After-use of Finnish cut-away peatlands: recent land-use trends and geology as a planning tool

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Summary

The area covered by peatlands in Finland is 8.9 million hectares. Approximately 60,000 ha are currently in peat production and 20,000ha have already been released from production. Agriculture (including field energy crop growing) and forestry are the most common after-use forms. Most of the current after-use areas have comprised the shallow edges of production areas. As soon as the deeper parts (difficult to drain –parts) are released on a larger scale, some changes in after-use planning can be expected. Also the demand of bio-fuels is growing and increasingly creates pressure to use areas for energy crop growing.

In Finland peat harvesting sites are utilised almost to the mineral subsoil. In this situation the properties of mineral subsoil have a considerable influence on the suitability for the various after-use forms. According to recent research a fifth of peat production areas were poorly suitable for economical use due to physical, geochemical or topography-hydrology-related reasons. However, most of the areas were well suitable for several different after-use options. One after-use option was seldom suitable for one whole cutaway area. The possibilities of using geology as a planning tool are presented in this paper.

Key index words: after-use, cutaway peatlands, geochemistry, sulphur

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Introduction

In Finland peat harvesting sites are utilised almost to the mineral subsoil and the properties of mineral subsoils have an influence on the suitability for the various after-use forms. Mineral subsoil grain size distribution can have an effect on the possibilities for forestry and agriculture. Forest growth is likely to be weaker when the amount of fine particles (<0.06 mm) is less than 15-20 % compared to finer grained sediments (Aro *et al.*, 1997; Aro and Kaunisto, 1998). Gravel and coarser sands are not ideal for agriculture (Heinonen *et al.*, 1992) due to their poor water holding capacity and cation exchange capacity. If sediments are very fine, their water retention is high, but water absorption is slow. These soils can also become hard and they may split when they dry.

Acidity of sulphur-rich soils can be a limiting factor for after-use. The Littorina zone of Finland is the area once covered by the ancient Littorina Sea. It is commonly known as 'the area of acidic clays'. The origin of sulphides in Littorina clays is from the seawater sulphates. Later land uplift has brought these old sea bottom sediments above the sea level. Draining these soils creates oxygenating conditions and sulphuric acid, iron oxides and hydroxides are formed (Yli-Halla, 2003). This creates acidic conditions, which also affects on the mobility of some other elements. Many heavy metals are highly mobile in acid sulphate soils and likely to get enriched in the recipient streams (Åström and Deng, 2002). However, Littorina zone is not the only special area in Finland. Geochemical differences are previously known to exist also in the fine material of till, between different geological areas related to bedrock characteristics (Koljonen,1992).

Climate politics is increasingly encouraging land-use for bio-energy production. This development is reflected also in the after-use of peat production areas. Similarly the value of forestry is high. It is also important to recognise the practical and ecological pressures for re-flooding and the biodiversity dimension of the after-use.

With this background the relevance of geology as an after-use planning tool is obvious. Based on the mineral subsoil study details requiring special attention and recommendations for actions and have been defined. In 2008 the role of geology has also brought recommendations for after-use planning in Finland (this research being one of the sources).

Materials and methods

The mineral subsoil research that forms the background of the recommendations presented in this paper was carried out 1998-1999 on 9,800 ha of existing and previous peat production area operated by Vapo Oy. Characteristics of mineral subsoils were defined and their suitability for different after-use forms was estimated. Research line orientations were mostly chosen to cross the previously known glacial flow directions. Areas close to the ice margin formations were an exception: there the latest glacial flow direction was used as the research line orientation. The idea was to cross most of the different mineral subsoil zones lying under the peat. The glacial flow directions can be found for example in The Geochemical Atlas of Finland (Koljonen, 1992). The top of the sample core was always 10cm under the peat layer. Three to five research lines were used for 100 hectares. In field conditions, all samples were classified to either tills or various sorted sediments. Some were also analysed in the laboratory. Grain size distribution was tested by dry sieving and aerometer analysis. Analysis of pH was carried out according to EN 13037:1999 and electrical conductivity (EC) according to EN 13038:1999 (methods accepted by European committee for standardization), from water solution. Organic matter was analysed according to EN 13039:1999. P, NO_3-N, NH_4-N, S and Fe was analysed from water solution (EN 13652:2001). Ca, Mg and K (exchangeable elements) were determined by modified EN 13651. Extraction with 0.5 M ammonium acetate (pH 4.65) was used instead of extraction with calcium chloride/DTPA (CAT). Nutrient analysis was carried out using an atomic absorption spectrophotometer.

Recommendations for using geology as a planning are based on different statistical analysis: correlation analysis and factor analysis with principal components extraction. SPSS version 13 was used as the statistical software. Methods of the original research were re-evaluated and the most successful parts were included in the recommendations.

Zones within mineral subsoils

Research outcome

The distribution of zones reflected generally the original mire formation environment (Picken, 2007). A 'ring like' zoning ('the central lake model') was common in sites where a lake or a pond had turned into a mire (overgrowth). In these sites clay or mud was found in the deepest part of the pool, surrounded by sandy shoreline formations. Often the outermost area was till: there the paludification had taken place in a forestland. In cases of a river or creek drying out the mineral subsoil zones were long and narrow and the mid-part included old river sediments. This zoning type ('the central river model') was commonly found near esker chains. It was probably often related to ancient glacial rivers. Close to the ancient ice margins, mineral subsoils were most complex. In this 'ice margin model' the sediments were sorted and the coarsest sediments were found closest to the ancient long-term ice margin.

Practical applications

One land-use option seldom suites well for a whole cutaway peatland. Different zones can be detected both in topography and soil types. In 'the central lake model' the centre of the peatland is deep and often difficult to drain. After production ends and the drainage pumps are shut down, these deep central parts are likely to become naturally flooded. In the other models the obvious topography–based reasons for individual after-use options are more rare.

Special characteristics of mineral subsoils

Research outcome

In mineral subsoils the concentrations of phosphorus (P) and nitrogen (N) were very low, often hardly above the detection limits (Picken, 2006). As the mineral subsoil samples were always taken 10cm under the peat layer, the presence of organic matter was relatively small. Though occasionally a lot of peat remains were found even at this depth. Organic matter percentage did not clearly control the concentrations of P, N and S. Sulphur (S) and EC had a significant correlation and EC and pH had a negative correlation. Concentrations of calcium (Ca), magnesium (Mg) and potassium (K) were strongly dependent on the fine material (<0.06 mm) percentage. A chemical summary of mineral subsoils is presented in the Table 1.

Practical applications: some analysis recommendations

The general characteristics of mineral subsoils lead to a conclusion that grain size distribution and concentrations of Ca, Mg and K are the variables best suitable for estimating the nutrition capacity in mineral subsoils. In principle, grain size distribution can also be used alone. Sulphur concentration and pH together seemed to have a high value as a classification tool. Areas with acidic development potential were easiest to spot, when these two variables were used together. Minimum depth of sampling should be 10cm under the peat layer, to minimise the quantity of peat mixed to the mineral soil. Presence of peat in the mineral sample can make it difficult to observe (and analyse) the grain size distribution.

Table 1. Examples of the chemical characteristics of the mineral subsoils (Picken 2006).

	Grains < 0,06 mm	**Organic matter**	**pH**	**EC**	**Exchangeable**			**Water soluble**			
					Ca	**Mg**	**K**	**P**	**NO3 -N**	**NH4 -N**	**S**
	%	%		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Median	35.0	1.3	6.1	2.3	239	60	24	4	1	4	5
Mean	44.1	2.5	6.0	4.8	287	86	36	5	2	6	27
Minimum	0.1		3.0	1.0	8	3	2	2	-	-	-
Maximum	99.2		6.9	70.1	925	400	190	36	11	29	627

Are some geological areas especially easy or especially sensitive?

Research outcome

Differences in concentrations of Ca, Mg and K were found between previously known geochemical provinces (Picken, 2005). These differences were most significant in the coarsest mineral subsoils. In the Lake Ladoga– Bothnian Bay zone, sediments had highest nutrient concentrations and granitoid areas and Archaean gneiss areas had the lowest concentrations. In the Littorina-zone 25 % of studied areas turned out to be relatively sulphur rich. Another area with many sulphur rich sites was the Lake Ladoga – Bothnian Bay zone. This zone is also known for many sulphide mineralizations in its rocks. In the Littorina zone the relatively sulphur rich sediments were usually clays, but in the other areas the higher sulphur concentrations were often present in coarse sediments.

Practical applications

Nutrient content varies between different geological areas (in samples with the same grain sizes). This could be interpreted as follows: for forestry and agricultural use the Lake Ladoga–Bothnian Bay zone requires less fine material in the sediment than the other areas. Cutaway peatland located in the Littorina-zone and in the Lake Ladoga–Bothnian Bay zone (and sites near other known sulphide mineralisations) are likely to demand special attention in after-use planning. In these areas (Fig. 1.) minimum disturbance of mineral subsoil might be required due to sulphur concentration.

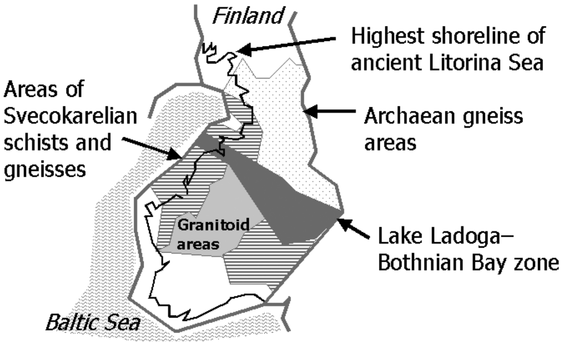

Figure 1. Location of some relevant geological areas.

Land-use possibilities

Research outcome

Afforestation was a well suitable after-use option in 57 % of the cutaway peatlands and agriculture was suitable in 42 % of the same areas (Picken, 2006). The percentage for forestry was higher because tills with larger boulders can also be forested. With special techniques (using also very fine or very coarse sediment areas) the percentages for forestry and agriculture could be increased to 80% and 65%. Natural re-flooding could take place in 9-14 % of all areas, but with special techniques also the percentage area for rewetting could be a significantly larger.

Discussion: future trends of after-use

At the end of 2004 the most important after-use options in Finland were forestry (26%), energy crop production (14%) and other agricultural production (27%). Other after-use options included bird sanctuaries and wetlands, production supporting areas and areas under preparation for after-use (Silpola and Tuomanen, 2005). Now approximately 20,000ha has already been released from peat production and the number is rapidly increasing. Percentages of after-use forms are unlikely to remain the same. Currently in Finland the share of wetland as an after-use form is relatively small, but it is likely to grow when more and more of the deepest parts of the peatlands are released. Usually production ends first in the shallowest side areas. In the long term up to 14% of all cutaway peatlands is likely to be rewetted due to topographic features in 'the central lake'–type sites. When water pumping stops these deep pools will simply become flooded. These practical reasons are not the only reasons to consider the option of rewetting: flooded cutaways often have high biodiversity.

Internationally, after-use applications are often developed for sites with thicker remaining peat layers and might not always be applicable without adjustments. In Finland, the remaining peat layer is usually extremely thin, almost completely removed. Any relevant differences between the local circumstances and the original technique development environment should be recognised when applying new or 'imported' after-use technologies.

The demand for bio-energy production is likely to cause a large increase in the share of field energy crop production. Reed canary grass growing is already the fastest increasing after-use option. Bio-energy production might even become the major after-use form in the long term - as long as land ownership circumstances favour this development. The other big economical after-use form in Finland is traditionally forestry and many private peatland owners still appreciate this after-use form. Forestry is likely to hold its position as the main after-use option at least for small scale private land-owners. At the end of the day the choice is with the land-owners. Geology presents some limitations but the rest is dependent on the values of the society and the largely politically driven economical factors.

Conclusions for after-use planners: relevant tools and details related to mineral subsoils

Research line orientations should cross the previously known glacial flow directions (which are the same as local esker orientation) or cross the ice margin formations (like Salpausselkä ridges). This way the different mineral subsoil zones lying under the peat are most likely to be crossed and detected. Peat samples should be taken deep enough below the peat layer. If the sample is taken from too close to the surface, true mineral grain size distribution cannot be analysed due to the peat concentration in the mineral subsoil. The minimum analysis of mineral subsoils should include pH, sulphur concentration and organic matter. Analysing Ca, Mg and K concentrations is also recommended.

Mineral subsoil studies are especially important in the Littorina-zone and in the Lake Ladoga–Bothnian Bay zone. In general, sites around known sulphide mineralisation areas should get special attention in after-use planning. In these areas minimum disturbance of mineral subsoil might be required due to sulphur concentration. Sulphur sediments are not always clays and sometimes very coarse sediments are sulphur rich.

In conclusion, one after-use option is seldom the best alternative for an entire cutaway peatland. Topography in central-lake model sites is likely to demand at least small scale wetland development in the middle parts. When applying new or 'imported' after-use technologies any relevant differences between the local circumstances and the original technique development environment should be recognised.

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