as additional financing given by the Society of Forestry in Finland, Kyösti Haataja Foundation of OKO Bank and the Academy of Finland. The Faculty of Forestry at the University of Joensuu provided the facilities. We retain responsibility for all errors.

References

Ahtiainen M. 1992. The effects of forest clear-cutting and scarification on water quality of small brooks. *Hydrobiologia* 243/244: 465–473.

Boyle K.J., Desvousges W.H., Johnson F.R., Dunford R.W. & Hudson S.P. 1994. An investigation of part-whole biases in contingent-valuation studies. *J. Environ. Econ. Management* 27: 64–83.

Carlsen A.J., Strand J. & Wenstop F. 1993. Implicit environmental costs in hydroelectric development: An analysis of the Norwegian Master Plan for Water Resources. *J. Environ. Econ. Management* 25: 201–211.

Desvousges W.H., Smith V.K. & Fisher A. 1987. Option price estimates for water quality improvements: A contingent valuation study for the Monongahela River. *J. Environ. Econ. Management* 14: 248–267.

Downing M. & Ozuna T. Jr. 1996. Testing the reliability of the benefit function transfer approach. *J. Environ. Econ. Management* 30: 316–322.

Garrod G. & Willis K. 1994. An economic estimate of the effect of a waterside location on property values. *Environ. Res. Econ.* 4: 209–217.

Hervik A., Risnes M. & Strand J. 1987. Implicit costs and willingness-to-pay for development of water resources. In: Carlsen A.J. (ed.), *Proceedings of the UNESCO Symposium on Decision Making in Water Resources Planning*, Oslo, Norway, pp. 195–202.

Hirvonen T., Virolainen A. & Ylönen S. 1994. [Fishermen's willingness to pay for the water quality in southern Lake Saimaa]. *University of Joensuu, publications of Karelian Institute* 107: 1–36. [In Finnish with English summary.]

Holopainen A.-L. & Huttunen P. 1992. Effects of forest clear-cutting and soil disturbance on biology of small forest brooks. *Hydrobiologia* 243/244: 457–464.

Hultkrantz L. 1992. National account of timber and forest environmental resources in Sweden. *Environ. and Res. Econ.* 2: 283–305.

Hyvärinen V. 1984. River discharge in Finland. *Publications of the Water Research Institute* 59: 3–23.

Hämäläinen A. 1987. Mikkelin läänin pienvesien tila, Helsinki, Ympäristöministeriö, Ympäristön- ja luonnonsuojeluosasto, Sarja D 29/1987, 33 pp.

Johansson P.-O. 1989. Valuing public goods in a risky world: An experiment. In: Holmer H. & van Lerland E. (eds.), *Valuation Methods and Policy Making in Environmental Economics,* Elsevier, Amsterdam.

Johansson P.-O. 1993. *Cost-benefit analysis of environmental change,* Cambridge, Cambridge University Press, 232 pp.

Johansson B. & Seuna P. 1994. Modelling the effects of wetland drainage on high flows. *Aqua Fennica* 24: 59–68.

Kattelus L. 1983. Lapuanjoen vesistötöiden taloudelliset vaikutukset. Vesihallitus. *Tiedotus* 232: 1–188.

Kenttämies K. 1981. The effects on water quality of forest drainage and fertilization in peatlands. *Publications of the Water Research Institute* 43: 24–31.

Kenttämies K. & Saukkonen S. 1996. Metsätalous ja vesistöt. Yhteistutkimusprojektin "Metsätalouden vesistöhaitat ja niiden torjunta" (METVE) yhteenveto. *MMM:n julkaisuja* 4/1996.

Komiteanmietintö 1991. Uhanalaisten eläinten ja kasvien seurantatoimikunnan mietintö 30, Helsinki, 328 pp.

Kubin E. 1995. Avohakkuun, hakkuutähteiden talteenoton ja maanmuokkauksen vaikutus ravinteiden huuhtoutumiseen. In: Saukkonen S. & Kenttämies K. (eds.), The effects of forestry on waters and their abatement. Final Report of METVE-project. Finnish Environment Agengy. *Finnish Environment 2 — Environment protection*: 65–71. [In Finnish with English summary.]

Kyber M. 1981. Vesistön likaantumisen virkistyskäytölle aiheuttamat haitat ja niiden arviointi katselmustoimituksessa. *Valtion teknillinen tutkimuskeskus (VTT) tiedotteita* 23: 1–90.

Lappalainen A. & Hildén M. 1993. Virkistyskalastajien kokemat metsä- ja suo-ojitusten vesistöhaitat. In: Lappalainen A. & Rask M. (eds.), Metsätalouden vaikutukset kaloihin ja kalatalouteen. Osahankkeiden raportit vuosien 1990–1992 tuloksista, Finnish Game and Fisheries Research Institute. *Research report* 69: 103–122.

Lehtonen H., Salojärvi K., Leinonen K. & Bakker B. 1988. Virkistys- ja kotitarvekalastus Suomessa vuonna 1981. *Suomen Kalatalous* 50: 30–72.

Loomis J.B. 1992. The evolution of a more rigorous approach to benefit transfer: Benefit function transfer. *Water Resour. Res.* 28: 701–705.

Matero J. & Saastamoinen O. 1993. [Economic evaluation of environmental impacts of forestry on water-based values: methods and preliminary calculations]. *Joensuun yliopiston metsätieteellisen tiedekunnan tiedonantoja* 11: 1–149. [In Finnish with English summary].

Matero J. & Saastamoinen O. 1994. Economic evaluation of environmental impacts of forestry on water-based values in Finland. In: Helles F. & Linddal M. (eds.), Proceedings of the Biennal Meeting of the Scandinavian

Society of Forest Economics, Gilleleje, Denmark, 22–25 November 1993, *Scand. For. Econ.* 35: 307–319.
Matero J. 1996. Costs of water pollution abatement in forestry. *J. For. Econ.* 2: 67–89.
Mäntymaa E. 1993. [Valuing environmental benefits using the contingent valuation method]. University of Oulu. Research Institute of Northern Finland. *Research Reports* 109: 1–140. [In Finnish with English summary].
Navrud S. 1993. Economic value of biological diversity in Norway. In: Linddal M. & Naskali A. (eds.), Proceedings of the workshop "Valuing biodiversity — on the social costs of and benefits from preserving endangered species and biodiversity of the boreal forests". Espoo, Finland, October 1992, *Scand. For. Econ.* 34: 74–97.
Navrud S. & Strand J. 1992. Norway. In: Navrud S. (ed.), *Pricing the European Environment,* Oxford, University Press, pp. 108–135.
Niemi A. 1982. Vesistötöiden vaikutuksista rapukantaan Pyhäjoella. *Suomen Kalastuslehti* 89: 131–135.
OECD 1988. *Environmental policies in Finland.* Paris. 229 pp.
Palko J., Merilä E. & Heino E. 1988. Land drainage planning for acid sulphate soils. *Publications of the Water and Environment Administration* 21: 1–61.
Randall A. 1991. Total and nonuse values. In: Braden J.B. & Kolstad C.D. (eds.), *Measuring the demand for environmental quality*, pp. 303–321.
Riista- ja kalatalouden tutkimuslaitos 1992. Kalanviljely Suomessa 1991. *Kalankasvattaja* 21: 50–51.
Saastamoinen O. 1995. [Towards the total value of forests in Finland: A theoretical framework and model calculations]. University of Joensuu. Faculty of Forestry. *Research Notes* 36: 1–39. [In Finnish with English summary.]
Saukkonen S. & Kenttämies K. (eds.) 1995. [The effects of forestry on waters and their abatement]. Final Report of METVE-project, Finnish Environment Agengy, *Finnish Environment 2 — Environment protection,* 419 pp. [In Finnish with English summary].
Seppälä H. & Siekkinen V. 1993. Puun käyttö ja hiilitasapaino. Tutkimus puun käytön vaikutuksesta hiilen kiertokulkuun Suomessa 1990. *Metsäntutkimuslaitoksen tiedonantoja* 473: 1–54.
Siivola L. 1992. Virkistyskäyttö. In: Äijö H., Siivola L. & Vakkilainen P. (eds.), *Hyödyn ja vahingon arviointi vesitaloudessa,* Teknillinen korkeakoulu, Rakennus- ja maanmittaustekniikan osasto, Vesitalouden laboratorio, pp. 451–470.
Smith V.K. & Desvousges W. H. 1986. *Measuring water quality benefits.* Kluwer-Nijhoff Publishing, Boston, 327 pp.
Smith V.K. & Kaoru Y. 1990. Signals or noise? Explaining the variation in recreation benefit estimates. *Amer. J. Agr. Econ.* 72: 419-433.
Solberg B. & Svendsrud A. 1992. Environmental factors and national account of forestry — some findings from Norway. Paper for IUFRO Centennial Meeting, Berlin Aug. 31–Sep. 4, 1992, Department of Forestry, Agric. Univ. of Norway, 5 pp.
Strand J. 1981. Verdsetting av ferskvannfisk som kollektivt gode i Norge. Resultater fra en intervjuundersokelse. Sosialokonomisk Institutt, Universitetet i Oslo, Notat, 111 pp.
Tammi J. & Lappalainen A. 1993. Hajakuormituksen vaikutukset sisävesialueiden kalan- ja ravunviljelylaitosten käyttöveden laatuun. In: Lappalainen A. & Rask M. (eds.), Metsätalouden vaikutukset kaloihin ja kalatalouteen. Osahankkeiden raportit vuosien 1990–1992 tuloksista, Finnish Game and Fisheries Research Institute, *Research report* 69: 123–136.
Tervonen J., Alasaarela E. & Svento R. 1994. Household water quality and consumer welfare: An application to the city of Oulu. *Aqua Fennica* 24: 83–92.
Veisten K. & Hoen H. F. 1993. Contingent valuation of biodiversity in Norwegian Forests. In: Linddal M. & Naskali A. (eds.), Proceedings of the workshop "Valuing biodiversity — on the social costs of and benefits from preserving endangered species and biodiversity of the boreal forests". Espoo, Finland, October 1992, *Scand. For. Econ.* 34: 147: 148.
Vesihallitus 1983. Yhdyskuntien vedenhankinnalle tärkeät pohjavesialueet. Vuosina 1977–1982 tehdyn tarkistustyön tulokset. *Tiedotus* 225, Helsinki. 140 pp.
Vuorinen P.J., Vuorinen M., Peuranen S. & Tigerstedt C. 1995. Veden rauta-, alumiini- ja humuspitoisuuden sekä happamuuden vaikutukset harjukseen ja taimeneen laboratoriokokeissa. In: Saukkonen S. & Kenttämies K. (eds.), The effects of forestry on waters and their abatement. Final Report of METVE-project. Finnish Environment Agengy. *Finnish Environment 2 — Environment protection*: 297–312. [In Finnish with English summary.]
Westman K. 1991. The crayfish fishery in Finland — its past, present and future. *Finnish Fisheries Research*, Fisheries Division, Aquaculture Division, 12: 187–216.
Yrjänä E.-R. 1983. Esiselvitys korkeiden nitraattipitoisuuksien esiintymisestä pohjavesissä. *Vesihallituksen monistesarja* 156: 1–69.

Received 15 April 1997, accepted 18 March 1998