Abstract No: A-270

FORESTRY USE OF BOREAL PEATLANDS – CHALLENGES AND POSSIBILITIES

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SUMMARY

Approximately 15 million ha of peatland have been drained to improve forest growth. Most of this area is in Northern Europe, while Finland holds the world record with close to 5 million ha of forestry-drained peatlands. Drainage aims to lower the water-table level, thus extending the rooting zone and improving its oxygen status, and increasing tree growth through improved root functioning. Many peatlands are well suited for forestry because of the relatively high soil nitrogen content, even though the nutrient regime of peatlands varies widely. Yet, since peatlands are highly dynamic ecosystems with an organic soil, they are likely to respond to land use with greater adverse environmental impacts, such as loading of watercourses and release of CO_2 from the soil, than mineral soil sites. Currently, the main targets for both research and political guidance concerning peatland forestry in Finland are to find management options for reducing the harmful impacts, and to identify such areas that should be excluded from active, regulated forestry due to low productivity. Here, we review 1) the potential of continuous-cover forestry (CCF) to reduce harmful environmental impacts, 2) means to improve ecosystem condition with active management, and 3) identification and potential novel uses of low-productive drained peatlands.

Keywords: *drainage, peatland forestry, continuous-cover forestry, restoration*

INTRODUCTION

The aim of draining peatlands for forestry is to increase forest stock and thus raw material for the forest and wood products industry. Forestry in peatlands is most common in Northern and North-Western Europe, especially in some of the Nordic countries (Finland, Sweden, Norway), Baltic countries (Estonia and Latvia) and Russia (Päivänen and Hånell 2012). In addition, peatland forestry has some importance in the United Kingdom, Ireland, Canada and the United States (Minkkinen *et al*., 2008). It has been estimated that around 15 million ha of peatlands in total have been drained for forestry in the boreal and temperate zones during the last century (Päivänen and Hånell 2012).

Drainage is a prerequisite for peatland forestry in most countries. Drainage is needed to enhance the productivity of the tree stand and alleviate operational limitations of the peatland. Drainage also causes ecological changes in the ecosystem, which affect the carbon sink function and greenhouse gas (GHG) dynamics of the peatland.

In the Nordic countries peatland forestry is extensive: it is based on the use of natural tree stands, and management intensity is high with final cuttings, soil preparations, plantings, and fertilizations. In temperate zone countries, like UK and Ireland, forestry is much more intensive. It is mostly based on plantations on originally treeless peatlands, including, e.g., soil preparation and repeated fertilizations. Often these forest sites are former peat production areas, afforested as an after-use. In both areas, however, the stands are cut and regenerated, either by planting or natural regeneration. Regeneration often involves soil preparation. Continuous cover forestry (in which no clear-cuts take place) has gained more interest lately in the Nordic countries, but is still marginal. The intensity of forestry operations is reflected in stand productivity but unfortunately also environmental impacts.

In Finland, which probably holds the world record in forest drainage, about half (appr. 5.5 million ha) of the mire and peatland area has been drained for forestry since the beginning of 1900s. The proportion of growing tree stock on drained peatlands is about one quarter of the total (Päivänen and Hånell 2012). The economic value of timber growing on drained peatlands in Finland was estimated to be around 11 billion euros in 2013. Both state subsidies and private investments have been used to finance initial and maintenance drainage operations. The crucial questions for the future are: can we continue to grow forests on drained peatlands sustainably and what should we do with those drained peatlands deemed unsuitable for the continued practice of forestry?

Peatlands drained for forestry may be roughly divided into three groups: 1. Productive sites where forestry is profitable, 2. Sites that are low-productive because of nutritional imbalance (high N but low K and/or P in peat), and 3. Sites that is low-productive because of generally insufficient nutrient regime (low N). Common for both 2 and 3 is that their ecosystem services (C sequestration, provision of clean water) are degraded while low or no economic profit is gained. Their future land-use options may differ, however; while type 3 sites are moved from forestry to some other land use, type 2 sites may alternatively be reclaimed for forestry with the aid of ash fertilization (Huotari *et al.,* 2015). In the following, we present possible future scenarios for these different cases.

ALTERNATIVES FOR FORESTRY ON DRAINED PEATLANDS

As of 2014, revamped forest legislation in Finland has permitted alternatives to conventional silvicultural practices. For instance, instead of traditionally intensive forest management aimed at producing even-aged, single-species stands which are then clear-cut upon reaching maturity, forest owners now have the option to practice uneven-aged, continuous-cover forestry (CCF), thereby avoiding stand-replacing clear-cuts. In continuous-cover forestry, trees are, e.g., harvested selectively and/or in small gaps (repeatedly) to advance natural regeneration by creating suitable light conditions, and providing shelter, for seedlings. Thus, the goal is that the forest continually regenerates without clear cutting, soil preparation and planting. The legal possibility of managing forests in an unconventional, less disturbing manner coincides with the changing structure of forest ownership and public attitudes and preferences in Finland which increasingly emphasize other forest-related values (e.g., recreation, conservation, landscape), non-timber forest products, and non-market ecosystem services. While economics are always an important consideration in commercial forestry, ecologically and socially sustainable alternatives to even-aged forest management regimes are pivotal to progression towards a climate-smart, resource-efficient, carbon-neutral society.

Compared to mineral soil forest, peatland forest stands may offer better possibilities for shifting towards continuous-cover forestry. This results from their tree stand history and dynamics. Tree stand structure in undrained peatlands is usually very uneven considering both tree age and size (e.g., Heikurainen 1971). Also, the spatial distribution of trees is often clumped, with open treeless areas surrounded by dense tree stands. After drainage, new seedlings start to grow especially on formerly wet treeless surfaces, which increase the unevenness of the stand structure even further (Sarkkola *et al.,* 2005). As stands age, the size differences of stems decrease but in old mature peatland tree stands, stem number distributions are nevertheless usually broader than in the corresponding mineral soil stands. Even after canopy closure of the dominant tree layer, more undergrowth will arise which further increases stand variation.

In peatland forests the associated environmental benefits of CCF could also be considerable. To prevent the water table from infringing on tree growth, ditch network maintenance (DNM) (i.e., cleaning ditches and making supplementary ditches as necessary) is typically performed once or twice during the stand rotation in the traditional management schemes. However, this practice is harmful to downstream watercourses due to consequent leaching of nutrients, suspended solids and organic matter. At the same time, lowering the water table increases the thickness of the oxygenated peat soil layer, hence accelerating its decay and the release of CO_2 and in some cases also N_2O into the atmosphere. Add commonly applied clearcutting and soil preparation treatments at the end of the stand rotation to the silvicultural equation, and the need for alternative, less intensive management schemes for forestry-drained peatlands is obvious from the environmental point-of-view. From the economic perspective, ditch network maintenance in particular is a costly investment which can ―make or break” the forest owner; if applied on sites where it does little or naught to increase stand growth, the overall profitability of peatland forestry is significantly undermined.

Recent research (Sarkkola *et al.,* 2010, 2013) indicates that a tree stand volume of around 100 m^3 ha^{-1} in drained peatland forests may maintain WL deep enough for tree growth, 30-40 cm, via evapotranspiration. Maintaining a continuous cover of forest could thus pre-empt intensive forestry practices like DNM on such sites. If continuous-cover methodology facilitates forestry on drained peatlands without clear-cuts, soil preparation, artificial regeneration and regular ditch network maintenance, while maintaining WL relatively close to the surface, GHG emissions and harmful effects on watercourses may be greatly reduced. This seems a plausible scenario especially for the most nutrient-rich and most productive sites, where the harmful environmental impacts are the strongest. These sites are typically dominated by Norway spruce which tolerates shade and has a large leaf area that facilitates efficient biological drainage through evapotranspiration.

Although legal backing exists for practicing continuous-cover forestry, its practical application by forest managers and owners is hindered in part by the lack of research-based information available. Informational constraints concern, e.g., forest growth and yield, economic productivity, stand structure development and natural regeneration in various conditions, optimization models for uneven-aged, mixed stands, impacts on biodiversity, carbon cycling and storage. Furthermore, as most forests in Finland have thus far been managed as even-aged, there is limited knowledge and experience of how the residual stand responds after transformation cutting aimed at altering the present stand structure from even-aged towards an irregular (uneven-aged) one for the purposes of CCF.

OPTIONS FOR THE MANAGEMENT OF UNPRODUCTIVE DRAINED PEATLANDS

In Finland, there are nearly one million hectares of drained peatlands that are so low in productivity that active forestry is not economically feasible. About 0.5 million hectares are so poor that the landowner will not be obliged to regenerate such sites after cutting, which is otherwise a legal responsibility. This means that in the future around 4 million hectares will remain in more or less active forestry use.

An imbalanced nutrient regime, i.e., high peat N content but low phosphorus (P) and/or potassium (K), may check tree growth especially in originally wet, treeless peatlands where such soil conditions are common. Such imbalances can be remedied with wood ash fertilization, which contains all other nutrients that trees require, and in favorable proportions, except for N which is removed in combustion. In well-targeted sites, ash application increases tree production and reduces the acidity of the soil while increasing base cation reserves, with few harmful side-effects (Huotari *et al.,* 2015). Whether this is economically feasible depends on several factors, such as the potential productivity of the site after fertilization, and the costs of the fertilization operation.

Where low productivity is primarily caused by lack of N, fertilization is, as a rule, not feasible. Such sites are best left out of active forestry. There are different possible scenarios for such sites, which are also valid for the nutritionally imbalanced sites if fertilization is not a feasible option. Restoration to a functional peatland is an option that may mitigate climate change if the usually slightly negative soil C balance of such sites is replaced by C accumulation into peat, as is characteristic of these sites in pristine conditions. Restoration implies active measures, which aim to accelerate the regeneration of peatlands towards the structure and function of natural mires. Energy wood may be harvested before restoration, which may both speed up the regeneration process and provide income for covering the costs of active restoration. Where economic profit is sought, some sites may be suitable for peat extraction, or provide opportunities for producing renewable *Sphagnum* biomass. Present requirements for profitable industrial-scale peat extraction are that the size of the area is at least 20 ha, and the peat layer is at least 1.5 m thick. In addition, the distance to a peat-burning power plant must be reasonable. About 57% of cut-away peatlands have been evaluated to be suitable for forestry, and 20-25% for rewetting (Picken 2007).

As for renewable *Sphagnum* biomass, it has the potential to replace peat as growing medium in horticultural production. It is believed that harvesting of living *Sphagnum* biomass to a maximum depth of max 20-25 cm on poor, forestry-drained drained sites will ensure sufficient *Sphagnum* regeneration thereafter. The rotation time is presumed to be 20-30 years. However, *Sphagnum* species diversity, species suitability as horticultural substrate, and the abundance of cotton grass are critical factors to consider when selecting the appropriate sites for this purpose. The precise amount of suitable sites in Finland is not known. Thus far, only limited experiences of *Sphagnum* farming and its environmental sustainability have accumulated worldwide (Gaudig *et al.,* 2014, Pouliot *et al.,* 2015), mainly from cut-over or bog grassland sites.

CONCLUSIONS

In Finland there is now a boom in bio economy. This also means that there is greater demand for raw materials like wood – also from drained peatlands. The principles of ecologically, economically and socially sustainable development have to be followed when managing forests on drained peatlands. To safeguard the sensitive and dynamic peat soils, logging methods and machinery will also need to be further developed, taking into account the low bearing capacity of these soils.

We must also consider other ecosystem services of peatlands besides wood production. The most important are the maintenance and increase of carbon stocks, regulation of water flow and water quality as well as the maintenance of typical plant, animal and microbe communities in mires and peatlands.

ACKNOWLEDGEMENTS

Tiina ja Antti Herlin Foundation made it possible for HV to join IPS 2016 conference in Kuching, Malaysia.

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