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PEATLAND FORESTRY AND SURFACE WATER QUALITY IN FINLAND

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SUMMARY

The drainage of peatlands for forestry started in Finland about 100 years ago, and to the present date, approximately 55,000 km^2 have been drained. Forest research first started to study the effects of peatland drainage on the amount and quality of discharge water in the late 1960s when concern was raised about increased flooding and sedimentation in the lakes surrounded by drained peatlands. Subsequent studies have proved these supposed impacts. Peatland forestry also includes fertilization, different cuttings, and site preparation during the regeneration of tree stands, and the maintenance of drainage systems. All of these can have adverse effects on the quality of discharge water unless active preventative measures have been taken.

KEYWORDS: Drainage, fertilization, ditch network maintenance, sedimentation, leaching

INTRODUCTION

The original mire area in Finland has been estimated to have been some 104,000 km^2 (Lappalainen, 1996). Nowadays, approximately 90,000 km^2 of that original area belongs to forestry land (Tomppo, 1999). Of this total area, about 77,000 km^2 has a peat layer of some 30-40 cm in thickness, thus constituting true peatland (Lappalainen, 1996). In Finland the drainage of mires to increase tree growth started more than a hundred years ago, and to the present date, approximately 55,000 km^2 have been drained for forestry. Of this total area, 48,000 km^2 has some peat or at least mire vegetation, and about 6,600 km^2 have already been classified as mineral soils (Tomppo, 1999). Before World War II about 6,000 km^2 had been drained, and, following the war, drainage started to increase in the 1950s. The annual drainage area gradually increased to almost 2,950 km^2 by 1969, and then decreased again to almost zero by the end of the 20th century. Drainage has doubled the growing stock volume of forests in the drained area and the annual increment has developed by 105 % compared with a 37 % increase in mineral soils after 1951–53 (Tomppo, 1999). Research into the effects of drainage on water quality started in 1977 (Heikurainen *et al*., 1978; Ahtiainen and Huttunen 1999).

In roughly the 25 years from the mid-1960s to 1990 approximately 30,000 km^2 were fertilized, but since 1990 fertilization has practically ceased. One half of this area is PK fertilization in drained peatlands (Joensuu *et al*., 2002). Studies of the chemical quality of the water running from fertilized peatland forests started to be conducted in 1965 (Karsisto, 1970; Särkkä, 1970). In the past ten years, annual regeneration cuttings in peatland forests have covered some 150-200 km^2 and their area will need to increase in the future. Research into the effects of forest regeneration, mostly clear-cutting and ditch-mounding, on the quality of runoff water in the peatlands was commenced in the early 1990s (Nieminen, 1998). The most important task to be undertaken regularly in the drained peatland forests is the maintenance of the drainage system, required, on average, at roughly twenty year intervals. This kind of work has been done annually in an area of some 700-800 km^2. Research into the impact of ditch network maintenance on the discharge water quality started generally at the beginning of the 1990s (Joensuu *et al.*, 2002).

THE EFFECTS OF PEATLAND FORESTRY ON SURFACE WATER QUALITY

Before we can discuss the effects of management activities on water quality, we need to know the quality of the water running from natural peatland areas. Precipitation water contains NO_3-N, NH_3, organic N, different cations, and a little phosphorus. In the course of its flow through natural land ecosystems, the quality of water changes to that of natural streams by losing its N and P, leaching organic C and N, and cations, and also by eroding soil materials (Table 1; Mattsson *et al.*, 2003; Finér *et al.*, 2004; Kortelainen *et al.*, 2006). There is considerable annual, seasonal and local variation in the concentrations contained in precipitation and natural stream water. In excellent, good, and satisfactory lake water, the concentration of P should be < 12, < 30 and < 50 µg L^{-1}, respectively. The natural concentration of the total N in the water of lakes is < 500 µg L^{-1}.

Table 1. Average concentrations of suspended solids (SS), total organic carbon (TOC), total (N_t) and nitrate (NO_3-N) nitrogen, total phosphorus (P_t), potassium (K), and iron (Fe) in precipitation water, stream water from natural catchments (> 30 % peatlands), and from catchments after ditching part of the mire area (Drainage), before (Average) and after ditch network maintenance, and after forest regeneration. n = number of catchments, a = number of years measured, Ref. = references used: a) Mattsson *et al.* (2003); b) Finér *et al.* (2004); c) Kortelainen *et al.* (2006); d) Ahtiainen and Huttunen (1999); e) Joensuu *et al.* (2002); f) Nieminen (2003, 2004); g) Joensuu *et al.* (2001).

Studied material	SS mg L^{-1}	TOC mg L^{-1}	N_t mg L^{-1}	NO_3-N µg L^{-1}	P_t µg L^{-1}	K mg L^{-1}	Fe mg L^{-1}	n	a	Ref.
Precipitation	..	1.4	1.0	..	20	0.2	..	22	27	a,b,c
Natural streams	0.9	19.5	0.4	8	14	0.4	1.3	22	3	a,b,c
Drainage	35.5	..	0.6	21	26	..	..	3	3	d
Maintenance	68.5	24.3	0.7	64	64	1.1	2.3	40	1	e
Regeneration	..	30.1	1.0	88	80	..	..	7	3	f
Average	4.7	26.1	0.8	64	61	0.6	1.6	75	3	g

The impact of management activities in peatland forestry on the quality of the discharge water has mostly been studied in relation to the concentrations and loads of suspended solids, N and P, which are the most important for the surface water quality (Table 1). Drainage will always greatly increase the amount of suspended solids in runoff at the time of the digging of the ditches (100-200 mg L^{-1}), and the impact will usually last for only one year after that (Heikurainen *et al.*, 1978; Ahtiainen and Huttunen, 1999). The amounts are so large that their sedimentation into brooks, ponds or lakes can change the conditions in these very much for the worse, for instance for certain species of fish. During periods of high flow, some erosion may also occur later. The impact of ditch network maintenance on suspended solids is a little less than that of first-time ditching, but in any case it is the most serious impact resulting from this activity (Joensuu *et al.*, 2002, Nieminen *et al.*, 2010). First-time ditching will increase total nitrogen leaching by 50-100 % only for the first year after the digging, but the ditch network maintenance on average not. Ditch network maintenance increases mineral nitrogen concentrations such as NH_4-N by roughly 100 % and NO_3-N by roughly 50 % during high flow periods, and the total P and Fe will also occasionally have increased a little, whereas the Al concentration will always and only increase during the first year by 100-300% (Table 1, Joensuu *et al*., 2001, 2002; Nieminen *et al*., 2010).

Nutrients present in fertilizers will leach quite easily from peatlands (Karsisto, 1970; Särkkä, 1970; Karsisto and Ravela, 1971; Nieminen, 1997; Kenttämies, 1998). Only in the case of ash fertilization has no significant increase in nutrient leaching occurred, although with the exception of potassium, which in any case is not harmful to surface waters (Nieminen *et al*., 2005b). Acid soil water in peat will also dissolve slow-release phosphorus fertilizers and cause a long-lasting increase in the leaching of P which is also related to the small amount of iron contained in the peat (Nieminen and Jarva, 1996; Nieminen, 1997). Hence attempts have been made to avoid this problem by adding iron to the fertilizers used in peatland forests (Nieminen *et al*. 2011).

If it has been done during winter on frozen peat, regeneration cutting has not increased the amount of suspended solids in runoff. The leaching of DOC and various forms of nitrogen has increased especially in fertile peatland forests dominated by Norway spruce (Lundin, 1999; Nieminen, 2004). On nutrient-poor peatland forests dominated by Scots pine, cutting alone has not increased the leaching of nitrogen, but it has started after the completion of ditch-mounding, and the leaching of water soluble PO_4-P has always increased if the Fe and Al concentrations in the peat have been low (Nieminen, 2003). Ditch-mounding will increase the load of suspended solids, especially in conditions where shallow (40-60 cm deep) ditches reach into the erodible mineral soil beneath the peat, and this will always be the case for the leaching of potassium, which under certain conditions will have to be compensated for at some point in the future by means of potassium fertilization (Nieminen, 2003, 2004).

WAYS TO DECREASE THE EFFECTS OF PEATLAND FORESTRY ON SURFACE WATER QUALITY

There are numerous methods in peatland forestry that might be used to reduce negative impacts on water quality, such as careful planning, digging sedimentation pits in drainage ditches, providing larger sedimentation ponds in the main ditches (Joensuu *et al*., 1999), leaving untouched sections in ditches by cleaning them, leaving shelter belts between brooks and managed areas in fertilization and clear-cutting (Ahtiainen and Huttunen 1999), and also using overland flow areas and riparian buffer zones in connection with ditch network maintenance or ditch-mounding (Nieminen *et al*., 2005). The last of these is regarded nowadays as the best way to reduce the suspended solids because of its capacity for also retaining fine-textured material and P (Nieminen *et al*., 2005a; Väänänen *et al*., 2008). A new peak runoff control structure to reduce erosion has also been developed (Marttila *et al*., 2010).

CONCLUSIONS

Most conclusions concerning the impact of management activities on the quality of surface water have been reached on the basis of only a very few experiments. This needs to be investigated in many more varieties of conditions because of the large areal variations in the quality of natural stream water. One special problem not yet studied is ditch network maintenance in peatlands with acid sulphate bottom soils. It has, however, been suggested that the dearth of field experiments might to some extent be compensated for by the use of modeling (Lappalainen *et al*., 2010). After 40 years of research into the impact of peatland forestry on surface waters, we now know the broad outlines of impacts and the developing trends in the most noticeable of them. The results of research always vary so much that some observations may even contradict the main impact. There are by no means sufficient results yet for us to be able to attempt to evaluate the impacts reliably in terms of discrete local conditions or watersheds. Despite these shortcomings, approximate average estimates and calculations have in any case been made even to the whole country (Finér *et al*. 2010), but with no real knowledge of just how correct or incorrect they may be.

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