Sediment runoff characteristics of four Fitzroy Basin soils in semi-arid Australia

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Abstract

Managing soil in rangelands is a crucial component of soil conservation and maintaining productivity. Pressures of grazing can increase sediment export through ground cover reduction, increasing the detachment potential of soil particles exposed to raindrop impact and overland flow. In the Great Barrier Reef catchment, grazing is a significant source of fine sediment export into the Great Barrier Reef lagoon. This study investigated sediment export characteristics of four different grazed soil types in the Fitzroy catchment, Queensland, where 75% of the catchment is utilised for grazing. Rainfall simulation was applied over four bare soil types—Tenosol, Black Vertosol, Brown Sodosol and Black Dermosol—to determine erosion parameters for modelling sediment loss using the Revised Universal Soil Loss Equation. These four soil types are representative of 70% of the Fitzroy Basin and 57% of the GBR catchment. Data collected provided an understanding of detachment properties and particle size distribution of eroded sediment, and found that hydrological properties, sediment loss and particle size distribution differed depending on soil type.

Keywords: sediment, grazing, erosion, fine sediment export.

Introduction

Sediment generated from grazing land in the Great Barrier Reef (GBR) catchments poses a significant threat to the GBR lagoon. Approximately 1,500 kt/year of fine sediment (<20 µm) is exported from the Fitzroy catchment (15,610,200 ha), Central Queensland, into the GBR, where 75% of this catchment is grazed (McCloskey *et al.* 2021).

Particles less than 20 microns (<20 µm), are considered the fine portion of sediment modelled from hillslope, gully, and stream networks to the end-of-system. The presence of <20µm particles in the reef ecosystem are associated with decreased coral cover and diversity due to turbidity and the addition of bioavailable nutrients bound to clay and silt aggregates(Fabricius *et al.* 2014; Garzon-Garcia *et al.* 2021). Ecologically, this fine sediment fraction is the most detrimental and has the highest chance of reaching the GBR lagoon (Bainbridge *et al.* 2012; Bainbridge *et al.* 2023).

Understanding sources of fine sediments has been extensively researched with in the GBR catchment (Garzon-Garcia *et al.* 2016; Packett 2020; Bainbridge *et al.* 2023). Soil erosion is affected by intrinsic characteristics including texture, structure, chemistry, and hydraulic properties. Water-driven erosion, such as from raindrop impact or runoff, is exacerbated by land use practices where changes in vegetative cover, soil hydrology, soil structure, or chemistry increases the detachment and transport potential of soil particles (Bui *et al.* 2011). Grazing, deforestation and excessive cultivation are three leading causes of accelerated soil erosion (Blanco-Canqui *et al.* 2016). This study looked at the sediment loss response on bare soil for four different soil types on grazing lands in the Fitzroy catchment.

Methods

Rainfall simulation was applied over four soil types (Tenosol, Black Vertosol, Brown Sodosol and Black Dermosol) in plot sizes of (2 x 1.4 m) to determine erosion parameters for modelling sediment loss with the Revised Universal Soil Loss Equation. These four soil types are representative of 70% of the grazed Fitzroy catchment (Vertosol 28%, Sodosol 28%, Dermosol 11%, Tenosol 3%) (Roots 2016) (Figure 1). Two vegetated treatments, where ground cover was > 50%, were also used for soil loss comparison on the Vertosol and Sodosol.

Hydrology parameters were observed through the simulated rainfall event. Runoff water quality samples were collected at 5-minute intervals for 30-minutes. Total and suspended solids and particle size distribution by laser diffraction were analysed. Data collected provided an understanding of detachment properties and particle size distribution of eroded sediment.

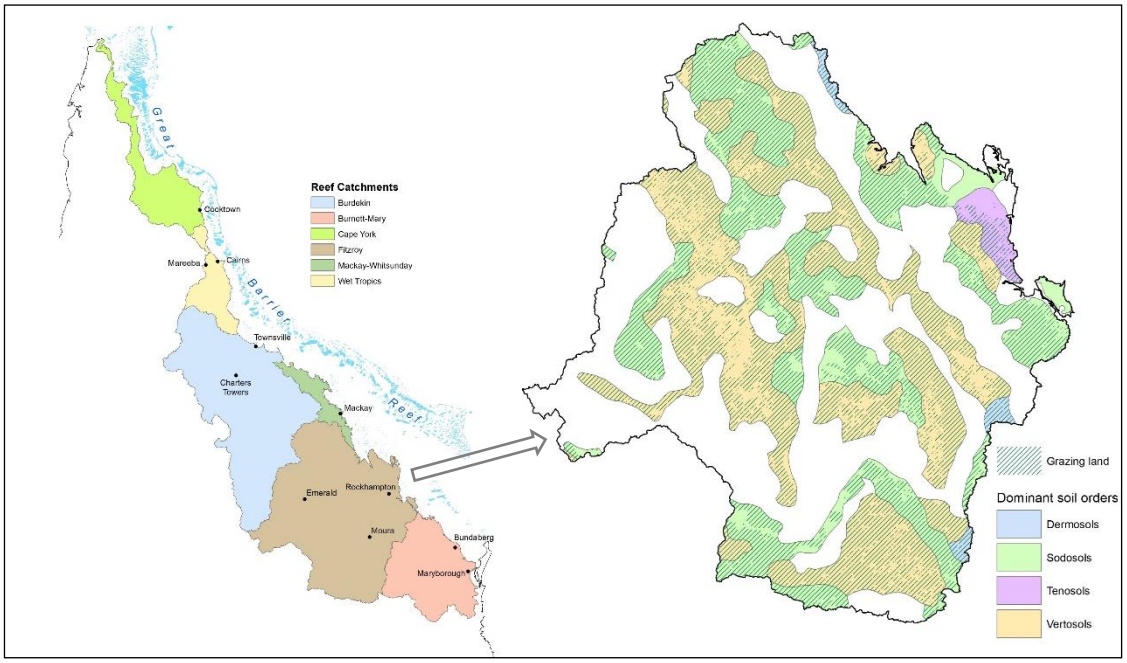

Figure 1 Great Barrier Reef catchment regions (left) and coverage of grazing land use across the four soil types studied in the Fitzroy catchment, Queensland (right).

Results and Discussion

Table 1 Observed hydrology and sediment characteristics from four grazing soils in the Fitzroy catchment, Queensland.

Soil type	Treatment	Event mean infiltration	Event mean sediment concentration	Event mean sediment transport rate	Percent <20µm	Event sediment load
		mm/hr	g/L	g/min	%	t/ha
Black Dermosol	Scald	11.2	4.6	18.0	43.5	2.5
Black Vertosol	Scald	8.3	8.7	33.3	38.8	1.4
	Vegetated	52.6	7.4	7.6	20.4	0.3
Brown Sodosol	Scald	5.1	8.6	36.4	23.0	2.5
	Vegetated	24.8	6.6	18.7	12.6	0.7
Tenosol	Scald	6.4	12.8	51.4	47.0	7.2

Scalded Tenosol plots recorded the highest event mean concentration for sediment (12.8 g/L), mean sediment transport rate (51.4 g/min), sediment load (7.2 t/ha) and proportion of fine sediment (47.0%) when compared to other soil types at the plot scale. Scalded Dermosol plots also exported a high proportion of <20 µm sediment at 43.5%. However, despite Vertosols and Sodosols having lower percentages of fines in the sediment runoff, these two soil types—when extrapolated to the proportion of the Fitzroy catchment of 54%—presents a greater potential risk to fine sediment contribution.

Meanwhile, the two vegetated plots had a mean infiltration rate > 3.8-fold higher than the scald plots on the same soil type. Greater infiltration resulted in lower runoff rates (not shown) and reduced capacity to transport sediment. Sediment eroded from vegetated plots had up to 47% less fine sediment and up to 78% lower sediment load compared to bare plots. This highlights the importance of ground cover and the role it plays in reducing soil erosion.

Conclusion

Hydrological properties, sediment loss and particle size distribution differed depending on soil type and presence of ground cover. Of the soils studied, the Tenosol appears to have the highest risk of sediment loss and suspended particle export where bare soil is exposed, however, when compared to the other three soil types, this is the least common soil type in the Fitzroy catchment used in this study. The Black Vertosol and Brown Sodosol present the greatest risk of sediment export with a combined proportion of the catchment of 54%.

This study highlights that management of ground cover is an important component of reducing sediment loss in Reef catchments, where ground cover targets of at least 50% are recommended in the late dry season (The State of Queensland 2022). Improving our understanding of fine sediment budgets across GBR soils improves catchment models used to develop

sediment exports. These findings are applicable for grazed lands both in the GBR and rangelands outside the GBR catchment.

Conflicts of Interest

All authors declare they have no known conflicts of interest.

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(QLUMP)"; and "P2R_56_sub_basins" shapefile provided by C. Dougall (Paddock to Reef modeller, Department of Natural Resources and Mines) dissolved to the Fitzroy Basin using "PROP.QLD_NRMREGBDY_100K" natural resource management boundaries. Developed using ArcGIS version 10.3. Department of Natural Resources and Mines, Rockhampton.

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