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Editors Toomas Tamm and Liisa Pietola

Liisa Pietola: University of Helsinki, Department of Applied Chemistry and Microbiology P.O. Box 27, FIN-00014 Helsinki, FINLAND

Present address: Kemira GrowHow Oyj, Research Centre, P.O. Box 2,
FIN-02271 Espoo, FINLAND

Toomas Tamm: Estonian University of Life Scienses, Department of Water Management. Kreutzwald Str 5, EE51014 Tartu, ESTONIA.

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Nutrient retention of vegetated buffer strips on a cropped field and a pasture

Jaana Uusi-Kämppä

MTT Agrifood Research Finland, Plant Production Research,
FIN-31600 Jokioinen, Finland
E-mail: jaana.uusi-kamppa@mtt.fi

Abstract

The effects of 10-meter wide grass buffer strips (GBS) and vegetated buffer strips under natural vegetation (VBS) on losses of sediment, phosphorus (P) and nitrogen (N) from cropped soil plots has been studied for 15 years on Lintupaju field at Jokioinen. The results have been compared with those from 70-m-long and 18-m-wide plots without buffers (NBS). Surface and subsurface water to a depth of 30 cm were sampled, soil and plant samples taken from the buffers for nutrient analyses. Spring barley or oats were grown on the field in 1991–2002 and dairy cows grazed on the grassed field and grazed grass buffer strips (gGBS) in 2003–2005. Buffer strips decreased losses of sediment, total P and total N by 60, 40 and 40–60% in surface run-off from a cropped field. However, the loss of PO_4-P was 70% higher from the field with the non-harvested VBS than from the field without buffers (NBS). On the pasture, erosion and N losses were quite low, whereas PO_4-P losses from all treatments were rather high. The high loss of PO_4-P from the VBS and pasture was most likely due to PO_4-P leaching from the soil surface and decaying grass residue in spring.

1. Introduction

Buffer strips are uncultivated vegetated areas between cropped fields and water-courses. They improve water quality in different ways. Firstly, buffer areas are out of production because soil tillage is not allowed on them. Erosion is therefore mitigated by buffers on steep slopes near watersheds. Secondly, the addition of manure, fertilisers and pesticides is not allowed on buffers – these pollutants thus have to flow a longer way from the applied field area over the buffer strip to watersheds than from the edge of the field. Thirdly, the buffers can retain eroded soil particles, nutrients, pesticides, faecal microbes, and other pollutants from the surface run-off water via sedimentation, adsorption and plant uptake.

2. Materials and methods

A six-plot experimental field (3 treatments X 2 replicates) was established on clay soil at Jokioinen at SW Finland (60°48' N and 23°28' E) in autumn 1989 (Uusi-Kämppä & Yläranta 1992, Uusi-Kämppä 2005). Ten-metre-wide buffer strips were planted below the cropland source area (60 m long) in spring 1991. The field area was fairly even, whereas the buffers were on a steep slope varying between 12% and 18%. Grass buffer strips (GBS) sown with timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) were harvested annually. Vegetated buffers strips (VBS) growing typical Finnish hardwood trees, scrub plants, grasses and wild flowers were not harvested. Both the field area and the buffer area on the NBS were sown with spring cereals and fertilised in 1990–2002 whereas the buffer areas of GBS and VBS were not fertilised. The results of both GBS and VBS plots were compared with plots without buffer strips (NBS).

In spring 2002, grass with spring barley was sown on the field and the buffer area of NBS (Figure 1). From two to five head of cattle were grazed both on the grassed field and the buffer area of NBS (gGBS since 2003) for 24, 48 and 28 days in summer 2003, 2004 and 2005, respectively. The pasture and gGBS were fertilised with N-fertilisers (150 kg N ha^{-1}) and N-P-K fertiliser (6 kg P ha^{-1} and 80 kg N ha^{-1}) in year 2003 and in spring 2004 respectively. The pasture was annually fertilised by N fertilisers (130–185 kg N ha^{-1}) in 2003–2005. The results of both GBS and VBS plots were compared with gGBS plots.

Surface and subsurface water to a depth of 30 cm flowed into collector trenches designed by Puustinen (1994); there was one of these on each plot. The volume of water was measured with a tipping bucket and representative samples were taken for laboratory analysis. Precipitation was measured at the Jokioinen Observatory, Finnish Meteorological Institute, about 3 km from the field.

Water samples were stored in a cool, dark place. Concentrations of total P and total N were determined in unfiltered water samples according to Finnish standard methods (SFS 3026, SFS 3031). For the determination of orthophosphate phosphorus (PO_4-P), nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N) water samples were filtered through a membrane filter (Nuclepore®, Polycarbonate, pore size 0.2 µm) before analysis. PO_4-P was determined by means of a molybdate blue method, using ascorbic acid as the reducing agent (SFS 3025). The samples for NO_3-N and NH_4-N were analysed according to Finnish standard methods SFS 3030 and SFS 3032, respectively. Total solids (TS) were measured to estimate erosion losses.

3. Results and Discussion

The mean annual load of total solids (TS) in surface run-off was the highest (1.1 tn ha^{-1}) from the NBS plots during cereal years 1991–2002, when the field and the buffer area of NBS were ploughed in autumns (Table 1). The mean TS loss from the GBS and VBS plots was half of that from the NBS. During the grazing period (June 2003–August 2005), the mean TS loss (0.3 tn ha^{-1} yr^{-1}) with surface run-off was smaller from all treatments than during cereal growing.

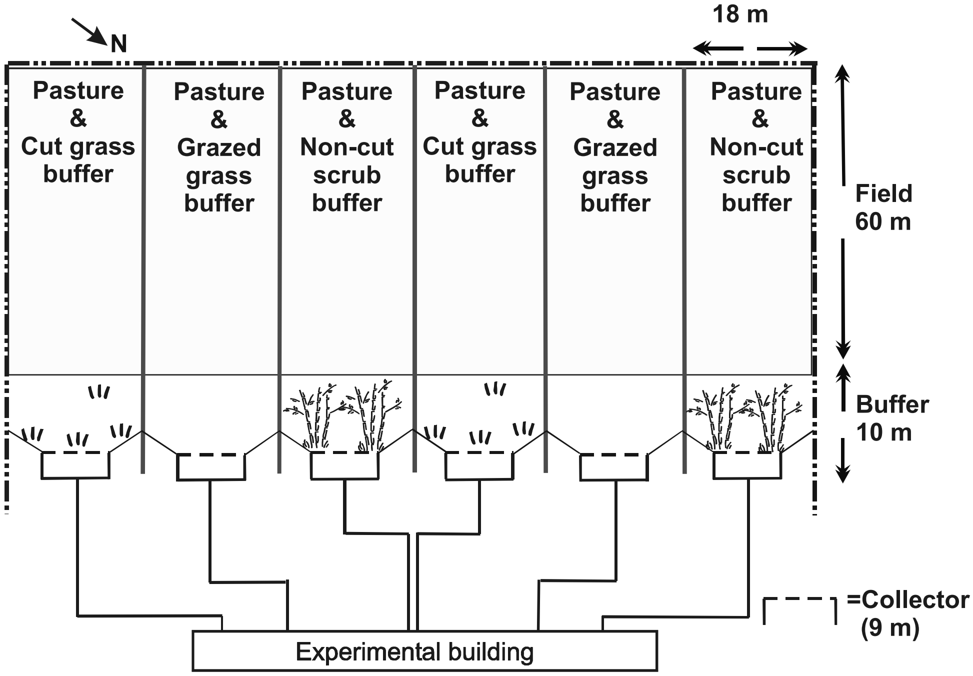

Figure 1. Schematic diagram of the experimental field in 2002–2005.

Also the mean annual total P, total N and NO_3-N losses in surface run-off were the highest during cereal years (Table 1). The loads of total P, total N and NO_3-N were decreased by 30, 40–50 and 50–70%, respectively, on the plots with buffer strips. The retention of total P was rather low on this field compared with other Nordic buffer zone experiments where the purification of total P varied from 27 to 97% (Uusi-Kämppä *et al*. 2000). On the pasture, the annual total P, total N and NO_3-N losses were smaller than on the cereal field. The annual PO_4-P load was, however, the highest (0.3–0.5 kg ha^{-1}) on pasture, whereas it was 0.2–0.3 kg ha^{-1} on cereal fields. The buffers were not effective to mitigate surface run-off PO_4-P losses. In fact, on cereal field plots, the cumulative PO_4-P loss was 70% higher from the VBS, of which plant cover was not harvested, than from other plots (Uusi-Kämppä 2005).

Also the mean flow weighted TS, total P, total N and NO_3-N concentrations in surface run-off were the highest on the cereal field plots, whereas PO_4-P concentrations were the highest on the pasture (Uusi-Kämppä & Palojärvi 2006).

Exceptional high PO_4-P concentrations ($\geq$ 1.0 mg l^{-1}) were measured from surface run-off water from all treatments in spring 2003. The previous summer had been warm and long – the trees and plants still had green leaves when the ground was covered by snow in October. The sudden onset of winter when grass was still growing may have been the main reason for high PO_4-P concentrations. Also in the laboratory test, PO_4-P losses in plant leachates from frozen and thawed plant material collected in from buffer strips were high (Uusi-Kämppä & Palojärvi 2006). This may be a reason, why the PO_4-P losses are extremely high in spring run-off. E.g. on the VBS plots, over 80% of the PO_4-P was flown during spring run-off (Uusi-Kämppä 2005).

The level of Olsen-P was also higher in uncut VBS (60.0 mg l^{-1}) than in annually cut GBS (33.3 mg l^{-1}) and in NBS (44.9 mg l^{-1}) in the surface soil (0–2 cm) in autumn 1998 (Uusi-Kämppä 2005). Some PO_4-P may thus be leached from the soil surface, which snow-melt water leaches in spring. Yli-Halla and Hartikainen (1996) reported that a low salt concentration in surface run-off water, as well as a high water/soil ratio, favours desorption of P from soil to surface run-off water. Low temperature may also affect P sorption/desorption (Yli-Halla & Hartikainen 1996) and thus promote P retention in buffer strips in spring.

Table 1. Mean annual rainfall, total solids and nutrients losses (mean ± range between mean and maximum values) in surface run-off from the field with no buffer strips (NBS), annually cut grass buffer strips (GBS), uncut vegetated buffer strips (VBS) and grazed grass buffer strips (gGBS).

Cereal field	NBS	GBS	VBS
June 1991–May 2003			
Rainfall 603 mm			
Surface run-off, mm	130 ± 20	110 ± 20	120 ± 20
Total solids, tn ha^{-1}	1.1 ± 0.4	0.5 ± 0.1	0.5 ± 0.1
Total P, kg ha^{-1}	1.1 ± 0.4	0.7 ± 0.1	0.7 ± 0.1
PO_4-P, kg ha^{-1}	0.2 ± 0.02	0.2 ± 0.04	0.3 ± 0.02
Particulate P, kg ha^{-1}	1 ± 0.4	0.5 ± 0.1	0.5 ± 0.1
Total N, kg ha^{-1}	6 ± 0.9	2 ± 0.5	3 ± 0.5
NO_3-N, kg ha^{-1}	4 ± 0.4	1 ± 0.3	2 ± 0.3
Pasture	**gGBS**	**GBS**	**VBS**
June 1991–May 2003			
Rainfall 560 mm			
Surface run-off, mm	120 ± 10	100 ± 10	100 ± 1
Total solids, tn ha^{-1}	0.3 ± 0.01	0.3 ± 0.03	0.3 ± 0
Total P, kg ha^{-1}	0.8± 0.1	0.7 ± 0.02	0.6 ± 0.02
PO_4-P, kg ha^{-1}	0.5 ± 0.04	0.4 ± 0.01	0.3 ± 0.06
Particulate P, kg ha^{-1}	0.3 ± 0.08	0.3 ± 0.03	0.4 ± 0.08
Total N, kg ha^{-1}	2 ± 0.2	1 ± 0.2	1 ± 0.03
NO_3-N, kg ha^{-1}	0.2 ± 0.04	0.2 ± 0.05	0.2 ± 0.06

4. Conclusions

The buffer strips are effective in mitigating both erosion and particulate P losses from the surface run-off on cereal fields. However, retention of PO_4-P losses is not as successful as retention of erosion material and particulate P. New methods will be needed to increase the retention capacity of PO_4-P on buffer strips. The losses of total nitrogen and NO_3-N in surface run-off are also smaller from the field plots with buffer strips than without buffers in cereal fields. On pastures where phosphorus fertilisers are not used, losses of eroded material, phosphorus and nitrogen in surface run-off from fields with buffer strips are as high as from pastures without buffers. This shows that in cereal production buffer strips are more important to mitigate erosion and particulate phosphorus losses than on pastures.

In cold climates, buffer strips work fairly well during the growing season in summer and autumn. However, the buffers do not effectively retain pollutants from surface run-off in winter and spring, when the soil is under frost and plants are not growing. During the past decade, surface run-off has increased during winter months and thus nutrient losses have also increased. More research will be needed to increase the retention capacity of buffers during cold seasons even if climate warming with mild winters continues.

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