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ASSESSMENT OF NUTRIENT RELEASE FROM HARVEST RESIDUES AND THE ROLES OF BUFFER AREAS AND SEEDED VEGETATION IN NUTRIENT RETENTION IN HARVESTED BLANKET PEAT FORESTS

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SUMMARY

The mature blanket peatland forest catchments are efficient P and N conservation ecosystems and hydrological losses of P and N are low. However, forest harvesting disrupts the nutrient cycling, reduces the nutrient conservation capacity and results in increased nutrient release to water bodies. To protect the water quality deterioration, whole-tree harvesting and use of buffer areas are proposed as a means to decrease nutrient release. However, the efficiency of buffer areas in blanket peat catchments may be low due to frequent occurrence of high hydraulic loadings. This study uses laboratory flumes, simulated rainfall and overland flows to study the nutrient release dynamics from brash windrows, and to predict the efficiency of buffer areas in retaining nutrients under high hydraulic loadings. The results suggested that decay of brash windrows is a major source of P release soon after clear-felling but not a source for N. Retention of dissolved reactive P (DRP) by buffer area flumes decreased significantly with increasing hydraulic loading. During high hydraulic loading the grassed flumes retained 50% more DRP than the non-grassed flumes, however, the overall retention was less than 28%, suggesting that buffer areas in blanket peatland forests may not be efficient in P retention. Therefore other mitigation methods like stimulating the growth of native grasses on clear-felled area should be studied as a mean of increasing onsite retention and reducing nutrient export from blanket peatlands.

KEYWORDS: Blanket peat, Buffer area, Flumes, Simulated rainfall

INTRODUCTION

Several research studies have reported that harvesting on peatland forests leads to nutrient leaching to water courses (Nisbet et al., 1997; Nieminen, 2003; Cummins and Farrell, 2003; Rodgers et al., 2010). In operational forestry in blanket peat catchments in Ireland and the UK, the cutting residues are collected to form brash mats/windrows (width about 4 m) that run along the main slope at parallel rows at intervals of 12 meters (Rodgers et al., 2010). Decomposition of logging residue brash windrows is considered as one of the major sources of nutrients to recipient water bodies after clear-felling.

To prevent possible negative impact of forest activities on the recipient watercourse, it is recommended to direct the outflow over a buffer area. However, in Ireland and the UK, many of the earlier afforested upland blanket peat catchments were established without any riparian buffer areas, with trees planted to the stream edge (Ryder et al., 2010). Construction of buffer area before main forest harvesting has been proposed. However, construction of a well-functioning buffer area in many blanket peat catchments may be difficult because of high hydraulic loadings, typical in high precipitation conditions in west of Ireland (>2000 mm a^{-1}). A number of previous studies have shown that high hydraulic loadings significantly decrease buffer nutrient retention efficiency (Väänänen et al., 2008; Vikman et al., 2010). Furthermore, utilizing the buffer vegetation as a nutrient sink is complicated as the recovery of natural vegetation following buffer construction takes for several years (O'Driscoll et al., 2011). Thus, unless the buffer area is constructed long before harvesting the main plantation it may be inefficient in retaining the P export that mainly occurs in the first 3 years after harvesting (Cummins and Farrell, 2003; Nieminen, 2003; Rodgers et al., 2010). In order to stimulate the establishment of the vegetation, seeding proper grass species could be one option. O'Driscoll et al. (2011) showed that *Holcus lanatus* and *Agrostis capillaris* vegetation could be well established in blanket peat buffer area two months after harvesting.

The aim of this work was to study 1) if the brash windrows are a significant source of N and P to recipient water courses and 2) to estimate the efficiencies of seeded and non-seeded buffer areas in dissolved reactive P (DRP) retention, using laboratory flumes. Laboratory flumes have been widely used to study the soil processes and nutrient transports under simulated rain and overland flow (Mulqueen et al., 2006; Hussein et al., 2007; Regan et al., 2010). We hypothesize that brash windrows are a major source of P release but not a source of N. We also hypothesized that the grassed flumes have higher dissolved reactive phosphorus (DRP) retention than non-grassed flumes and that the high hydraulic loadings, typical in high precipitation conditions in west of Ireland, significantly decrease buffer DRP retention efficiency.

MATERIAL AND METHODS

To study nutrient leaching from brash windrows four flumes were prepared from to the soil samples collected from the forested Srahrevagh catchment, two were used as controls with no brash and two had brash windrows on the upslope end of the flume, covering 25% area. To prepare the flumes, slabs of peat soil (0.1 m-deep) were collected using a 1 m long, 0.225 m wide and 0.1 m deep rectangular flume sampler made of galvanized material. The flume sampler was pushed upside down into the peat and then cut off from the peat layer using a shovel. The peat inside the sampler was then transferred into a 2 m long, 0.225 m wide and 0.13 m deep flume so that two slabs of peat surface layer were placed up against each other to form a continuous peat surface (Mulqueen et al., 2006, Fig. 1). The brash windrows for both flumes were prepared using 2.63 kg dry mass (5.85 kg m^{-2}) of lodgepole pine (*Pinus Contorta*) logging residue. Of the total logging residue biomass 36% was needles, 34% was small diameter (<10mm) branches and 30% was bigger diameter (15-30 mm) branches.

To study the effect of seeded vegetation and hydraulic loading on P retention by buffer areas, two flumes were prepared from the soil slabs collected from a buffer area that was seeded with Holcus lanatus & Agrostis capillaris (50:50) with the total seeding rate of 36 kg ha^{-1}, and two flumes were prepared from the soil slabs collected from an un-seeded buffer area.

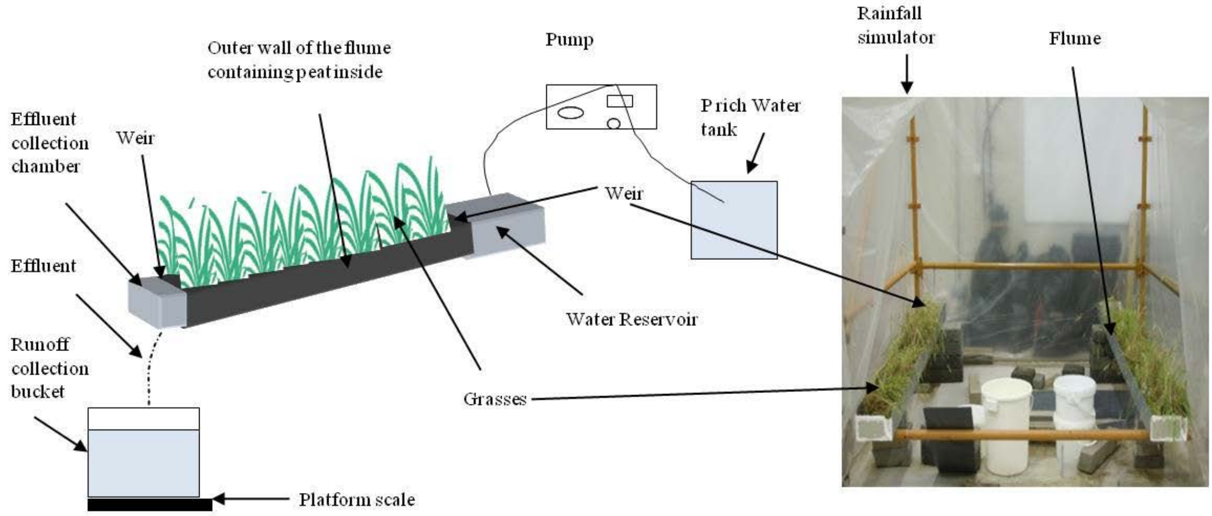

Fig. 1. Overview of flume, simulated rainfall and overland flow setup in the laboratory.

Flumes with brash windrows were adjusted to 5° slope during the experiment and irrigated with simulated rainfall using rainfall simulator (Regan et al., 2010) on weekly or biweekly basis over a period of one year. Every rainfall event was applied for 1 hour after the start of runoff and surface runoff samples were collected from a bucket at the tail end of the flume. At the end of rainfall flow event the bucket was removed to measure the runoff volume and to take a water sample for nutrient analysis (Fig. 1).

Grassed and non-grassed flumes simulating buffer areas were subjected to three different high hydraulic loading testings with constant DRP concentration (0.425 mg l^{-1}), giving hydraulic loadings of 123 mm hr^{-1}, 256 mm hr^{-1} and 444 mm hr^{-1}, and DRP inputs of 62, 121, and 198 mg m^{-2}. P rich water was prepared by dissolving KH_2PO_4 in the tap water and pumped to the upslope end of the flume and collected in the bucket at the water collection end. Slope of these flumes was adjusted to 1° angel, corresponding to an average slope of blanket peat catchment near the stream edge, i.e. the potential location of buffer area.

RESULTS

Nutrients release from brash windrows

The P release from the flumes with brash was over tree-fold higher compared with the non-brash control flumes. However, nitrogen release showed no significant differences between the flumes with brash or no brash (Table 1).

Table 1. Average of nutrients release to runoff from flumes with and without brash.

Nutrients released from flumes with no brash (mg m^{-2})			Nutrients released from flumes with brash windrow (mg m^{-2})		
PO4-P	NH4-N	NO3-N	PO4-P	NH4-N	NO3-N
147 ± 85	545 ± 96	145 ± 19	484 ± 33	619 ± 149	94 ± 10

P retention by grassed and non-grassed flumes under different hydraulic loading

In the grassed flumes, the DRP removal efficiencies gradually decreased from 40% to 30% and 18% when the hydraulic loadings increased from 123 mm hr^{-1} to 256 and 444 mm hr^{-1}, respectively. In the non-grassed flumes, the DRP removal was 7-23% lower compared with the grassed flumes (Table 2).

Table 2. Average DRP removal by grassed and non-grassed flumes, simulating buffer areas

Flow event	Hydraulic loading (mm hr^{-1})	Number of flows applied	Grassed flumes		Non-grassed flumes	
			DRP removal (%)	DRP retained (mg m^{-2})	DRP removal (%)	DRP retained (mg m^{-2})
Q1	123	2	40 ± 4	25 ± 0	17± 6	10 ± 2
Q2	256	2	30 ± 7	36± 2	15± 2	18 ± 1
Q3	444	1	18 ± 1	36± 2	11± 3	22 ± 11

DISCUSSION

Decomposition of logging residue, especially needles, can start to release P soon after clear-felling. Based on our results, the released P can be a significant source of P to water courses from blanket peats. Owing to the low P retention capacity of blanket peat, much of the P released from brash may not be adsorbed by soil. Results also suggested that brash windrows are not a likely source of N leaching, at least in the first year after harvesting.

Our results from grassed and non-grassed flumes simulating buffer areas supported the hypothesis that buffer areas along streams receiving frequent high hydraulic loadings may not be efficient for P retention in blanket peat catchments. Less than 28% and 14% of the added DRP was retained by grassed and non-grassed flumes, respectively, during high hydraulic loadings (Q1 – Q3, Table 2). The monitoring of runoff in a blanket peat catchment in west of Ireland indicated that more than 50 % of annual runoff could occur during flow conditions corresponding to flow testings Q1-Q3. Many other studies also show that nutrient retention decreases significantly when the hydraulic loading is high (Väänänen et al., 2008; Vikman et al., 2010). The low P retention is because of low water residence time that is disadvantageous for an efficient retention of P (Koskiaho et al., 2003). Rodgers et al. (2010) found that over 80% of the P released from forest harvesting on blanket peat catchment was during the storm events with high hydraulic loading.

Although grassed flumes removed about 50 % more DRP compared to non-grassed flumes, the overall P retention efficiency was low for both flumes due to high hydraulic loading. Due to the low P retention capacity of buffer areas, other mitigation methods to decrease the export of nutrients should also be studied. One means might be to create the brash mats/windrows no longer along the main slope, but against it and then seed with native grasses the strips between brash mats/windrows. Thereby the seeded strips would act as mini-buffer areas, where hydraulic loading would be low and the P released from brash mats/windrows could be effectively immobilized onsite.

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