Sednet Modelling in the Fitzroy Basin (2007); Spatially Variable Ground Cover and Revised Gully Layers Can Potentially Generate Significant Changes in Erosion Sources and Patterns

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EXTENDED ABSTRACT

Across Great Barrier Reef (GBR) catchments, there is general concern surrounding the impact of catchment runoff on freshwater, estuarine, and marine ecosystems. In response, water quality models such as SedNet are being used by government agencies and regional bodies to help investigate and support water quality target setting. SedNet is a water quality model which was first applied in GBR catchments at a continental scale. Since then a range of SedNet models have been applied in GBR catchments; with each subsequently building on previous work.

Recent SedNet modelling in the Fitzroy basin highlighted several input spatial data layers used in SedNet that could potentially be improved. These included the National Land and Water Audit (NLWA) gully density and the hillslope erosion layer.

The NLWA gully density map was built with little Fitzroy specific data at a continental scale. The local consensus was that the layer did not accurately represent the spatial pattern of gullies in the basin.

The other input layer highlighted for improvement was the hillslope erosion layer. The hillslope erosion layer used a constant grazing management cover factor over the entire basin. In reality, the region has a diverse range of land types and variable rainfall, and the influence of these factors generates extensive spatial variation in ground cover.

With the advent of new locally specific data products becoming available it has been possible to develop new SedNet input data sets to attempt to address these previous limitations.

This paper outlines preliminary results for a Fitzroy Basin SedNet model, generated from new data layers and parameters. The paper compares the results generated by the layers against the previous SedNet model.

Inspection of the spatial arrangement of the surface erosion grid; identifies a (10%) reduction in area for erosion values >5 (t/ha/y). Although high values have declined, the relative pattern of surface erosion remains unchanged.

The average annual hillslope erosion rates for 2006, and the current modelling are 3.68 (t/ha/y), and 1.37 (t/ha/y) respectively. An initial comparison suggests the new *Cover* layer is contributing the greatest proportion of the change in the annual average erosion rate.

In comparison to the NLWA gully density map, significant additions of areas > 3km/km^2 are apparent. The area of heavy gully density has increased in the Nogoa, Dawson, Isaac and Mackenzie catchments.

The use of this model again identifies the fact that without appropriate data, it is difficult to assess the performance of new data layers and parameters.

The delineation of the relative impact of different erosion sources across the Fitzroy is crucial in targeting hotspot areas. To reduce uncertainty future work is required in the basin to assess the relative contribution of the sources.

1. INTRODUCTION

Across Great Barrier Reef (GBR) catchments, there is general concern surrounding the impact of catchment runoff on freshwater, estuarine, and marine ecosystems (Anon 2003). In response, water quality models such as SedNet are being used by government agencies and regional bodies to help investigate and support water quality target setting. SedNet is a water quality model which was first applied in GBR catchments at a continental scale (Prosser *et al.* 2001). Since then a range of SedNet models have been applied in GBR catchments; with each subsequently building on previous work (McKergow *et al.* 2005; Cogle *et al.* 2006).

This paper outlines preliminary results for a Fitzroy Basin SedNet model, generated from new data layers and parameters. The paper compares the results generated for the layers against the previous SedNet outputs generated by Dougall *et al.* (2006).

2. STUDY AREA

The Fitzroy Basin is the largest of the Great Barrier Reef (GBR) catchments (142 000 km²). Six major rivers drain the basin: the Isaac-Connors, Dawson, Nogoa, Comet, Mackenzie and Fitzroy Rivers. Major agricultural landuses are grazing (82%) and dryland cropping (7%) (Calvert *et al.* 2000).

Mean rainfall for the basin is approximately 630 mm and mean annual discharge is around 4800 Gigalitres (1920-2005). The Isaac catchment contributes about 50% of the total flow (1974-2003), with the other catchments contributing around 10% each. Rainfall, stream discharge and ground cover are highly variable across the basin.

3. MODEL DESCRIPTION

SedNet is an average annual sediment and nutrient model (Wilkinson *et al.* 2004). The model uses a DEM and floodplain mapping to configure catchments, streams and floodplains in a node link arrangement. Sediment and nutrients are generated spatially using maps for hillslope, gully and bank erosion. These are then lumped at a subcatchment scale and delivered to the stream via a delivery ratio. Transport down the stream network is calculated via inputs from upstream catchments and losses for floodplain and reservoir deposition (Figure 1).

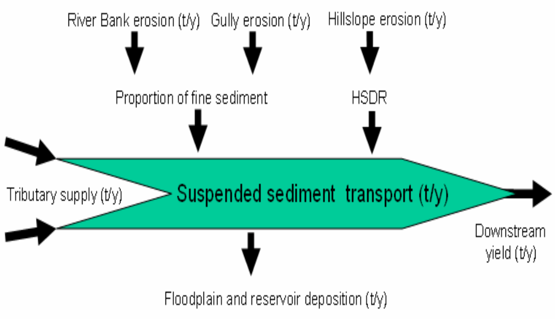

Figure 1. SedNet model, schematic (Prosser *et al.* 2001).

4. PREVIOUS DATA LIMITATIONS

Recent SedNet modelling in the Fitzroy basin, has highlighted several input spatial data layers used in SedNet that could potentially be improved (Dougall *et al.* 2006). These included the National Land and Water Audit (NLWA) gully density (Hughes *et al.* 2001) and the hillslope erosion layer.

The NLWA gully density map was built with little Fitzroy specific data at a continental scale. The local consensus was that the layer did not accurately represent the spatial pattern of gullies in the basin.

The other input layer highlighted for improvement was the hillslope erosion layer. The hillslope erosion layer used a constant grazing management cover factor over the entire basin. In reality, the region has a diverse range of land types and variable rainfall, and the influence of these factors generates extensive spatial variation in ground cover.

With the advent of new locally specific data products becoming available it has been possible to develop new SedNet input data sets to attempt to address these previous limitations.

5. METHOD

The following methods outline the construction of the new data layers and parameter changes. Version 2.0 of SedNet was used. Unless otherwise stated all other parameters and datasets are the same as Dougall *et al.* (2006).

5.1. Configuration DEM

The primary function of the configuration DEM is the building of the node link framework. The input DEM was constructed from the latest 25m DEM (Smith & Brough, 2006)). To define the spatial location of the streams, the drainage digitised from 100K topographic mapping, was burned into the DEM to a depth of 0.5 m. The DEM was then clipped to the extent of the previous Fitzroy SedNet model (Dougall *et al.* 2006) to facilitate comparisons. The DEM was then resampled to 100m, and pitfilled.

5.2. Bank Erosion

Riparian coverage was populated with the 2004 Landsat Foliage Projected Cover (FPC) layer Goulevitch et al. (2002). FPC values > 20%, were assumed to provide stream bank protection, indicating presence or absence of vegetation.

Due to observations of bank stability in 3rd and 4th order streams bank erosion, parameters were returned to that of McKergow *et al.* (2005).

5.3. Hillslope Erosion

Hillslope erosion was calculated using the Revised Universal Soil equation (RUSLE) (Renard *et al.* 1997).

$A = R*K*S*L*C*P$

Where

A = Annual soil erosion per unit area (t ha^{-1})
R = Annual Rainfall erosivity EI30 (t m ha^{-1})
K = Soil erodibility (t ha^{-1} $EI30^{-1}$)
S = Slope Steepness
L = Slope Length
C = Cover management factor
P = Conservation measures

Methods used to generate the individual factors are outlined below.

R factor: The *R factor* was calculated for the period 1973-2003, to facilitate potential comparisons with rating curves, calculated by (Joo *et al.* 2005). Similar to previous modelling the Rfactor was generated from the SILO grid (Jeffrey *et al.* 2001), using methods described in Yu *et al.* (1996).

***K factor**:* The *K factor* was calculated using the Queensland Department of Natural Resources & Water (QNR&W) best soil coverage (Brough *et al.* 2006) and methods outlined in Littleboy (1997).

***LS factor**:* The *LS factor* was calculated using a 25 DEM and methods outlined in Lu *et al.* (2003). L was set to 1 for all landuses except cropping and irrigation.

C factor: Spatial variations in mean cover were estimated from the QNR&W Ground Cover Index (GCI) (Scarth *et al.* 2006) which is derived from Landsat TM Satellite imagery. GCI was calculated each year (1988-2005) using a Fitzroy basin mosaic of July to October (Dry season) Landsat scenes. The GCI is currently only considered to be accurate in areas where the FPC is less than 20%. To deal with this, the GCI was classified into “No tree” areas (FPC < 20%) and “Tree” (FPC > 20%) and separate methods for calculating cover from the GCI were used.

In wet periods the FPC cover, was observed to over calculate “Tree” cover. To minimise this effect, and improve the delineation of “Tree” areas, the 2004 (a particularly dry year) FPC coverage was used to represent the “tree” coverage, for all years.

In the “No tree” areas, the GCI mosaics were averaged for the period (1988-2005) to create a mean cover grid. The crude assumption here is that dry season cover from (1988-2005) represents the average cover for the basin under current conditions. The main reasons for this is the fact that the majority of Landsat scenes in the NRM archive are from the dry season due to a lack of cloud during this period, and this represents ground cover levels approaching the start of the regions summer rainfall period.

A comparison was conducted between the GCI and several experimental sites where ground cover levels had been determined. GCI was found to over estimate the on ground measurements by approximately 30%. However as cover is often underestimated visually, in trial sites, the mean cover grid was reduced by a conservative 15%.

To represent cover in “Tree” areas and capture the spatial variability of cover across the catchment, a regionalisation approach was applied. A zonal map of landuse, landtype and rainfall (1988- 2005) was created producing 960 regional combinations. From this grid, average cover levels for “No tree” areas were applied to the corresponding “Tree” regions.

The generated ground cover grid was then converted to a *C factor* grid using methods outlined in Rosewell (1993).

5.4. Gully Erosion

On Ground Mapping

The distribution of existing gullies was captured by digitising locations off 19 pan-sharpened

Quickbird scenes (0.6 m ground cell resolution, 8*8 km window). The scenes were specifically selected to encompass a range of environmental attributes across the basin.

Ten percent of each Quickbird satellite imagery scene was randomly sampled, with sample sites of 1 hectare resolution (100m x 100m). The presence or absence of gullies for each sample site was then ascertained according to the criteria defined by Hughes *et al.* (2001); that is, a catchment area <10km^2, being incised, steep walled, and poorly vegetated. Gullies clearly identifiable at a scale of 1:4000 were then on-screen digitised. Sample sites where it was not possible to ascertain the presence or absence of gullies from the imagery were recorded as non-response and excluded from further analyses.

The connectivity of the gullied sites to the stream network (defined as catchment area >10km^2) was also recorded (connected or not-connected), to assess the transport efficiencies of sediment to the stream network.

Extrapolation to non mapped areas

The statistical package Cubist (Rulequest, 2001) was used to extrapolate the mapped gully densities across the entire Fitzroy basin.

The software package compared known environmental attributes against the mapped density data, generating rule based models for the presence or absence of gullies. Ten major environmental attributes were selected for use in the modelling, based on their perceived influence on gully formation (Table 1).

To statistically assess the performance, 70% of the data to was used to construct the density model, with the residual 30% used as test data.

Table 1. Environmental attributes used in Cubist.

Data Name	Scale	Source
Land Types	1:100,000	EPA
Rainfall	5*5km grid	BOM
Bare Ground Index	25m pixel	NR&W
Slope	25m DEM	NR&W
Flow Accumulation	25m DEM	NR&W
Soil A Horizon Clay %	1:500,000	NR&W
Soil B Horizon Clay %	1:500,000	NR&W
Soil A Horizon depth	1:500,000	NR&W
Hillslope Length	25m DEM	NR&W
Curvature	25m DEM	NR&W

5.5. Hydrology

Comprehensive sediment rating curves have been constructed for the Fitzroy basin for the period from 1973 to 2003 (Joo *et al.* 2005). To facilitate comparisons, the mean annual rainfall grid was created for the same period (1973-2003). Corresponding stream gauge data was clipped to this period.

6. RESULTS AND DISCUSSION

6.1. Sediment budget comparisons

Using the new input data sets, estimates of gully erosion inputs have increased significantly (+2793 kt/y) with hillslope (-3301 kt/y) and bank decreasing (-1772 kt/y) (Table 2.). There is little difference in end of valley exports (+145 kt/y) and these are still significantly larger (+1630 kt/y) than rating curve estimates of (3090 kt/y) by Joo *et al.* (2005).

Table 2. Sediment summary budget, comparison between Dougall *et al.* (2006) and current SedNet outputs.

Inputs (kt/y)	Dougall *et al.* 2006	This study 2007	*Diff*
Gully	3006	5799	+2793
Bank	2137	364.9	-1722
Hillslope	5266	1964	-3301
Suspended Outputs			
Export	***4575***	***4720***	***145***

6.2. Hillslope erosion layer

Inspection of the spatial arrangement of the surface erosion grid; identifies a (10%) reduction in area for erosion values >5 (t/ha/y) (Figure 2, a, b). Although high values have declined, the relative pattern of surface erosion remains unchanged.

The average annual hillslope erosion rates for 2006, and the current modelling are 3.68 (t/ha/y), and 1.37 (t/ha/y) respectively. An initial comparison suggests the new *C factor* layer is contributing the greatest proportion of the change in the annual average erosion rate (Table 3), with the new S, R, or K Factors contributing proportionally smaller increases in average annual erosion rates.

Table 3. New RUSLE factors and their impact on the 2006 RUSLE erosion rate (3.68 t/ha/yr).

Factor	Mean(t/ha/yr)	*Diff*
New C factor	1.70	-1.98
New S factor	4.12	+0.44
New R factor	4.18	+0.5
New K factor	4.13	+0.45

Cover Spatial and Temporal differences

The mean ground cover values for the 2006 and current SedNet study were (55%) and (64%) respectively. Although this is only a minor change, there is significant spatial variation across the basin with higher cover levels closer to the coast (Figure 2, c). In comparison to the global landuse cover levels used in the 2006, the GCI levels are up to 30% higher for the high erosion areas in the northern coastal ranges. This contributed a significant proportion of sediment load for the 2006 study, thus minor cover changes has greatly reduced the hillslope sediment budget.

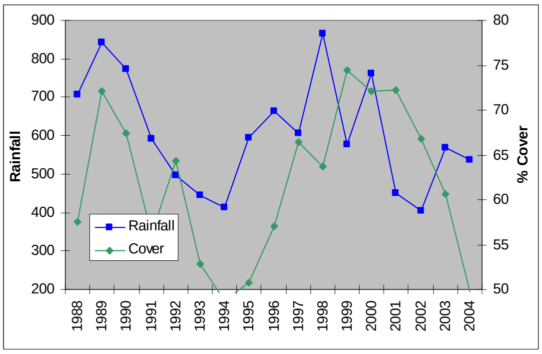

Figure 3. Fitzroy Basin, GCI (June October) cover levels and yearly rainfall (1988 -2004).

Analysis of the rainfall and GCI 1998-2005, identifies variability; both spatially and temporally (Figure 3). Given this variation it may be impractical to construct an average annual model due to the difficulties, in parameterisation. As cover measurements need to be correlated with

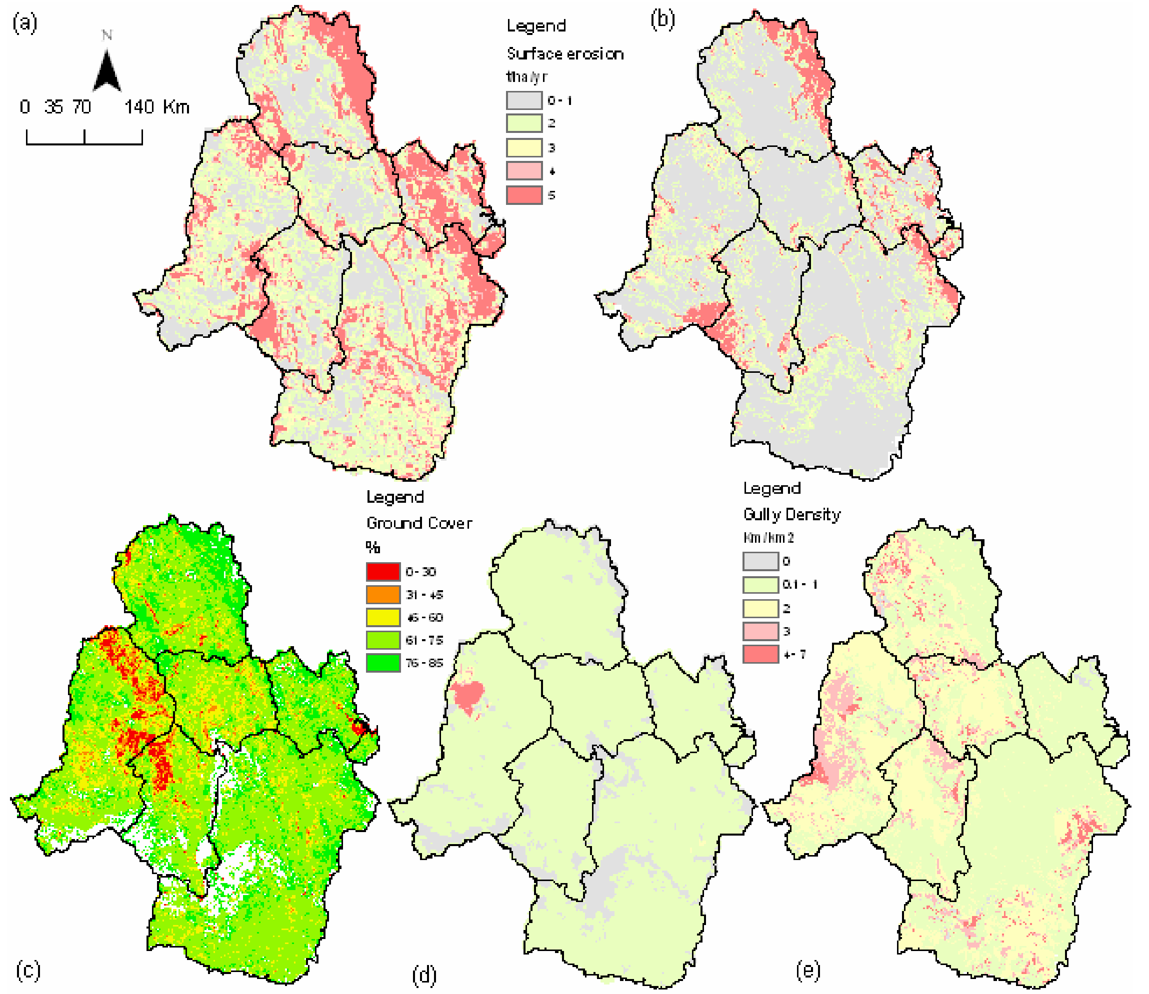

Figure 2. (a) 2006 RUSLE (b) New RUSLE (c) GCI 88-05 (d,) NLWA Gully density (e) New Gully density

periods of high erosivity. However applications of RUSLE have successfully overcome these issues in the past.

6.3. Gully erosion layer

In comparison to the NLWA gully density map, significant additions of areas > 3km/km^2 are apparent (Figure 2. d, e). The area of heavy gully density has increased in the Nogoa, Dawson, Isaac and Mackenzie catchments. Land resource officers and catchment managers agreed that the representation of gullies developed in this study better matched observations on the ground. A potential error identified in cultivated areas, was the under calculation of density. These areas can have extensive gullies, after large episodic events. Further non formal validation included the interrogation of hotspot areas, with Quickbird imagery. This analysis acknowledged comparable gully densities to that of the modelled densities.

In terms of SedNet sediment input, the new density map has resulted in a significant increase in gully erosion, (+2793 kt/yr). It was identified during the mapping process, that the finer scale used in gully capture (1:4000) may increase the number of gullies identified in comparison to that of Hughes *et al.* (2001). This is important since the current default cross sectional area parameter (10m^2), may now be too high.

High intensity LIDAR transects has been flown for ten of the Quickbird images. Once this data becomes available it will be used to generate cross sectional volumes for gullies in key Fitzroy landscapes. This may change the current default value used for cross sectional area of (10m^2), an area identified as potentially contributing a large source of uncertainty (Smith *et al.* 2007).

The gully erosion in this study has shown that an alternative approach to the NLWA can identify new spatial patterns of gully erosion across a basin. This fact is compounded by the considerable uncertainty attached to the SedNet gully density model (Smith *et al.* 2007). Unfortunately there are no current sites with reliably measured gully erosion rates in the Fitzroy to determine whether the gullies mapped are active or not.

More detailed studies are required in key landscapes scales to determine current gully erosion rates.

7. CONCLUSION

The use of this model again identifies the fact that without appropriate data, it is difficult to assess the performance of new data layers and parameters.

The delineation of the relative impact of different erosion sources across the Fitzroy is crucial in targeting hotspot areas. Future work is required in the basin to assess the relative contribution of the sources.

This could be achieved for several landscapes, in the Fitzroy instrumented with the focus neighbourhood catchments (Spottswood and Gordonstone) (Carroll *et al.* 2004). However, erosion rates in high gullied and steep hillslope areas need to be monitored.

In addition, further work is required to validate the GCI index. Monthly analysis of cover is required at a Fitzroy scale to identify cover levels during periods of high erosivity.

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