Comparison Of Mean Annual Suspended Loads Estimated By The Sednet Model And Rating Curves In The Fitzroy Catchment, Australia

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EXTENDED ABSTRACT

Due to the lack of adequate observed suspended sediment concentration (SSC) data, researchers have used sediment-rating (sediment transport) curves to estimate SSCs to calculate sediment loads. However, measurements and the subsequent use of rating curves alone would not answer a number of spatial and temporal scale related questions with regard to management decisions to improve water quality. These questions are better addressed using a catchment-scale spatially based model.

The SedNet (**Sed**iment River **Net**work) model is a sediment generation and transport model to estimate long-term mean annual end-of-valley and in-stream sediment loads. Due to lack of appropriate data, very little work has been done to test the accuracy of model predictions in Queensland catchments.

The objective of this study is to compare mean annual total suspended sediment (TSS) load data estimated from rating curves with predictions of the SedNet model at six sites in the Fitzroy catchment in Queensland, Australia.

The relative differences between TSS loads from SedNet and those estimated using rating curves varied from sub-catchment to sub-catchment in the Fitzroy, with the least variation for the largest sub-catchments, and greatest variation for the third and fourth smallest sub-catchments. However, a plot of the relative differences in TSS against catchment area showed no significant relationship between them although this needs to be further tested with more data and modelling in the future.

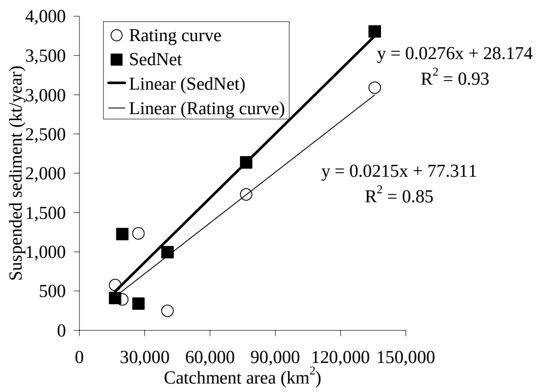

Figure 1. TSS estimated using SedNet versus TSS estimated using rating curves. The 1:1 line represents perfect agreement between the two estimates.

The SedNet model estimated more suspended sediment in the three largest and the fifth largest sub-catchments than the rating curve method (Figure 1). However, SedNet estimated less suspended sediment at the smallest and the fourth largest sub-catchments. Given the errors involved in estimating TSS from rating curves and the uncertainty associated with estimates from the SedNet model, the similarity of suspended sediment load estimated by the two methods in some of the sites should improve our confidence in both methods.

Uncertainties in both the rating curve and SedNet are expected to explain some of the discrepancy between TSS values estimated by the two methods. Therefore, future research must be directed towards quantifying and reducing the uncertainties in the TSS estimations.

1. INTRODUCTION

Contaminant transport, water-quality trends, reservoir sedimentation, channel and harbour silting, soil erosion and loss, as well as ecological and recreational impacts are some of the reasons for the need to quantify suspended sediment transport.

Whilst monitoring is a very important component of water quality protection plans and management support tools, it is not possible to answer all temporal and spatial questions using monitoring alone. Modelling can be a very useful tool that can complement monitoring to assist managers. It is recognised that it is impossible to evaluate the effectiveness of management actions without simulating them by modelling.

Suspended sediment rating curves have been widely used to estimate suspended sediment when and where measured data are not available (Asselman, 2000; Horowitz, 2003). More recently a catchment-scale sediment generation and transport model referred to as SedNet has been developed and used at the continental scale and across a number of catchments in Australia. However, the SedNet model has not been extensively tested in tropical catchments of Queensland. As part of a qualitative test of the model, this study compares sediment rating curve and the SedNet modelling methods of estimating suspended load in the Fitzroy catchment

It is recognised that the sediment rating curve method tends to underpredict high, and overpredict low suspended sediment concentrations (SSCs) (Horowitz, 2003). Moreover, the range of errors associated with the corresponding flux estimates for relatively short time-frames (e.g. daily, weekly) are likely to be substantially larger than those associated with longer time-frames (e.g. quarterly, annually). This is because, in short time-frames, the over-predictions and under-predictions do not have sufficient time to balance each other (Horowitz, 2003).

Table 1 gives annual total sediment export from the Fitzroy basin to the coast reported by a number of studies, including the SedNet estimate from the current study. It is clear from Table 1 that there is a considerable discrepancy between sediment export estimates reported by the various studies exasperating the effort to build confidence in modelling results.

The purpose of this study is to discuss the discrepancy between total suspended sediment values estimated by the rating curve and SedNet modeling methods by highlighting the possible reasons for the discrepancies so that improvements in both techniques can be targeted towards addressing these issues.

Table 1. Mean annual total sediment export from the Fitzroy catchment to the coast (kt/y) from different studies.

Study	Sediment export to the coast (kt/year)
Current study	4890
Brodie *et al.* (2003)	2915
Furnas (2003)	2230
Belperio (1983)	2200
Moss *et al*. (1992)	1861
Neil *et al*. (2002)	10466
Horn *et al*. (1998)	4330
NLWRA (2001)	2640
Bloesch and Rayment (2001)	11463

Whilst the role of the SedNet model is in getting relativities right so that processes and parts of the catchment that contribute the most to the problem of concern (e.g., quality of receiving waters) are targeted, confidence in the use of the model is expected to improve if it can be shown that the model gives reasonable estimates at the end of the catchment or a point of interest. However, in comparing the difference between TSS estimates from the two independent methods, it is important to bear in mind the error and uncertainty involved in each method.

2. THE FITZROY BASIN AND ITS SUB-CATCHMENTS

The Fitzroy basin is located in the Tropic of Capricorn on the east coast of Australia, between latitudes 21°S and 27°S and longitudes 147°E and 151°E. It is the second largest coastal river system in Australia. Dominant land uses in the area include grazing and cropping. As shown in Figure 1, the Fitzroy basin consists of four upstream sub-catchments (i.e., Nogoa, Isaac, Comet, and Dawson) and two downstream sub-catchments (i.e., Mackenzie and Fitzroy). With an area of over 140,000 km^2, the Fitzroy catchment is the largest catchment draining into the Great Barrier Reef Lagoon. It is listed as a priority catchment in the National Action Plan for Salinity and Water Quality (NAPSWQ), and as a high impact catchment in the Great Barrier Reef Marine Protection Plan. A more detailed description of the catchment is given in Joo *et al.* (2005).

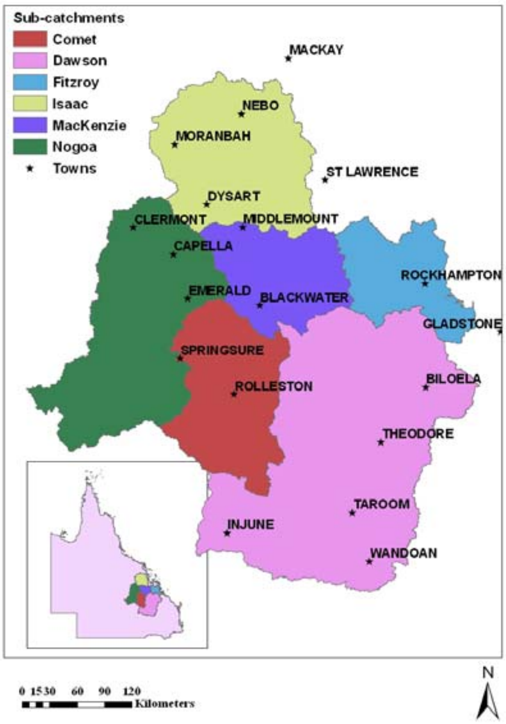

Figure 2. Sub-catchments of the Fitzroy.

3. THE SEDNET MODEL

The SedNet model is a sediment generation and transport model for predicting long-term annual average end-of-valley and in stream pollutant loads. The model has been initially developed to be used in the National Land and Water Resource Audit to estimate the generation of sediment and nutrients (nitrogen and phosphorus) at the continental scale (Prosser *et al.*, 2001). It has since been used in a number of catchment specific studies including the Burdekin catchment (Prosser *et al.*, 2002), Murray-Darling basin (De Rose *et al.*, 2003), Mary catchment (De Rose *et al.*, 2002), Herbert (Bartley *et al.*, 2003), and Douglas Shire catchments (Bartley *et al.*, 2004). However, except a similar study in the Mary catchment (De Rose *et al.*, 2002), very little work has been done to test the accuracy of SedNet model predictions in the tropical catchments of Queensland.

The SedNet model is based on a node-link configuration generated from a digital elevation model (DEM) of a catchment. The suspended load budget for a link is computed as a mass balance of inputs and outputs as shown in the conceptual model depicted in Figure 3.

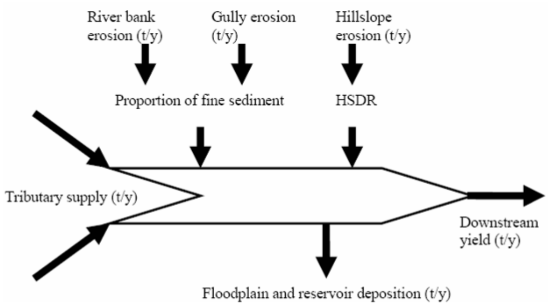

Figure 3. Components of the river link suspended load budget. After: Wilkinson *et al.* (2004).

As a qualitative test of the SedNet model, this study compares mean annual suspended load estimated using rating curves as described in Joo *et al.*, (2005) with model prediction at six sites across the Fitzroy catchment. The prediction of annual average suspended sediment from SedNet was made possible by what is called the contributor module, which estimates the contribution of sub-catchments to a point of interest within the stream network. The contributor module uses the probability of sediment load from a sub-catchment to reach at a point of interest (e.g., end of valley). The suspended load contribution of sub-catchment x (RSD_x) is then estimated as:

$$TSS_x = Supply_x \times RSD_x \qquad (1)$$

where:

$$RSD_x = \frac{Yield_x}{Supply_x} \times \frac{Yield_{x+1}}{Supply_{x+1}} \times ... \times \frac{Yield_n}{Supply_n} \qquad (2)$$

in which $Yield_x$ is the suspended sediment yield from the link, $Supply_x$ is the suspended sediment supply to the link from local hillslope (H_x), gully (G_x) and bank (B_x) erosion (i.e., $Supply_x = H_x + G_x + B_x$), and n is the number of links between link x and the catchment outlet or a point of interest.

Recent SedNet modelling in the Great Barrier Reef catchments using improved datasets such as land use and land cover and some locally determined parameters resulted in a TSS export to the coast of 4575 kt/y from the Fitzroy catchment (Dougall *et al.*, 2005). Note that 4890 kt/y in Table 1 is total sediment export (i.e, bed load plus TSS). This study used the results from this modelling exercise.

4. RESULTS AND DISCUSSION

Table 2 shows the sub-catchment area (km^2) and suspended load (tonnes/year) as estimated by the two methods. The comparison between the two suspended load estimates is also shown in Figure 4. The rating curve method resulted in less suspended load estimates in the Isaac, Mackenzie, Dawson, and Fitzroy and more suspended load estimates in Nogoa and Comet sub-catchments.

Table 2. Rating curve (with standard errors) from Joo et al., (2005) and SedNet estimates of annual suspended load at the six sites.

Sub-catchment	Area (km^2)	Suspended sediment (kt/y)	
		Rating curves	SedNet
Nogoa	27,130	1,234 ± 364	339
Comet	16,422	576 ± 148	411
Isaac	19,719	391 ± 111	1,225
MacKenzie	76,645	1,730 ± 481	2,138
Dawson	40,500	246 ± 59	1,300
Fitzroy	135,757	3,090 ± 865	3,806

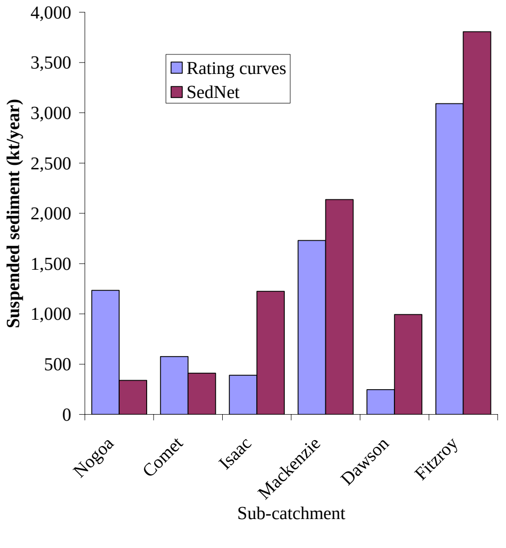

Figure 4. Comparison of average annual suspended sediment loads predicted from SedNet with loads estimated from gauging station sediment rating curves.

The low predictions of suspended sediment load from SedNet at the Nogoa sub-catchment might be due to the overestimation of suspended sediment deposition in the Fairbairn dam. However, this needs to be confirmed with further research. On the other hand, the high hillslope erosion generation (Figure 7) and total suspended sediment contribution (Figure 8) of the north-eastern parts of the Isaac sub-catchment as modelled by the SedNet model are expected to explain the higher suspended load estimation by the model than that estimated by the rating curve method.

In comparing TSS estimated from the rating curve method with SedNet estimated values in the Mary catchment, De Rose *et al.*, (2002) pointed out the importance of realising that SedNet predictions are 100-year mean annual averages as compared with sediment concentration data which have only been collected over the past 30 years.

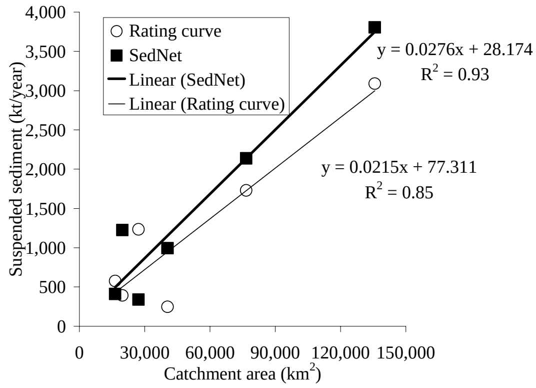

Figure 5. The relationship between TSS estimated by the two methods and catchment area.

The relationship between suspended sediment and catchment area shown in Figure 5 indicates that the relationship is stronger for the SedNet estimated suspended sediment load than that estimated from the rating curve method. It also indicates that, in four of the six sub-catchments, SedNet estimated greater suspended load than the rating curve method. Although this supports the fact that rating curves obtained by least squares regression on logarithmic transformed data underestimate long-term sediment (Horowitz, 2003; Asselman, 2000), corrections have been made to compensate for this error (Joo *et al.*, 2005).

As shown in Figure 6, the relative differences in the suspended sediment from the two methods for the Comet, Fitzroy, and Mackenzie sub-catchments are similar. This similarity indicates that the relative difference between suspended sediment estimates by the two methods is similar to the uncertainty in estimating suspended load by the rating curve method.

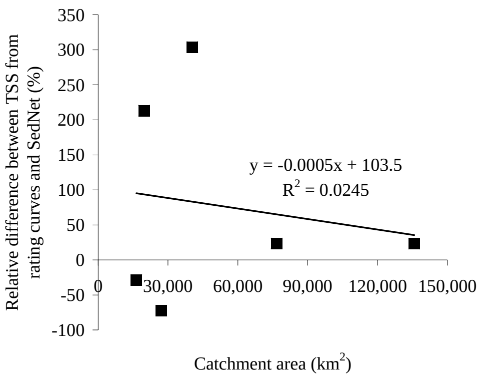

Figure 6. Relative difference between TSS from rating curves and SedNet estimates plotted as a function of catchment area.

Figure 7 shows the suspended sediment yield supplied to the river system from the three erosion processes. Figure 8 (a) shows the total suspended load contribution of the whole Fitzroy catchment to the mouth of the catchment, while Figure 8 (b) shows the contribution of upstream parts of each sub-catchment to the respective gauging station determined by the contributor module. The spatial patterns of erosion depicted in Figure 7 indicate that catchment size is not the sole influence on sediment loads. This may, explain the low R^2 value from the relationship between TSS export and catchment area depicted in Figure 5.

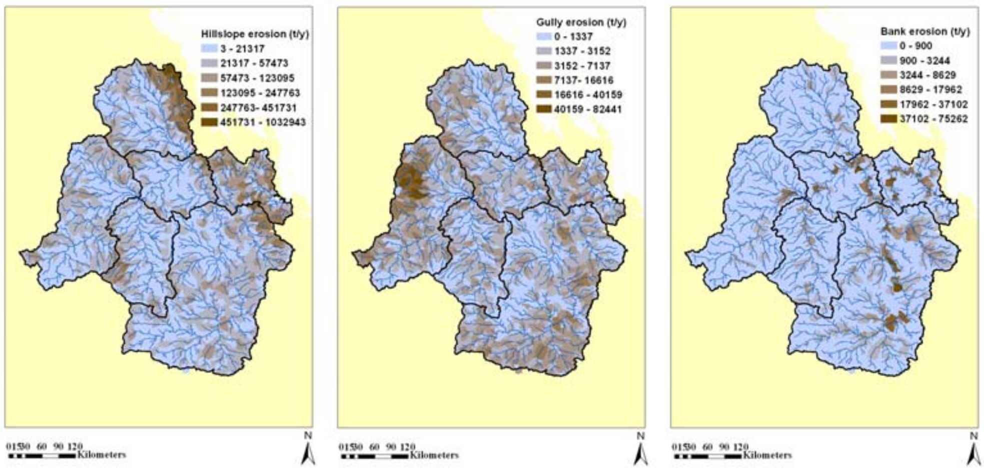

Figure 7. The sediment (t/y) supplied to the stream network by each of the three erosion processes (hillslope erosion, gully erosion, and bank erosion) for the whole of the Fitzroy catchment.

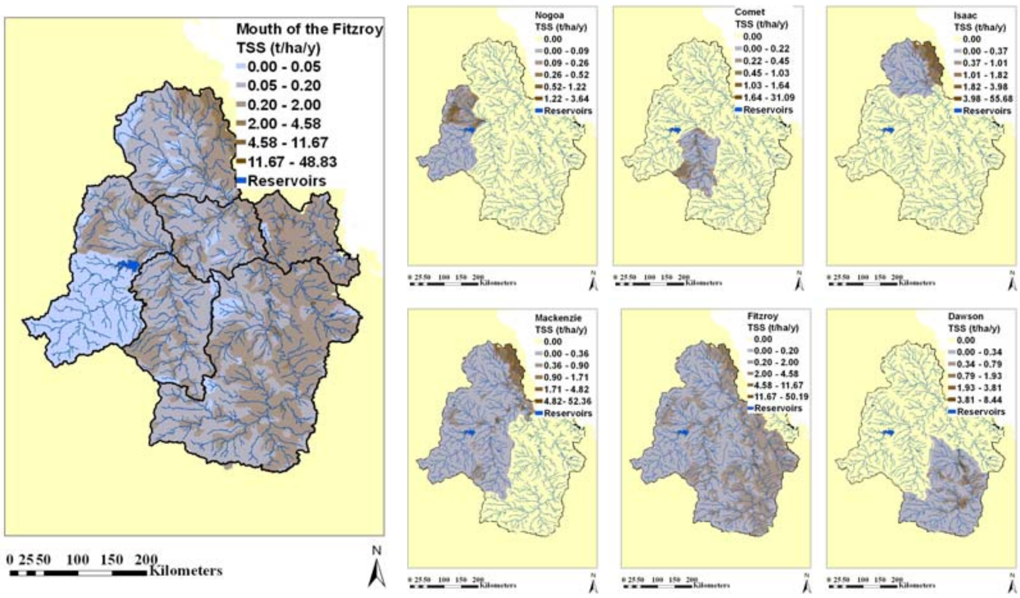

Figure 8. The contribution of SedNet generated sub-catchments to TSS (t/ha) at the mouth of the Fitzroy catchment and at the six gauging stations.

As shown by Fentie *et al.* (2005), one of the parameters SedNet is highly sensitive to is hillslope sediment delivery ratio (HSDR). Equation (3) was used to determine a hillslope delivery ratio that would result in TSS values estimated by the rating curve method at each site.

Let RCL_i be Load from rating curve at gauging station i; GE_i and BE_i, HE_i be gully, bank, and hillslope erosion contributions, respectively, of suspended sediment to gauging station i; HSDR be the hillslope delivery ratio used in the SedNet run; and $HSDR_i$ be the hillslope delivery ratio that produces rating curve estimates at gauging station i. Then it follows that:

$$HSDR_i = \left(RCL_i - GE_i - BE_i\right)\left(\frac{HSDR}{HE_i}\right). \quad (3)$$

A hillslope sediment delivery ratio of 0.1 has been assumed to be an appropriate value to use in the SedNet model for the catchment (Prosser *et al*., 2001). The results of HDRi value determined from Equation (3) for each site is shown in Table 4. The unrealistically high $HSDR_i$ value of 0.81 for the Nogoa and the low values of -0.06 and 0.02 for the Dawson and Isaac sub-catchments, respectively, reflect the relatively higher discrepancy between TSS estimates from the two modeling methods in these sub-catchments.

Table 4. Hillslope sediment delivery ratios that produce the same TSS as rating curve estimates.

Sub-catchment	RCL_i	BE_i	GE_i	HE_i	$HSDR_i$
Nogoa	1,234	37	219	120	0.81
Comet	576	62	101	309	0.13
Isaac	391	56	100	1,125	0.02
Mackenzie	1,730	290	468	1,670	0.06
Dawson	246	306	347	647	-0.06
Fitzroy	3,090	824	937	2,869	0.05

5. CONCLUSIONS

This study compared total suspended sediment outputs of the SedNet model with those estimated using the sediment rating curve method at six gauging stations in the Fitzroy basin. SedNet can assist the targeting of catchment management actions, by identifying dominant erosion processes and areas within the catchment. In order to increase our confidence in the use of SedNet we need to compare its outputs with estimates from other independent methods. However, to date, there has been very little comparison of SedNet outputs with those of other methods in catchments in Queensland.

The SedNet model estimated more suspended sediment load at four of the six sites while the rating cure method estimated more suspended sediment load at the other two sites. The standard errors associated with suspended loads estimated by the rating curve method were compared with differences between suspended load estimates from the two methods. This indicates that the difference can be accounted for by the standard error of suspended load estimates of the rating curve method. Uncertainties in SedNet estimated suspended loads arising from uncertainties in spatial input data and parameter values are also expected to contribute to the discrepancy between the two estimates. Further research is needed to determine reasons in both methods that resulted in discrepancies between estimated TSS values in each sub-catchment.

6. ACKNOWLEDGMENTS

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