Comparing grass filter strips and near-natural riparian forests for buffering intense hillslope sediment sources.

Peter Hairsine[1]

ABSTRACT: *In relating hillslope sediment and sorbed pollutant fluxes to in-stream water quality, it is often assumed that vegetation on the lower portions of hillslope can act as a buffer, or sink, by storing sediment and pollutant. Much of the literature on this topic concerns highly-idealised grass filters with a diffuse source. Riparian forests are commonly environments with heterogeneous vegetation and soil, and diffuse, but non-uniform, upslope sources. The study reported here compares the sediment filtering capabilities of grass filters strips with those of near-natural riparian forests. The study sites were in the catchment of the Tarago river in west Gippsland, Victoria.*

Fluxes of water, sediment and sorbed nutrients were measured at the inlet and outlet of the grass filter strips, riparian forests and a combination of both, with a range of sediment fluxes and runoff rates from an intense upslope source-area. Dense grass filter strips were found to have sediment trapping efficiencies of greater than 95% for a relatively high intensity sediment source. Near-natural riparian forest, was found to have trapping efficiencies greater than 90% for a range of sediment-laden inflows. The sediment trapping efficiencies of both buffer types were found to diminish slightly with increasing water inflow, though the results support the overall effectiveness of these buffers as measures to lessen the downstream impact of intensive land use.

1. INTRODUCTION

It is now widely recognised that grass filter strips and riparian forests have a significant role in reducing the movement of sediment and sediment-attached pollutants to streams. Grass filter strips and riparian forests are both a subset of buffer strips, a term used to describe any zone of vegetation between the hillslope and the stream. The role of buffer strips in the management of waterway pollution may be divided into the protection of stream banks and the reduction of pollutant fluxes from adjacent hillslopes. In a recent review of research concerning buffer strips, Barling and Moore (1992) found that there are two general approaches to the design of buffer strips: stream protection based on transport distances through the buffer strip, and stream protection based on the protection of runoff generating areas. In this paper the first of these approaches is examined for contrasting buffer types.

Grass buffer strips are purpose planted, or reserved, areas of pasture with the single purpose of reducing the movement of pollutant from an intense upslope land use. Riparian forests are multiple objective zones of remnant or planted near-natural vegetation adjacent to stream channels. It is the objective of this paper to compare the effectiveness of these two types of zones in reducing sediment movement for the same upslope source. This comparison is made in the environment where the input of water, sediment and nutrient is delivered as an intense localised input to the buffers. The effectiveness of the zones is examined for three different magnitudes of runoff from upslope.

The difference in behaviour of these two types of buffers is expected to be understandable in terms of the difference in the hydraulic roughness provided by the different plant material. Overland flow through grass filter strips is expected to be nearer uniform flow conditions than is overland flow through riparian forests where there will be more discharge through preferred flow paths (Mackenzie and Hairsine, this volume).

2. METHODS

Experiments were conducted in the catchment of the Tarago Reservoir in West Gippsland, Victoria. The hillslope was planar with a mean slope of 16 percent, and has been in pasture for many years. An intact riparian forest forms the lower boundary of this pasture.

The general lay out of the experiments is shown in figure 1. Overland flow was generated on the hillslope prepared as for the planting of potatoes using local practice. The slope was tilled and rotary hoed four weeks prior to the experiments. A ridge and furrow system was formed with the ridges orientated along the natural fall line. Furrows were at a spacing of 0.85 m. Inflow was provided to the

[1] CSIRO Division of Soils and the Co-operative Research Centre for Catchment Hydrology,
PO Box 639, CANBERRA, 2601, AUSTRALIA.
Telephone: 06 246 5924 Fax: 06 246 5965 Email: peterh@cbr.soils.csiro.au

upslope end of each of two furrows to generate a water and sediment flux at the top of each buffer strip. The water inflow rates provided to buffer strips are given in table 1. The three inflow rates are equivalent to 5, 10 and 20 mm hr^{-1} runoff rate for a 50 metre slope length above the buffer strip.

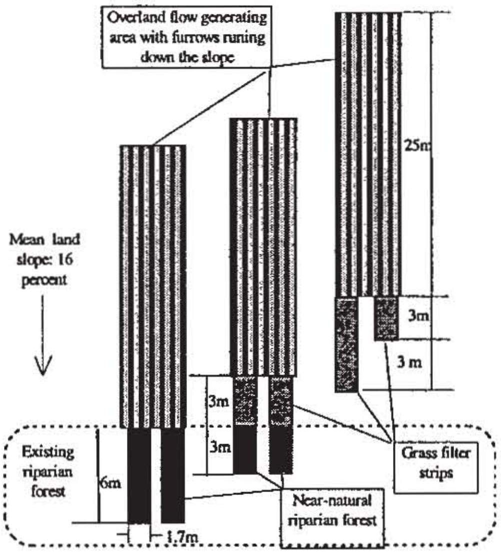

Figure 1. General layout for field experiments.

Inflow Level	Water Discharge per unit width ($m^3s^{-1}m^{-1}$)
Low	0.069 x 10^{-3}
Medium	0.138 x 10^{-3}
High	0.278 x 10^{-3}

Table 1. Nominal water discharges entering buffer strips for the three levels of inflow.

Six buffer strips, as described in table 2, were tested. The three and six metre wide grass filter strips were unreplicated. The combined grass buffer / riparian forest and 6 metre wide riparian forest had two replicates.

Soils are sandy loams overlying sandy clay subsoil and are derived from Upper Devonian Granites (Soil Conservation Authority, 1973). Sediment was transported predominantly in an aggregated form. Analysis for soil classification and aggregate size distribution are in progress.

Layout of buffer	Vegetation
3 m wide grass buffer strip (GFS)	dense near-uniform pasture dominated by Dactylis glomerata (cocksfoot) and Agrostis capillaris (brown top bent grass)
6m wide grass buffer strip (GFS)	dense near-uniform pasture (as above)
3 m wide grass buffer strip (GFS) + 3m wide riparian forest (RF)	medium density grass (as above), some patchiness and complete cover of litter including leaf mat, sparse woody debris and understorey shrubs dominantly Kunzea ericoides , Olearia stellulata (daisy bush) and Cassinia longifolia (common cassinia)
6 m wide riparian forest (RZ)	complete cover of litter including leaf mat, sparse woody debris and understorey shrubs (as described above)

Table 2. Description of buffer strips investigated.

Rainfall was provide on the buffer strip area using the CSIRO Division of Soils portable rainfall simulator. Rainfall having a mean drop size of 1.5 mm and terminal velocity was provided to the full area of the buffer. Rainfall intensity was fixed at 60 mm hr^{-1} for all runs. Having rainfall present was considered essential as the action of raindrop impact will influence sediment transport within the buffer strip.

Each buffer strip was subjected to the three inflows in order of increasing magnitude, each of duration 30 minutes with no delay between. Outflow discharge was measured continuously using a calibrated runoff collection tower. Runoff samples were collected at both the inlet and outlet of the buffer strips at three minute interval. These samples were analysed for total sediment concentration, sediment by aggregate size class, total nitrogen (TKN), total phosphorous (TKP), nitrate/nitrite (NO_x-N) and ammonia (NH_4-N), ortho-phosphate (PO_4-P) and for selected samples for TKN, TKP, NO_x-N, NH_4, PO_4-P for each of seven aggregate size classes. Only the total sediment concentration data are reported here. Analysis concerning nutrient transport, size sorting of sediment and the influence of the roughness configuration of the buffer material is in progress.

Additional measurements include the sediment fan dimensions with time, and measurements of the

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vegetation in terms of projected cover, contact cover and above ground biomass.

3. RESULTS

Figure 2 shows the sediment concentration leaving the range of buffer strips. All buffers acted to trap greater than 90 percent of the sediment entering the buffer strip. This is encouraging in view of the high sediment concentrations entering the buffers shown in table 3. The combination of 3 metre wide grass filter strip and 3 metre riparian forest was less effective in removing sediment than the 3 m wide grass filter strip. This reflects the reduced density and uniformity of the grass at the fringe of the riparian forest. As expected, the riparian forest was less effective in trapping total sediment, though the percentage passing is still very low.

Inflow level	Mean sediment concentration entering buffer ($kg\ m^{-3}$)
Low	10.2
Medium	14.1
High	23.7

Table 3. Mean sediment concentrations entering the buffer strips for the range of inflows.

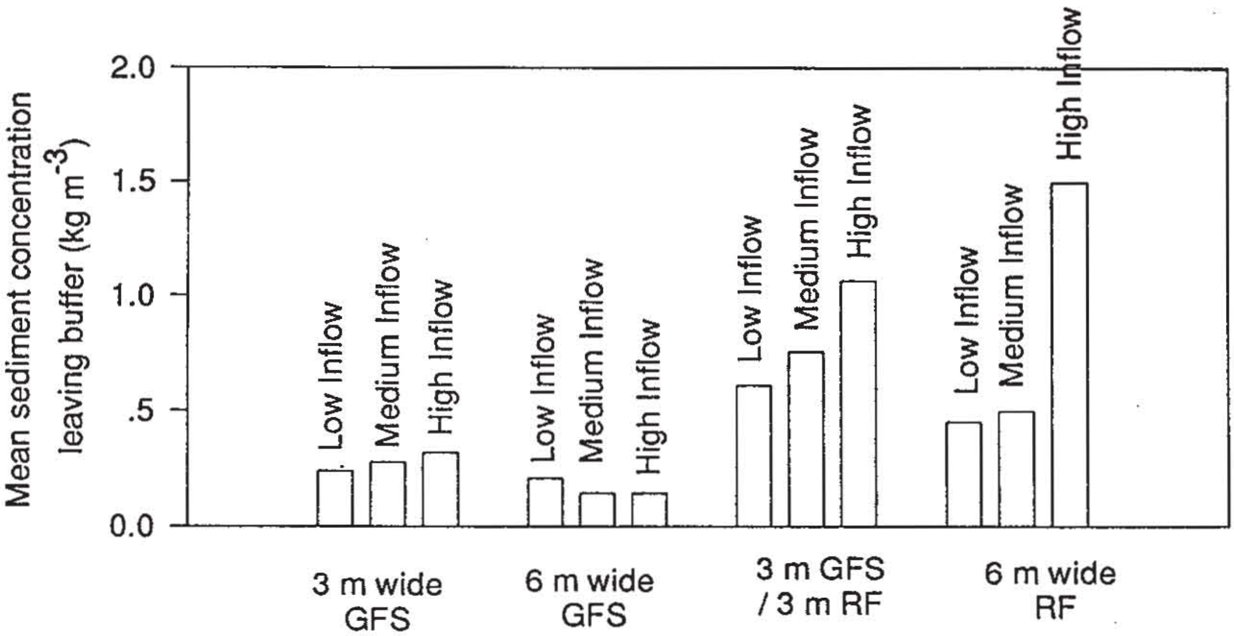

Figure 2. The mean sediment concentration leaving the range of buffer strips (grass filter strips, GFS and riparian forest, RF) for the three inflows.

As shown in figure 2 the mean sediment concentration of outflow from the 6 metre wide near-natural riparian forest is higher than that of the 6 metre wide grass filter strip. Also, the trend to higher sediment concentration with increasing inflow is most marked for the riparian forest. It should be noted that the sediment concentrations leaving the strips are still high relative to typical instream sediment concentrations.

While the total sediment trapping efficiencies reported here are high, it is expected that the size analysis of the sediment leaving the buffers will find it to be predominantly fine sediment. This sediment is likely to be enriched in sorbed nutrients relative to the sediment trapped in the buffer strip. Also this sediment is likely to be of increased importance in terms of stream turbidity.

4. DISCUSSION

Grass filter strips have been reported to have reduced sediment fluxes by 20 to 97 percent in field and rainfall simulator experiments (Wilson, 1967, Magette et al., 1989, Flanagan et al., 1989). This wide range of behaviour is likely to result from a range of factors including the intensity of the sediment source, the degree of channelisation, width of the strip, the land slope and the nature of the filtering material. It should be noted that the high trap efficiencies obtained in this study were obtained under conditions of relatively high sediment input, relatively high slope and relatively concentrated flow

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at the entry to the buffer strip. It appears the high density of the surface roughness, produced by vegetation and litter, resulted in these high trap efficiencies.

There has been comparatively little research done on the sediment trapping ability of near-natural riparian forest. The results presented here demonstrate the considerable potential of both grass filter strip and riparian forest to reduce the movement of sediment from an intense hillslope sediment source. This is particularly encouraging for natural riparian forests given the additional physical and ecological roles these systems have. The results also show that the effectiveness of both buffers can be maintained across a range of inflow rates. The high trapping efficiencies obtained for the high inflow rate are particularly encouraging as it is widely recognised that infrequent high intensity rainstorms are responsible for the majority of sediment entering streams from hillslope sources.

Interpretation of the above results must recognise the short term nature of these experiments. No conclusions can be drawn about the remobilisation of the deposited sediment in subsequent events. Also, conclusions regarding the relative trapping efficiencies for fine sediment and nutrient analysis.

5. CONCLUSIONS

Dense grass filter strips were found to have sediment trapping efficiencies of greater than 95% for a relatively high intensity sediment source. These results were relatively high compared with other studies. This was attributed to the high input load and the dense and near-uniform nature of the grass in the strip.

Near-natural riparian forest, predominantly litter with sparse understorey shrubs and woody debris, was found to have trapping efficiencies greater than 90% for a range of sediment-laden inflows. The sediment trapping efficiencies of both buffer types were found to diminish slightly with increasing water inflow, though the results support the overall effectiveness of these buffers as measures to lessen the downstream impact of intensive land use.

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