Suspended sediment yield following riparian revegetation in a small southeast Queensland stream

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Abstract:

Riparian revegetation is often used as method to reduce sediment delivery to receiving waters. We investigated the role of revegetation in controlling suspended sediment delivery to a small stream in South East Queensland by continuously monitoring suspended sediment as turbidity at a treatment stream and adjacent unforested control and forested reference streams for 3 years. We found that the unforested stream yielded 14.5-87.8 $t/km^2/a$ compared to the forested stream yielding 3-78 $t/km^2/a$ and the treatment stream yielding 12.3-212.2 $t/km^2/a$. The treatment stream initially had a similar suspended sediment yield to the control stream. The revegetation activities in the treatment stream resulted in an increase in suspended sediment yield (to approximately double that of the control stream). The revegetation process required the removal of existing invasive pasture grass ground cover and woody weeds. We suspect that this disturbance of the riparian zone and the period taken for the planted trees to become established has caused the increase in suspended sediment yield from the treatment stream. We expect the suspended sediment yield in the treatment stream to reduce to below the control stream once the riparian vegetation is fully established and any resulting channel change is complete. Although revegetation will ultimately reduce the suspended sediment yield in the previously cleared catchment, large-scale revegetation projects should be staged to avoid instream habitat destruction due to the initial increase in sediment yield.

Key Words:

Suspended sediment, turbidity, revegetation, restoration, rehabilitation

Introduction:

Stream rehabilitation project goals are focused on the endpoint of a fully restored stream, however we rarely give consideration to the intermediate period of high stream disturbance immediately following rehabilitation. Riparian zone revegetation is a common stream rehabilitation technique (Rutherfurd, Jerie, & Marsh, 2000), with a frequent goal of reducing sediment delivery to receiving waters (Dennison & Abal, 1999). Riparian vegetation controls sediment delivery by restricting the channel size (Abernethy & Rutherfurd, 1998; Huang & Nanson, 1997)and trapping sediment (Abu-Zreig, Rudra, Lalonde, Whiteley, & Kaushik, in press; Allan, Erickson, & Fay, 1997; Sutherland, Meyer, & Gardiner, 2002). To rehabilitate the riparian zones of modified streams requires an intermediate period for vegetation to become re-established. During the re-establishment of vegetation, the shading out and killing of invasive pasture grass may result in the liberation of large quantities of sediment to be delivered to receiving waters. A key consideration for this study was to determine if the sediment load of a small stream did increase following revegetation, and over what period was the sediment load elevated.

This study presents the results of 3 year project to monitor the changes in suspended sediment delivery following a riparian revegetation project.

Methods:

To gauge the impact of stream revegetation on suspended sediment (SS) yield we installed turbidity loggers at three similar sized ($1.5km^2$) tributaries of the South Maroochy River in South East Queensland from December 2000 until March 2004. The treatment stream (Echidna Creek) was revegetated in February to April 2001 by clearing scrubby weeds and planting tube-stock of endemic species at 2m centres. The second stream was a nearby control stream (Dulong Creek) where the riparian zone is vegetated with pasture grass (mostly Kikuyu grass (*Pennisetum clandestinum* Hochst. ex Chiov)). The third stream was a reference stream (Piccabeen Creek) with a fully forested catchment located in nearby Mapleton State Forest. All streams had similar elevation, topography and geology.

For each stream we used automatic turbidity loggers to record the turbidity at 15 minute intervals. This turbidity recording interval was further reduced to 1/2hourly intervals by averaging adjacent turbidity values. We also collected spot measurements of turbidity and suspended sediment to develop a turbidity-suspended sediment relationship so that the turbidity values could be presented as suspended sediment concentration. We gauged the stream discharge at each of the sites (1/2 hourly recording), and used this discharge data to convert the suspended sediment concentration to a suspended sediment load for each stream. The suspended sediment yield was calculated by dividing the load by the contributing catchment area. To determine the contributing area we assumed 100% trap efficiency for the farm dams in the catchments of the treatment and control streams. The contributing area is therefore only the catchment area downstream of the dams (82.5 ha for the treatment stream, 101ha for the control stream and 155 has for the reference stream). We investigate the difference in suspended sediment yield for the three sites over the study period as well as investigating how the revegetated stream responded to treatment by considering changes in suspended sediment yield for each of 28 identified storm events.

Results and discussion:

We collected simultaneously collected turbidity and suspended solids data on 70 occasions (3 replicates on each) and found a good correlation (R^2=0.79) using a linear model forced through zero. This correlation compares well with the range normally reported in the literature (R^2= 0.5-0.9). The turbidity suspended solids relationship was combined with ½ hourly discharge data to produce a ½ hourly time series of suspended solids load.

The closest long-term rainfall gauge to the treatment site is located in Nambour (approximately 5km from the site). The long term rainfall for the Nambour gauge is 1736mm/year (since 1952) The first two years of the study were quite dry 1180mm in 2001, and 1055mm in 2002 compared to a slightly above average rainfall for 2003 of 1974mm. As a consequence, the suspended sediment delivery was much higher in 2003 than the first two years of the study for all three streams. The suspended sediment load for the reference stream was consistently lower than the control stream (Figure 1, left). The treatment stream produced a similar suspended sediment load to the control stream for 2001 and 2002 but had more than double the suspended sediment load of the control stream in 2003.

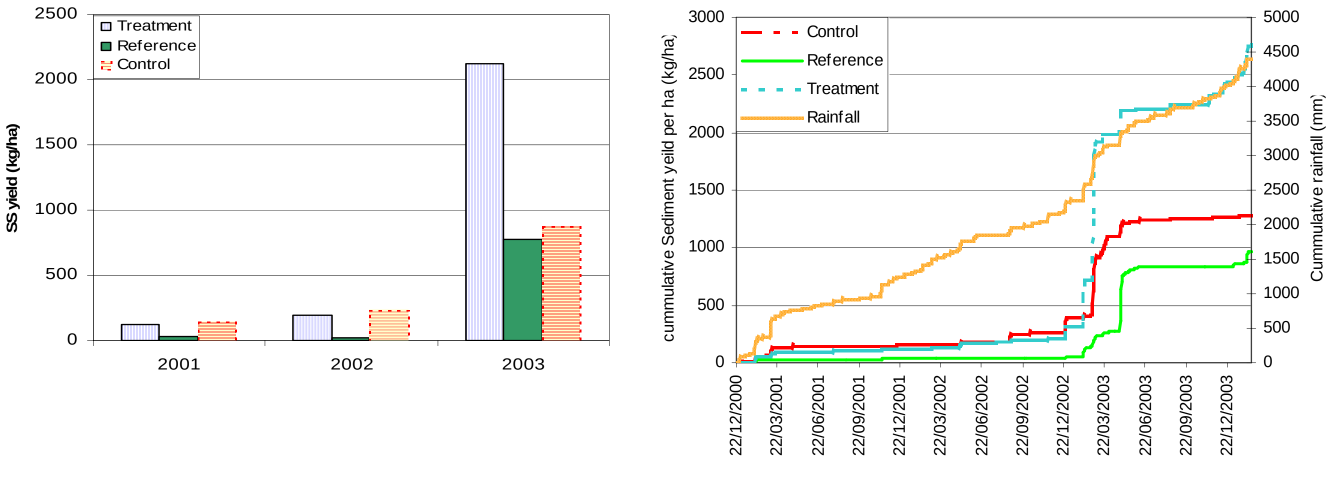

Figure1: Annual summaries of total suspended sediment yield (left), and cumulative suspended sediment yield per effective catchment area (right)

Over the period of monitoring, the treatment stream yielded about double the suspended sediment as the control stream and 3 times as much as the reference stream (figure 1 right). The treatment stream had a very similar suspended sediment yield to the control stream until March 2003, when it yielded much more sediment than the other streams for a series of late wet-season floods. This large sediment load from the treatment site occurred approximately 2 years after the treatment, before vegetation had become well established, but after weeds that had been poisoned prior to replanting had completely died off. In response to this wet period in March 2003 there was some visible channel change at the treatment site in the form of local channel widening in areas that were previously vegetated with pasture grass.

Suspended sediment yield occurred primarily during storm events, with 85% of the total suspended sediment yield from the three streams occurring during storm events. This storm driven response in suspended sediment yield is evident the stepped shape of the cumulative suspended sediment yield curves in Figure 1 (right). We defined 28 independent storm events based on periods when discharge exceeds a baseflow threshold defined in (Marsh & Rutherfurd, 2004). We found it very difficult to compare the suspended sediment yield on an event by event basis because of the high inter-event variability of suspended sediment yield for each stream. Suspended sediment is primarily a function of event discharge and the discharge for each event differed by around one order of magnitude cross the three streams. To compare between sites we standardised the suspended sediment yield for each storm at each stream by dividing by the total event discharge at each stream. These standardised suspended sediment yield results (suspended sediment yield/m^3) still showed considerable variation at each site relative to the other sites (Figure 2). We attempted to explain the inter-event variation in suspended sediment yield/m^3 for each site by constructing multiple linear regression models using storm variables (peak discharge, rainfall intensity, time since last event, and time of the year) but we were unable to construct significant models to help explain the inter-event variability. This inter-event variation has also been illustrated by Walling (1974) who successfully developed multivariate models of instantaneous suspended sediment concentration for single storm events but was less successful at building models based on data combined from several events.

Despite the inability to explain the inter-event variation at each site, the trends in suspended sediment yield/m^3 for each site can be considered by smoothing the data by considering a running mean of three consecutive events (Figure 2). The reference site had a consistent suspended sediment yield/m^3 of around 1x10-3 kg/ha/m^3 for the full study period. The control site initially had a higher running mean of around 4x10-6kg/ha/m^3 which dropped below that of the reference site in early 2003 to 1x10-4 kg/ha/m3, and has remained below or similar to the reference site. This reduction in suspended sediment yield at the control site has occurred during a period of larger, more intense storm events (early 2003) whereby a greater proportion of the event discharge has come directly from overland flow. The completely grassed catchment of the control site has yielded less suspended sediment for these events with overland flows than the other sites which have more bare soil. The suspended sediment yield/m^3 appears to depend on the event specific conditions which are likely to be threshold driven (e.g. overland flow), which may explain why multiple linear regression models could not be used to adequately describe the inter-event variability in suspended sediment yield.

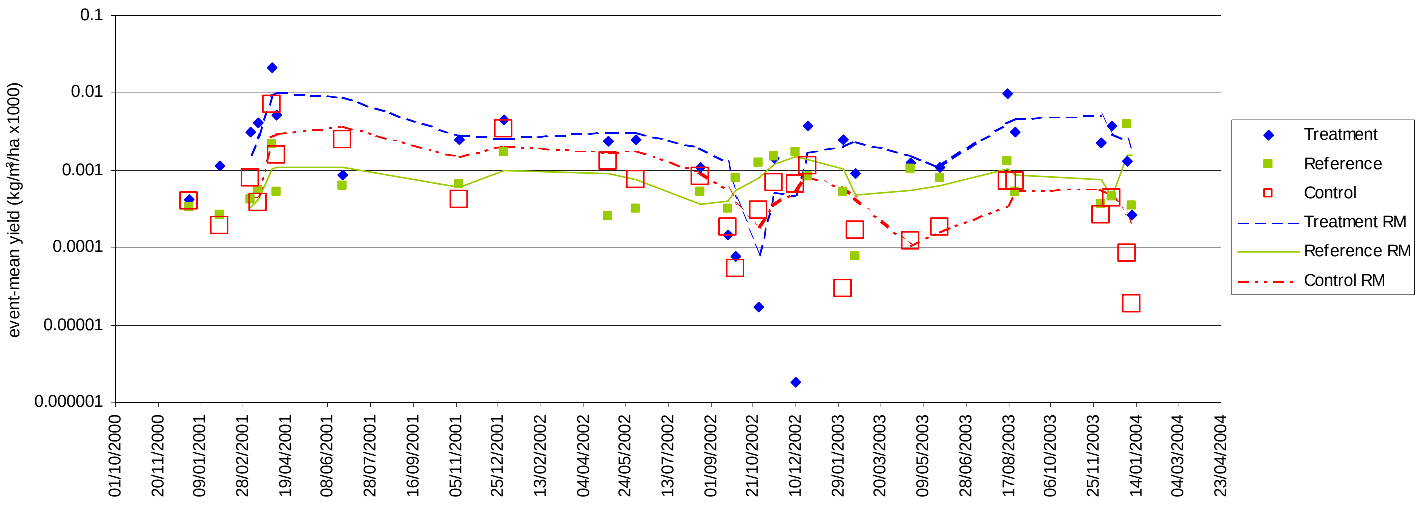

Figure 2: event-mean suspended sediment concentration per hectare of contributing catchment. RM in refers to 3 event running mean)

Conclusions:

The results of this study have provided four main advances;

1) We have shown that automatic turbidity loggers can be successfully used for long term continuos monitoring.
2) We have quantified the total suspended sediment yield from three small subtropical streams of different vegetative cover, yet with little variation in other landscape variables that are known to influence suspended sediment yield. The results of this study can be used to test existing models of catchment sediment yield such as SedNET (Wilkinson, Henderson, & Chen, 2004)
3) We have shown that the suspended sediment yield from a forested subtropical stream is around 30% less than from an adjacent fully cleared (but grassed) catchment, and
4) We have shown that following the channel distance activities associated with revegetation, the suspended sediment yield can increase by around 100%.

The rehabilitation work monitored in this study was mostly out of channel and required no heavy machinery in and around the channel. If soft restoration activities such as presented here can double the suspended sediment yield, then one would expect a much greater effect from more invasive stream rehabilitation work such as willow removal or instream habitat creation. The primary conclusion to be drawn from this study is that stream rehabilitation work is likely to at least temporarily cause an increase in suspended sediment yield, although ultimately we would expect a lower suspended sediment yield than pre-rehabilitation. Rehabilitation plans should accommodate the temporary increase in suspended sediment yield and any effect that this may have on instream biota. Where stream ecosystems are already under stress due to a highly degraded stream, stream managers must consider the likely impact of dramatic but short lived increases in suspended sediment yield from large scale works compared to lower magnitude but longer duration of impacts from staged local rehabilitation work.

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