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PROCESSES AND SITE CHARACTERISTICS CONTROLLING NUTRIENT AND SEDIMENT RUNOFF LOADS FROM PEAT HARVESTING SITES

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SUMMARY

Peat drainage and peat harvesting activities result in increased suspended solids (SS) and nutrient runoff loads to watercourses. According to current EU legislation, these harmful environmental impacts must be assessed before peat production can start. However, not enough is known about processes and potential site-specific characteristics which determine the variation in load from different peat production sites. To better assess and predict loads from peat production, extensive data from production methods, geology, hydrology, water protection structures and water quality were collected from 22 peat harvesting catchments around Finland. This study focuses on statistical analyses of the collected data.

KEY WORDS: peat harvesting; water quality; load formation; load prediction; runoff

INTRODUCTION

Peatland drainage, that is a prerequisite for energy peat harvesting, induces changes in both runoff water quality and quantity (e.g. Sallantaus 1983, Marja-Aho and Koskinen 1989). Furthermore, peat harvesting activities expose bare peat soil to erosion forces and thus significant suspended solids (SS) load may occur, especially during high flows (Sallantaus 1983, Kløve 1998, Röpelinen 2000, Marttila and Kløve 2008). Peat harvesting also increases transport of nutrients. Leaching of nitrogen (N) and phosphorus (P) from peat harvesting sites is affected by the increased decomposition of organic matter (Laiho and Laine 1994), ground water level and flow routes (Kløve 2001), peat type and degree of peat humification (Sallantaus 1983, Svahnbäck 2007), pH and also temperature. Particulate P and N can be delivered from peat harvesting sites with the SS.

Peat harvesting is subject to environmental permit licensing in Finland, and thus its impact on water quality needs to be assessed. Recently, loading to watercourses is estimated on the basis of an average SS and nutrient load from monitored peat harvesting sites. Although water quality impacts have been monitored and analysed broadly in Finland, and process based studies have been performed in several peat production sites, simple methods to predict SS and nutrient loads have not been proposed. Thus, new knowledge and methods are needed to better assess case-specific water quality and load from peat harvesting sites. The main objectives of this study were i) to find simple indicators for SS and nutrient loads from characteristics of peat harvesting sites, and ii) to estimate the impacts of runoff events on water quality and total load.

MATERIALS AND METHODS

The data for the study was collected from 22 peat harvesting sites across Finland. The study sites consisted of milled and sod peat production sites and total catchment areas varied from 61 to 510 ha. The peat had been harvested from1976 to 2004. Data collection from existing sources and *in-situ* measurements were carried out during summer 2010. Water quality and discharge monitoring data consisted of continuous discharge measurement and at least biweekly conducted water sampling of SS, N_{tot}, P_{tot} and COD_{Mn} during production seasons or year-round. Additionally the concentrations of phosphate phosphorus (PO_4), nitrate nitrogen (NH_4), nitrite nitrogen ($NO_{2/3}$), Fe and Al together with water temperature and pH had been measured from some of the study sites.

In-situ field measurements included collection and analyses of soil samples, measuring of drainage ditch depths, erosion observations and mapping of water distribution and water protection structures. Soil samples were taken from ditches where the ditch bottom was dug through the peat layer into underlying mineral soil. All the soil samples were analysed for particle size distribution. This study reports statistical analyses made from the collected database, consisting of existing water quality data and complementary field measurements. Daily runoffs were plotted against SS and nutrient concentrations to explain seasonal and transient variations in runoff water quality and total load. Furthermore, average daily runoffs were used as explanatory variables for average SS and nutrient loads between the study sites. Linear regression and Spearman's correlation analyses were performed to evaluate the relationship between water quality measurements and catchment characteristics. Observation periods were limited to the summer season (May-August) as year-round monitoring data was available only from a few of the study sites.

RESULTS

Average water quality varied significantly between the study sites (Table 1). Annual, seasonal and daily fluctuations in water quality and quantity were observed to be significant even within individual peat harvesting sites. Strong correlations between SS and P_{tot} concentrations were observed in several catchments indicating that the large part of the P_{tot} loads were transported with the suspended solids. In general, runoff volumes were more impactful than runoff concentrations when the total amount of SS and nutrient loads were considered instead of runoff concentrations.

Both P_{tot} and PO_4 concentrations in runoff water were highest during base flow and summer low flows, and lowest during peak flows (Fig. 1). This phenomenon is seen in the combined dataset from all study sites (Fig. 1) but also, even more clearly, in a few individual catchments (e.g. Nanhiansuo and Hormaneva). However, the dispersion of the phosphorus concentration was considerable and correlation with runoff was not statistically significant in several study sites. A log-linear regression model revealed that average runoff (measured at water sampling days) explained 38 % of variation in average P concentrations between the studied peat harvesting sites ($p < 0.01$). SS, N_{tot}, NH_4, $NO_{2/3}$ and COD_{Mn} concentrations did not correlate with daily runoffs either between the study sites or within the study sites. Nevertheless, analyses of runoff–concentration time series showed some theoretically reasonable connections between the variables during extreme runoff events.

Table 1. Average water quality from studied peat harvesting sites. Total nitrogen (N_{tot}) and total phosphorus (P_{tot}) concentrations are not comparable with the concentrations of their fractions (PO_4, NH_4, $NO_{2/3}$) due to different monitoring periods and sampling frequencys.

Study site	Monitoring period	n	[mg l^{-1}] SS	P_{tot}	N_{tot}	COD_{MN}	Fe	PO_4	NH_4	$NO_{2/3}$
Hankilanneva	11.11.2008 - 14.10.2009	14	23.4	0.085	1.3	19.3	10.1	0.044	0.25	0.03
Hietalahdenaapa	18.5.2004 - 4.8.2008	21	22.7	0.073	1.5	14.5	5.9	0.034	0.40	0.22
Hormaneva	15.4.2008 - 26.5.2010	48	7.9	0.105	2.8	47.7	2.6	0.033	1.58	
Isoneva	5.5.2003 - 13.10.2005	46	18.0	0.106	2.5	64.3	5.3	0.016	1.05	0.08
Jämiänkeidas	21.6.2006 - 4.5.2010	65	53.6	0.149	2.0	56.0	6.1	0.055	0.79	
Karhunsuo	4.6.2000 - 15.10.2009	83	15.5	0.076	2.3	70.6	2.7			
Kiihansuo	8.5.2001 - 30.9.2009	62	13.4	0.061	2.1	51.4	2.0			
Konnunsuo	15.5.2007 - 17.11.2009	34	13.4	0.104	1.4	28.3	3.4	0.019	0.24	0.23
Kuivastensuo	2.6.2003 - 21.10.2009	95	27.4	0.078	1.6	36.0	5.4	0.011	0.32	0.19
Laukkuvuoma	17.5.2004 - 19.9.2005	20	10.7	0.042	2.5	25.6	3.2	0.010	0.78	0.48
Linnansuo	22.4.2003 - 21.10.2009	119	17.4	0.040	1.3	33.7	1.6		0.46	0.05
Muljunaapa	18.5.2004 - 20.9.2004	10	17.6	0.090	1.4	29.9	4.9	0.048	0.11	0.19
Nanhiansuo	14.3.2006 - 25.5.2010	91	32.2	0.218	2.2	90.3	5.2	0.063	0.47	
Okssuo	15.1.2002 - 11.8.2008	67	18.6	0.120	2.6	68.4	4.6	0.030	1.33	
Puutiosuo	10.11.2003 - 26.10.2004	18	7.2	0.077	2.3	23.8	3.7	0.080	1.06	0.13
Rajasuo	12.5.1998 - 21.10.2008	81	26.6	0.198	2.9	76.6				
Ristineva	16.4.2007 - 30.11.2009	48	14.1	0.059	1.4	50.6	2.0	0.008	0.35	
Röyhynsuo	10.9.2008 - 4.5.2010	28	70.2	0.268	4.0	63.8	4.5	0.042	1.92	
Sarvanneva	20.1.2003 - 28.7.2008	43	51.2	0.152	2.4	44.5	3.7	0.013	0.71	
Satamakeidas	20.1.2003 - 21.6.2010	151	11.7	0.095	1.2	16.6	2.2	0.037	0.58	
Savonneva	16.5.2001 - 8.6.2004	63	16.6	0.098	2.8	60.4	3.6	0.020	1.35	
Siiviläniemenaapa	30.5.2005 - 8.10.2006	20	17.0	0.039	2.3	17.7	10.0	0.019	1.15	0.11

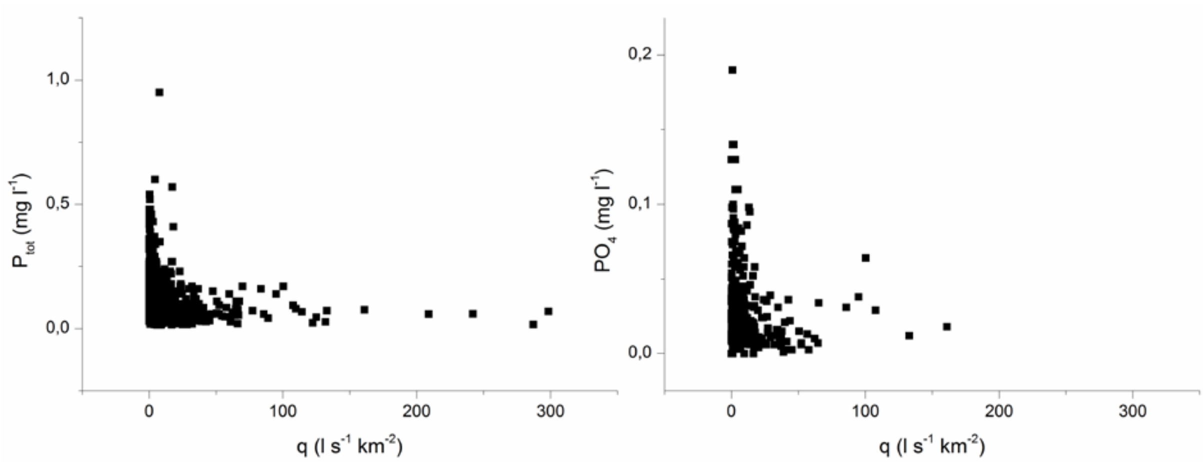

Fig 1. Variation of total phosphorus (P_{tot}) and phosphate phosphorus (PO_4) concentrations in 22 peat harvesting sites with daily average runoffs.

Several statistically significant correlations were found between the long-term average load and site-specific characteristics of the peat harvesting sites (Table 2). The particle size distribution (d50) and fine particle content of the sampled mineral soils correlated with the average SS load. The latitudinal locations of the peat harvesting sites had a strong effect on average COD_{Mn} load from independent study sites. Measured average COD_{Mn} loads were substantially higher in northern parts than in southern parts of Finland. Geographical location also seemed to have a little effect on total phosphorus and nitrite nitrogen loads (Table 2).

Table 2. Spearman's rank correlations between study sites properties and average load from peat harvesting sites.

Average load [mg/l]	Fine particle content (d < 0.063 mm)	Average (D50) particle size	Ditch depth	Latitudinal location	pH	*Carex* peat proportion
SS	0.81**	-0.67*	-0.46*	ns.	ns.	ns.
P_{tot}	0.61*	ns.	ns.	-0.44*	ns.	ns.
N_{tot}	0.61*	ns.	ns.	ns.	-0.48*	ns.
COD_{Mn}	ns.	ns.	ns.	-0.74***	-0.73***	ns.
PO_4	ns.	ns.	0.57*	ns.	ns.	ns.
NH_4	ns.	ns.	ns.	ns.	ns.	-0.9*
$NO_{2/3}$	ns.	ns.	ns.	0.65*	ns.	ns.

*$p < 0.05$ **$p < 0.01$ ***$p < 0.001$

DISCUSSION

Phosphorus concentrations in runoff water negatively correlated with runoff volumes (Fig. 2). This result is in line with the earlier findings and hypothesis of Kløve (2001). It is assumed that if the runoff is low, water retention time in the soil profile is increasing, and water infiltrates into drainage ditches from deeper, anoxic layers ("old water"), increasing the P concentrations in runoff water. If the runoff is high, water flows in the peat surface or topmost peat layers were the soil P concentrations are presumably lower that in deeper peat layers. Increased SS concentrations during peak flows were observed in a few study sites which can be explained by increased surface runoff and erosion. It is supposed that partly due to the discharge and water quality measurement setup, significant correlations between SS and runoff were not detected. Suspended solids were measured after sedimentation ponds which presumably have affected the measured SS concentrations. Water sampling frequency was also too long to catch the SS concentration-runoff interaction within single runoff events. In addition, pumping of water to treatment wetlands above discharge measuring points flattened the smaller peak flows.

The average SS load was dependent on mean (D50) particle size and fine particle content of the mineral soil beneath the peat layer (Table 2.). The smaller the average particle size, the greater was the average SS concentration in runoff. Similarly, the increased proportion of fine particles in mineral soil resulted in higher SS concentrations in runoff. Fine particles are easily prone to entrainment and transport. The result highlights the importance of particle size distribution to SS load from peat harvesting sites when mineral soil contacts occur. It can be thought that the properties of mineral soil may be more important in the comparison of peat soil properties when the total SS load is predicted for the peat harvesting sites where mineral soil contacts occur. However, more data are required to verify the result.

Concentration of COD_{MN} in runoff water correlated significantly with the latitudinal location of the peat production site (Table 2). The result confirms earlier findings of Kantonen (2011). Smaller average concentrations in Northern Finland can be the result of different geological and hydrological conditions. For instance, runoffs are typically higher in Northern Finland, temperatures lower and oligotrophic peatlands more common. COD_{Mn} concentration correlated negatively with average pH of runoff water (Table 2). Acidity of runoff water can be partly related to latitudinal locations of the study sites even though the correlation between these factors wasn't statistically significant in this data. Overall, the results of this study offer new information about the factors that affect SS and nutrient loads from peat harvesting sites.

Verification of the main findings still requires more data and more detailed analyses e.g. of peat soil properties. However, this study highlights some of the potential factors which can be taken for more detailed analyses in future.

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REFERENCES

Kantonen, S. (2011). Round-year wetland treatment of runoff from peat production areas. MSc thesis, Department of Process and Environmental Engineering, University of Oulu, Finland. 116 pp. (*in Finnish with English summary*).

Kløve, B. (1998). Erosion and sediment delivery from peat mines. *Soil and Tillage Research* **45**, 199–216.

Kløve, B. (2001). Characteristics of nitrogen and phosphorus loads in peat mining wastewater. *Water Research* **35**, 2353-2362.

Laiho, R. and Laine, J. (1998). Nitrogen and phosphorus stores in peatlands drained for forestry in Finland. *Scandinavian Journal of Forest Research* **9**, 251-206.

Marja-Aho, J. and Koskinen, K. (1989). Limnological effects of peat production. Helsinki, Vesi- ja ympäristöhallinnon julkaisuja 36. 203 pp. (*in Finnish with English summary*).

Marttila, H. and Kløve, B. (2008). Erosion and delivery of deposited peat sediment. *Water Resources Research* **44**, W06406.

Röpelinen, J. (2000). Measures applied within peat production areas and their effect on the quantity and quality of the runoff water. PhD thesis, Department of Process and Environmental Engineering, University of Oulu, Finland. 165 pp. (*in Finnish with English summary*).

Sallantaus, T. (1983). The load to watercourses from peat mining. MSc thesis, Department of Limnology, University of Helsinki, Finland. 122 pp. (*in Finnish with English summary*).

Svahnbäck, L. (2007). Precipitation-induced runoff and leaching from milled peat mining mires by peat types: a comparative method for estimating the loading of water bodies during peat production. PhD thesis, Department of Geology, University of Helsinki, Finland.111 pp.