SOIL EROSION AND DEPOSITION MODELLING IN A SEMI-ARID GRAZING CATCHMENT IN NORTH CENTRAL QUEENSLAND

B. Fentie[A], C.A.A Ciesiolka[B], D.M. Silburn[B], M. Littleboy[C], B. Yu[D], C.W. Rose[D]
[A] Department of Natural Resources, Mines and Energy, Indooroopilly, Brisbane, Australia. 4068
[B] Department of Natural Resources Mines and Energy, 203 Tor Street, Toowoomba, Australia. 4350
[C] Department of Infrastructure, Planning and Natural Resources, Queanbeyan, N.S.W., Australia. 2620
[D] Faculty of Environmental Sciences, Griffith University, Nathan, Brisbane, Australia. 4111

Abstract

The Springvale study site is a small 10 hectare, second order catchment in a badly degraded part of the Nogoa River basin that lies in the 600 to 700 mm rainfall belt of tropical Australia. Sheet and rill erosion are associated with highly dispersible subsoils developed from flaggy sandstones, siltstones and mudstones. Over grazing and unfavourable climate variability have been given as reasons for land degradation and reduced grass production within the catchment.

It has been postulated that in addition to the onsite effects of degradation of the catchment due to erosion associated with declining grass production, the millions of tons of soil removed from the Nogoa basin, in which the Springvale catchment is nested, would be a substantial threat to the economic life of the Fairbairn dam, which supports irrigation, industry and urban needs in the area.

Rainfall, runoff, soil loss and vegetation cover data have been continually collected both at hillslope and catchment scales in the Springvale catchment since 1979. In this study, data from hillslopes have been used to calibrate an erosion model, which has been modified and upscaled to simulate erosion and deposition at a small catchment scale using a raster based Geographic Information Systems (GIS). Data at the catchment outlet are used for model verification. Two erosion index models are also used to compare the spatial pattern of predicted net erosion and net deposition in the catchment and show that, while the *insitu* erosion is high, the exiting sediment load from the catchment is quite low by comparison. Sensitivity analyses were conducted to evaluate uncertainties in model predictions due to uncertainties in input values. It was shown that the model was more sensitive to changes in some model parameters than others.

Additional Keywords: sediment delivery, geographic information systems, erosion index, spatial erosion.

Introduction

Milton (1974) calculated that 20% of the dead storage area of the Fairbairn Dam would be filled with sediment in 40 years while Blandford (1977) measured similar high levels of sediment being removed from a gullied catchment. Ciesiolka (1987) showed that by understanding the pulsing of sediments throughout the various catchment scales, sediment delivered to the reservoir was much smaller than estimated in previous studies. Also, erosion was found to be not just a function of vegetative cover at the catchment scale but involved the landscape and hydraulic variables that affect the base levels of the various stream orders. The Springvale catchment was chosen because it was a mirror analogue of the larger catchments and contained plots and micro-catchments. Thus, in this study, a plot-scale erosion model was modified to address identified limitations (Fentie, 2001). The model was then linked with Geographic Information Systems (GIS) resulting in a catchment scale erosion- deposition model referred to as SWEPS (Spatial Water Erosion Prediction System).

Materials and Methods

Description of study site

Data for this study were collected from a 10 ha grazing catchment (Ciesiolka, 1987) located about 75 km west of Emerald in Queensland, Australia, in the north-western part of the Nogoa river catchment upstream of Fairbairn Dam (23º41.8'S and 147º27.32'E). Figure 1 shows the location map of the Springvale catchment. The duplex soils of the Springvale catchment have a thin hard-setting A-horizon and are derived form alternating beds of sandstone, siltstone and mudstone. All soils in the catchment belong to the solodised solonetz Great Soil Group. The study catchment has an annual average rainfall of 650 mm.
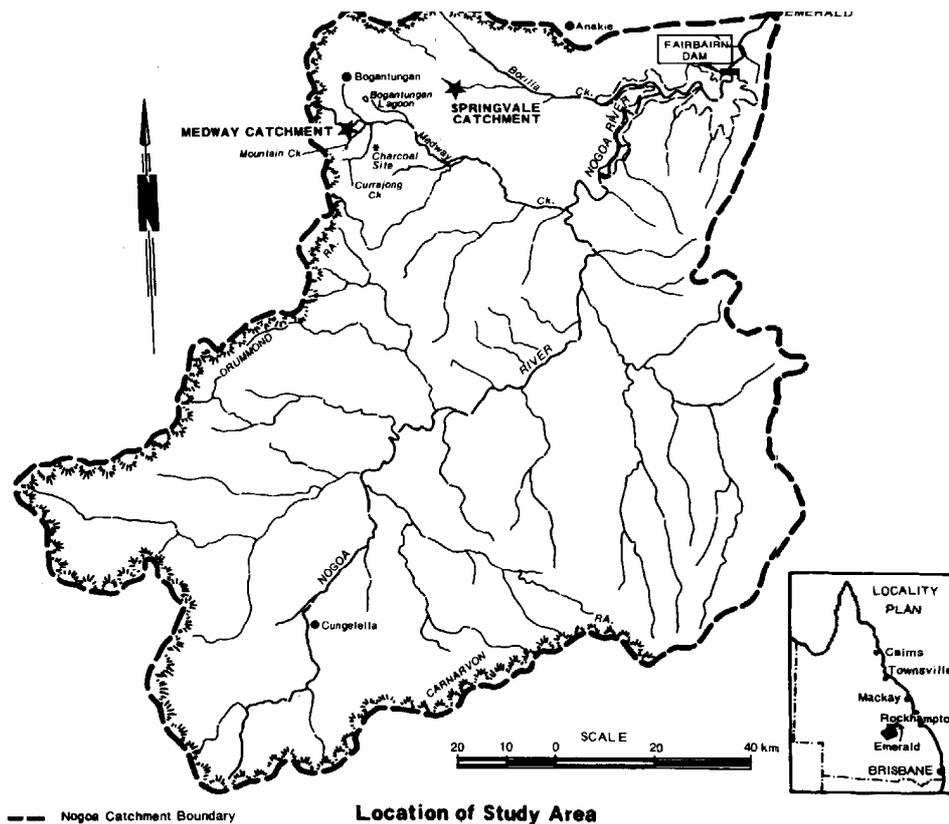
Figure 1. Location map of the Springvale catchment

Data collection
Rainfall, runoff, and sediment loss data used in this study were collected both at the catchment outlet and from experimental plots within the catchment, ranging in size from 30 to 640 m^2. Rainfall and runoff data from the experimental plots were measured at one or three minute intervals during storm events using tipping buckets and data loggers. Runoff at the catchment outlet was measured using a Parshall Flume and recorded using a Rustrack chart recorder or a frequency capacitance height recorder. Sediment loss from experimental plots was collected using modified Gerlach troughs, oven-dried, and measured. Model parameters relating to soil type were determined from these plots and used for modelling at the catchment scale.

A digital elevation model (DEM) of the catchment was created from one-metre contours. The DEM was then used to generate topographic attributes (i.e. slope, flow direction, and flow accumulation) required as inputs to the model. Vegetation cover is one of the spatial inputs to the model and was estimated visually by two operators.
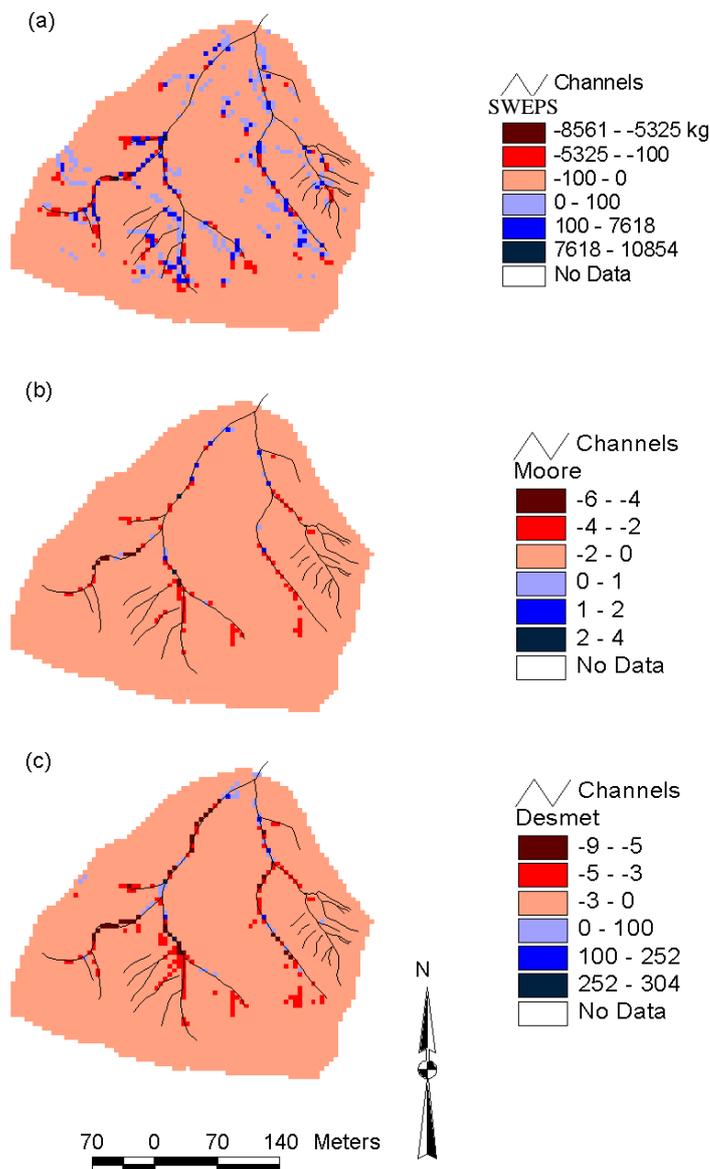
The erosion model
The erosion model used in this study is based on the plot scale erosion model called GUEST (Rose *et al*., 1997; Yu and Rose, 1997; and Fentie *et al*., 1999). Modifications to the model were carried out to address limitations identified by Fentie (2001) and to make it suitable for modelling erosion and deposition at the catchment scale. The resulting erosion model (SWEPS) was linked with ArcView GIS. The GIS generated spatial input data for the model, and model outputs were imported into the GIS for mapping the spatial distribution of erosion and deposition. The erosion index models of Moore *et al*. (1992) and Desmet and Govers (1995) have been used to ascertain the degree of agreement between the three models.

Results and Discussion
Figure 2 shows net erosion/net deposition maps of the catchment as (a) an output of SWEPS, (b) the erosion index of Moore *et al*. (1992) and (c) the erosion index of Desmet and Govers (1995). The SWEPS model predicted net erosion/deposition on 74.7 %, and 21.7 % of the catchment respectively, while the remaining 3.6 % of the catchment experienced neither net erosion nor net deposition.

Given the similarity between the models of Moore *et al*. (1992) and Desmet and Govers (1995), it is not surprising to see that both models resulted in similar spatial distributions of erosion and deposition, predicting net erosion on 98.8 and 98.7 % of the catchment, respectively. Since the two simple models do not impose a condition (threshold) below which no erosion takes place, all cells experience either net erosion or net deposition.

Figure 2. Spatial distribution of erosion and deposition predicted by the erosion model used in this study and two erosion indices: (a) SWEPS, (b) Moore *et al*. (1992) and (c) Desmet and Govers (1995). Negative values represent net erosion while positive values represent net deposition.

Despite the fact that areas of net deposition predicted by the SWEPS model were more widespread than the two simpler models, there is a similarity in the pattern in that in all cases the dominant areas of net deposition follow the channel floors. Since net erosion and net deposition values from the three models have different dimensions, a quantitative validation of the SWEPS model could not be carried out using this approach. However, close examination of the output map from SWEPS shows that it predicts more accurately most of the depositional areas when verified with field evidence. This can be attributed to the fact that the SWEPS model takes into account factors such as variations in cover and soil characteristics (i.e., depositability and erodibility), in addition to the topographic attributes (i.e. slope and flow accumulation) considered in the two simpler models.

Conclusions
The ability to model, not only the pattern, but also the magnitude, of net erosion and net deposition spatially has implications for the design of appropriate management actions targeting hotspots, which affects water quality

downstream. SWEPS has simulated the erosion and deposition areas on both the hillsides and the valley floors better than the two simpler models of Moore *et al*. (1992) and Desmet and Govers (1995).

Acknowledgements

References

Blandford,D.C. (1977). Medway Research Program. *Pilot Study Report. Internal Report, Development Planning Branch, Department of Primary Industries*, Queensland.

Ciesiolka, C.A. (1987). Catchment Management in the Nogoa Watershed. Completion Report for Australian Water Resources Council Research Project 80/128.

Desmet, P.J.J. & Govers, G. (1995). "GIS-based simulation of erosion and deposition patterns in an agricultural landscape; a comparison of model results with soil map information" in Special issue; Experimental geomorphology and landscape ecosystem changes; proceedings of the memorial symposium Prof. Jan de Ploey., eds. J. Poesen, G. Govers & D. Goossens, Catena-Verlag Rohdenburg, Cremlingen-Destedt, Federal Republic of Germany.

Fentie, B. (2001). Catchment-scale Water Erosion and Deposition Modelling: A Physically-based Approach, The University of Queensland.

Fentie, B., Rose, C.W. & Coughlan, K.J. (1999). GUEST 3.0:A program for calculating a soil erodibility parameter in a physically-based erosion model. Working paper 1/99. Faculty of Environmental Sciences, Griffith University, Brisbane, Australia.

Milton, L.D. (1974). Methodology for Studying Erosion in the Nogoa Watershed, *Queensland Department of Primary Industries internal Report*, 31p.

Moore, I.D., Wilson, J.P. & Ciesiolka, C.A.A. (1992). Soil erosion prediction and GIS: Linking theory and practice. Geographic Information System for Soil Erosion. ManagementTalyuan, Shanxi Province, China.

Rose, C.W., Coughlan, K.J., Ciesiolka, C.A.A. & Fentie, B. (1997), "Program GUEST (Griffith University Erosion System Template)". ACIAR Technical Reports Series, vol. 40 Using Smart Source Parsing English, pp. 34-58.

Yu, B. & Rose, C.W. 1997. GUEPS: A program for calculating the soil erodibility parameter b and predicting the amount of soil loss using GUEST methodology. pp. 27. Faculty of Environmental Sciences, Griffith University, Queensland, Australia, Brisbane.