Hydrological problems associated with mire restoration

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Introduction

Drainage of peatlands has been very extensive in Finland, especially in the southern part, where 78 % of spruce mire area and 72 % of pine mire and treeless mire area is classified as drained (Virkkala et al. 2000). Also a great part of the area classified as undrained has suffered from ditchings in the catchment or e.g. loggings and subsequent preparations of regeneration areas. The total mire area has diminished about 9 % since early fifties according to National Forest Inventories, mainly due to ditching of thin peated areas. There are also drained areas in protected areas or areas belonging to protection programmes. For example, private landowners have drained about 50 000 ha of mires belonging to the National Mire Protection Programme (Aapala & al. 1996).

The use of peatlands for forestry and especially for agriculture is most profitable on the nutrient rich mire sites and, therefore, those have been the first ones selected for drainage. Spruce mires can often be found as narrow strips in the ecotone between forest and mire ecosystems and these ecotones are easily destroyed by a single ditch and even have often been left out of the conservation areas. The need for restoration is very high in spruce mires in hemiboreal and southern boreal zones, where less than 1% of them have been protected, and almost half of these protected spruce mires have been drained (Virkkala & al. 2000). Even worse is the situation with rich fens, both treed and open; less than one percent of the original area is left in southern Finland, largely due to early clearing for agricultural use.

The aims of restoration are diverse. The nutrient rich mires are most potential habitats of threatened peatland species and the endangered twenty-three mire site types are mostly nutrient rich and often demanding flowing water (Aapala & al. 1996). These are some of the most urgent sites to be restored, especially since changes in the mire vegetation and peat properties are most pronounced after disturbance in wet, base rich mires. The Principles of the Protected Area Management in Finland (1999) state that, as a rule, all the disturbed mires in the state-owned protected areas should be restored. These include areas with special landscape value; the natural mosaic of dense forests and open or sparsely treed mires should be returned. The ecotones of mire and forest vegetation are ecological hot-spots for biodiversity. In many cases, ditches in these ecotones divert waters from the seemingly natural mire area and affect its natural state. By restoration, natural development can be retaken. Peatland restoration aims to revitalise a self-sustaining, naturally functioning mire ecosystem, which in most cases accumulates carbon and retains nutrients from through-flowing waters. Also water quality management may be included to the aims of restoration (Vasander & al. 1998). Unprofitable drainages should be returned to their natural state, e.g. to promote wild berry production.

Methods of mire restoration

The prerequisite of a successful mire restoration is to restore the original flow paths of waters. This is aimed at by damming or filling in the ditches. Usually excavators are used. Hand made dams are very expensive and, even when constructed as voluntary work with many people involved, many failures have occurred due to insufficient dams. Whether the aim is to construct dams or to fill in the ditches completely, in both cases it is important create water-tight dams frequently enough to make it possible for the water level to raise to original level also in the areas between the ditches. For the dams to be watertight, several meters of tightly compressed peat, using old excavated peat originating from the ditches or fresh peat from artificial hollows dug to vicinity, is needed. As peat subsidence due to ditching is usually most pronounced near the ditches, extending the dams, as low banks, several meters away from the ditches is necessary. The frequency of these watertight dams is obviously dependent on the slope of the ditches. With a steep slope, very frequent damming, e.g. distance less than 10 m, is necessary.

Some kind of treatment of the forest stand is usually involved in the restoration of mires. If the original mire has been open, complete harvesting is the obvious treatment. In naturally sparsely forested mires, such as pine mires, partial harvesting is often plausible for both ecological and economical reasons. In peatlands which originally had a dense tree cover, particularly spruce mires, the whole tree cover is usually left intact during restoration (The principles....1999). If the tree stand is manipulated, typical characteristics of pristine spruce mires, as long continuity, trees of all sizes and ages, large amounts of dead wood and gap-phase dynamics (Hörnberg & al. 1998, Kuuluvainen 1994) should be taken into account. Restoring the hardwood component of the natural tree stand structure is usually not a problem since birch (*Betula pubescens* Ehrh.) as a pioneer tree species, readily recolonises mire habitats, which receive enough light.

Problems encountered in mire restoration

Difficulties in restoring original water levels and water flow paths

Drainage always changes the natural flow of waters, and drainage in one part of a mire ecosystem may also change the hydrology in the undrained parts. The uneven subsidence of peat surface after drainage may complicate the restoration of the natural water flow. Peat subsidence is most pronounced near the ditches already due to drainage, and both the excavators used when filling in the ditches and possibly also harvesting machinery are moving on the old ditch banks. This may exacerbate the subsidence. Since the physical properties of the acrotelm of the mire have changed due to drainage, fully controlled re-wetting may not be possible.

At a larger scale, peat surface subsidence is greatest where the peat layer is thick, originally wet, and nutrient level is high, especially near the main drainage channels due to their deepness (e.g. Minkkinen & Laine 1998 and references therein). Therefore, exact original water conditions are impossible to reach, and the result is even in an optimal case a mosaic of drier and wetter areas. Also the fluctuations of the water table are expected to increase, due to the increased bulk density of the surface peat after drainage (Minkkinen & Laine 1998).

In many cases, the dams in the restored areas have been inadequate. If water is flowing over the dams, they often eventually break up in the most critical points, where diverting water to the original direction would be most important. Also untight dams may become a problem, even if the leakage was minute. In the long run, underground watertracks may be created. During the growing season, there is very little runoff and waters easily flow to the direction of ditches. A common scene in especially early restored areas, before accumulated knowledge of, is a striped peatland. There is green rheophilous vegetation over the old ditches, slowly changing dwarf shrub vegetation in the area between ditches, originating largely from the period of forest drainage. In worst cases, the minerotrophic waters from the catchment do not meet the areas fed originally by them at all, at least during the growing season, but are diverted along a few ditches to entirely wrong areas. Successful restoration requires that right kind of water and right kind of peat meet - in right proportions especially in the growing season.

A large hydrological problem is created from land ownership. In many cases, mire protection areas are surrounded by ditches and these ditches divert water around the area, instead of reaching the mire as in the natural state (Aapala & Lindholm 1999). Technically it would often be very easy to restore the original flow paths adequately by dams, but at the same time, water levels in the surrounding forestry land would also rise. In very flat areas, considerable water-logging would be created, extending hundreds of meters to the lands of the neighbours.

Treatment of the tree cover

The tree cover can also cause hydrological problems. Dense healthy forest evaporates efficiently and may thus prevent the establishment of mire plants. The annual evaporation from forest land is, on average, approximately 40 - 80 mm greater than from waste land or poorly productive forest land (Hyvärinen & al. 1995). However, in minerotrophic mires with large watershed compared with the size of the mire, runoff from the surrounding areas easily overrules the evaporation due to the tree stand. The trees suffer from water-logging and evaporation is reduced due to natural processes as well. Excessive treatment of the forest stand may also create thickets of e.g. young birch, both from seeds and as saplings. Pubescent birch tolerates water-logging rather well especially when it is young.

Treatment of the forest stand may cause also visual problems. Peatland forests maintain their uneven-sized and -aged structure for quite a long time after drainage, but thinning operations level off the unevenness of the tree stand structure (Hökkä & Laine 1988, Päivänen 1999). Sometimes all the original larger mire trees have been cut just before drainage. The remaining trees have responded to drainage and trees typical to natural mires do not exist anymore.

The excavators used when filling the ditches require space; in typical cases all the trees from the ditch banks are removed, and straight narrow clear-cuts are formed. The visual effects can be reduced, if untouched spots are left and the machinery alternates from bank to bank when moving along the ditches.

Very often some trees die due to the raised water table after damming of the ditches. If this is not to be expected, logs should be created by felling trees, since e.g. many insects and fungi are dependent on dead wood of different ages, typical to natural forested mires. However, sometimes very large and sudden tree deaths may occur, especially in topographically flat areas.

Water quality changes in recipient watercourses after restoration

The effects of restoration of drained mires have been monitored in the Seitseminen National Park, south-western Finland in 1997-1999 with co-financing from LIFE-Nature (Sallantaus 1999). This monitoring is still going on and new results from different restoration areas have been obtained. There are altogether five monitored catchments in Seitseminen. These are mostly dominated by oligotrophic or even ombrotrophic pine mires, some of which were nearly open before drainage. Also areas with hardwood and spruce mires are included. The treatments of the tree stands varied from almost complete tree removal to clearing just the tracks for the excavator, which blocked the ditches.

In all cases, concentrations of nutrients in downstream waters increased after restoration, as expected. However, the increase in phosphorus concentrations was unexpectedly high. In the two monitored lakes, total phosphorus concentration increased five-fold within one year, when all the drained mires in the catchments (25 and 38 % of the catchment area) were restored within a short period of time. Similar increases were observed also in the three monitored brooks, with similar degree of restoration. Although the mires were restored in late fall or early winter, the increase in phosphorus concentration took place late in the summer and in early fall, showing that biological processes are needed, directly or indirectly, to the phosphorus release. The poor oxygen conditions in the water-logged peat were demonstrated by the fact that the concentrations of sulphate dropped concomitantly with the increase in phosphorus.

Very high concentrations of phosphorus may occur especially during the low flow periods, up to more than 1000 μ/l. However, in the second year after restoration, the concentrations were already rapidly decreasing. Three years after restoration, average P concentrations in runoff seem to drop down to below 50 μg/l, but in some cases indications of a slower recovery were observed. The maximum annual phosphorus load due to restoration of a mire is on the order of one kg of phosphorus per restored hectare, based on the results of the catchments monitored in Seitseminen.

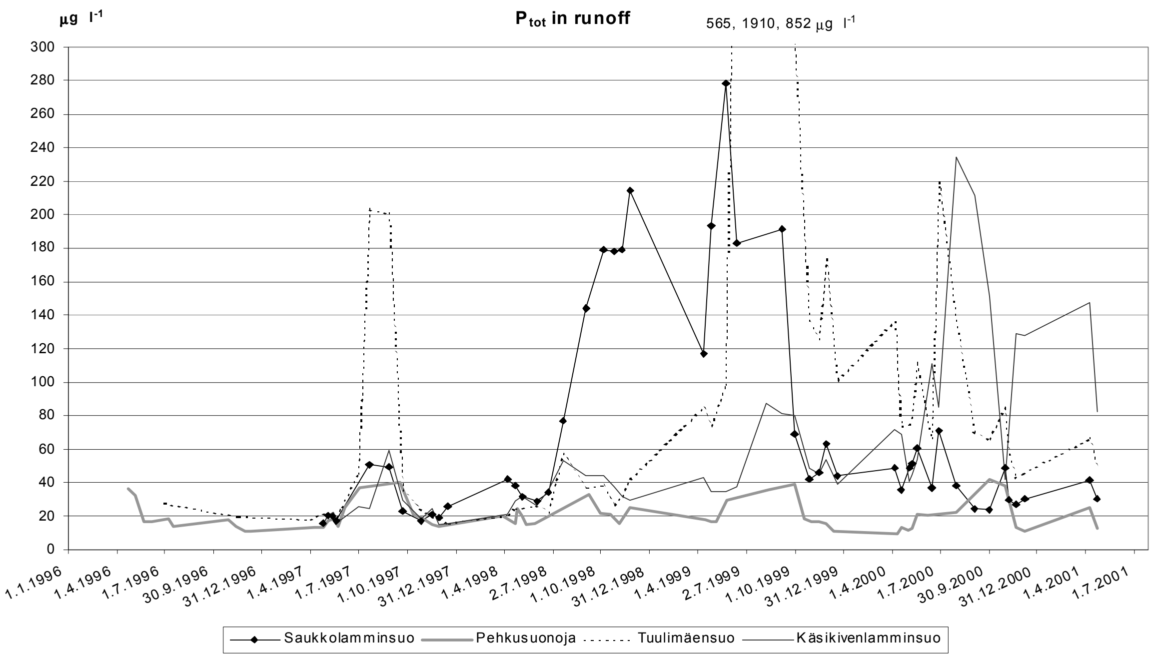

Figure 1. Total phosphorus concentrations in runoff waters from three catchments with mire restoration activities (30 - 40 % of the catchment area), and in a reference area (Pehkusuonoja). The restoration took place in the fall 1997 in Saukkolamminsuo, in the fall 1998 in Tuulimäensuo, and gradually in Käsikivenlamminsuo; small parts in 1997 and 1998, the main basin in 1999 and 2000.

The increases in concentrations of phosphorus and other nutrients after restoration were rather large, but not exceptional e.g. compared with the impacts of forestry practices in peat soils. Fertilisation of peatland forests with fertilisers containing some soluble phosphorus, used in Finland in a large scale still some 12 years ago, caused many-fold increases in concentrations and leaching and for a much longer time (Saura & al. 1995) Previous fertilisations of the drained mires may exacerbate the leaching of phosphorus due to restoration in the case of Seitseminen national park. Similar or even higher increases have been observed following clear-cuttings on peatlands, both in drained (Nieminen 1999) and undrained (Ahtiainen 1992) mires. In an area, which was previously a rich fen, outside Seitseminen, no greater increase in P concentration was recorded after restoration, in accordance with the results of Nieminen (1999) that many nutrient rich mires have a good P retention capacity.

Also other changes in water quality take place after restoration of drained mires (Sallantaus 1999). For example, leaching of dissolved organic carbon increases for some time after restoration, when increased amounts of water reach the changed, decomposed surface peat of the drained area. The higher concentrations of organic acids increase the acidity of runoff waters as well, and this may be the reason, why e.g. the establishment of brown mosses is very poor after restoration of sites where they thrived in the natural state. Also ammonium concentrations may slightly increase both in runoff waters and in the surface peat.

Conclusions

In spite of some draw-backs, the experiences of mire restoration are promising. The 5000 ha of mires already restored are, however, very young and many open questions still remain. Practical restoration projects should be closely linked with monitoring and research whenever possible (Heikkilä & Lindholm 1997). Monitoring enables to correct actions in order to better achieve the restoration goals (adaptive management, Walters & Holling 1990). Incorporation of research into management generates synergy benefits, e.g. by enabling to set up experiments at scales that are relevant both ecologically and for management. It also helps to ensure the formation of a knowledge basis about the long-term effects of restoration, which in turn can be used in planning future restoration efforts.

One of the most urgent questions today is the priority of the sites to be restored. High availability of nutrients favours rapid colonisers, but the succession of mire vegetation is still poorly known especially in the fertile sites. Restored habitats will be colonised by their typical species most likely if the patches are close to existing sources of potential colonists. Favourable objects are therefore those, in which wanted species still exist. The principles... (1999) include e.g. potential habitats of threatened peatland species and densely wooded nutrient rich peatlands to the priority category. The problems encountered with the restoration of these sites are not fully realised and, therefore, careful planning and monitoring are required - especially if potential damage can be made to nature values still existing.

The major adverse hydrological impact of restoration of drained mires is the increased leaching of phosphorus (Sallantaus 1999), although minor increases have also been reported (Vasander et al. 1998). It is still unclear how common this problem is, and whether it can be reduced or avoided. It is, however, a matter that must be taken into account when planning and conducting the restoration works in drained mires. Negative impacts in water systems may strongly affect the public attitudes towards restoration. Even in cases where there is no actual risk of harmful environmental impacts, the situation should be carefully demonstrated for the public.

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