Sediment erosion research in the Fitzroy basin central Queensland: an overview

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Abstract
Erosion research in the Fitzroy basin has consistently shown in dryland cropping, grazing, irrigation and coalmine rehabilitation landscapes that the retention of 40 to 60% surface cover and maintaining a large soil water deficit can reduce erosion rates to negligible levels (<0.5 t/ha), even on very steep slopes. Neighbourhood catchment sub-catchment and basin scale studies have highlighted that dryland cropping contributes the largest sediment concentrations, particularly during large episodic erosion events when crops are unable to be planted and surface cover is low. However, the majority of sediment load from the Fitzroy is generated from grazing due to the large proportion of this land use in the basin.

Key Words
Fitzroy, erosion, runoff, land use, monitoring, modelling.

Introduction
The Fitzroy River Basin in Central Queensland is the largest coastal catchment in eastern Australia, covering an area of approximately 142,000 km^2, consisting of six sub-catchments: Nogoa, Comet, Mackenzie, Isaac-Connors, Dawson and Lower Fitzroy. The Fitzroy Basin was settled in the 1850s, and in the first 100 years of settlement there was localised clearing, with limited sheep and cattle grazing, cultivation and mining activities. Development increased substantially with the Brigalow Land Development Scheme between 1962 and 1985 with the clearing of 4.5 million hectares of brigalow vegetation. By 1999 58% of the remnant vegetation in the Fitzroy had been significantly altered or cleared ,with the major land uses, grazing (82%), dryland cropping (7%), conservation (4%), irrigation (0.5%), and mining (0.5%). The clearing and development of the Fitzroy basin has led to a diverse and complex range of resource management issues. A mean annual sediment load of 3.1 Mt/yr is estimated to be exported past Rockhampton into the Fitzroy river estuary, with most of this sediment coming from the Nogoa and Comet sub-basins (Joo *et al.* 2005). A reef consensus statement on water quality in the Great Barrier Reef highlighted that *'land derived contaminants, including suspended sediments, nutrients and pesticides are present in the GBR at concentrations likely to cause environmental harm'* (Brodie *et al.* 2008). Numerous small scale and catchment scale experiments have been conducted in the basin to quantify and manage the impact of agricultural and mining industry on runoff and erosion (Ciesiolka 1987, Carroll *et al* 1997, 1995, 2000; Waters 2001, 2004; Thornton *et al.* 2007; Silburn *et al.* 2009). More recently, larger catchment scale monitoring and modelling has been undertaken to estimate sediment loads and sources within the basin (Joo *et al.* 2005; Dougall *et al.* 2009; Packett *et al.* 2009; Hughes *et al.* 2009). An overview of the runoff and erosion research conducted in the Fitzroy is presented in this paper.

Fitzroy Studies
Forest, cropping, grazing, irrigation and mining
The Brigalow Catchment Study in the Dawson sub-basin and was established in 1965 in response to the large scale clearing of brigalow vegetation (*Acacia harpophylla*). An initial pre-clearing calibration stage (1965-82) was conducted on three catchments (12-17ha), with two catchments subsequently cleared for cropping and grazing in 1982 (Thornton *et al* 2007). A 12 year dryland cropping study commenced at Capella in 1982 on a shallow vertosol soil to determine the effect of crop type, crop rotation and tillage practice on runoff and soil loss from nine contour bay catchments (approximately 13 ha) (Carroll *et al.* 1997). In the late 1990's zero tillage was moving towards a control farming systems that would facilitate opportunity cropping, minimise soil compaction and increase farming efficiency. In 1999 experiments were conducted to compare zero tillage with control traffic farming and contour farming on two properties (Moonggoo, Cowendilla) in the Dawson and Nogoa sub-basins.

The first hydrologic experiment on a grazing catchment (9.6 ha) commenced in 1979 on a cattle property (Springvale) in the Nogoa sub-catchment (Ciesiolka 1987). Vegetation was silver-leaf ironbark trees (*Eucalyptus melanophloia,* dominant pastures *Bothriochloa ewartiana*, *Heteropogon contortus* and *Themeda triandra*. The catchment was fenced and de-stocked in 1981, and in 1987 runoff plots were installed both inside (ungrazed) and outside (grazed by cattle) the area (Silburn *et al.* 2009). A further grazing study commenced in 1994 on two properties (Keilambete and Glentulloch) to measure the effects of three pasture utilisation rates, 75, 50 and 0 % on runoff and erosion processes (120 m^2 plots) (Waters 2004). Carroll *et al.* (1995) and Waters (2001) quantified erosion rates from furrow irrigation and rainfall from cotton production systems in the Emerald Irrigation Area (EIA) on Vertosol soils, and considered a range of management practices to minimise erosion and pollutant transport. The final and major land use monitored was open-cut coalmining where landscapes are created with parallel spoil piles, with very steep slopes of approximately 75%. To provide guidelines for mine rehabilitation Carroll *et al.* (2000) compared erosion rates from three rehabilitated slope gradients (10, 20, 30%), topsoil and spoil materials at three coalmine sites in the Mackenzie and Isaac sub-catchments.

Neighbourhood catchments

Two local neighbourhood catchments were established in 1999 at Gordonstone Creek, and Spottswood Creek in the Nogoa and Dawson sub-catchments to quantify the offsite transport of sediment and pollutants at cascading scales. Both neighbourhood catchments are approximately 300 km^2, with 20 and 25 properties respectively in each catchment, the Moonggoo and Cowendilla properties and paddock scale experiments were in the respective catchments.

Basin monitoring and Modelling

At a basin scale Joo *et al.* 2005 used measured total suspended solids (TSS) concentrations from the six sub-basins in the Fitzroy to develop sediment rating curves. These rating curves combined with streamflow data were used to estimate long-term mean annual sediment load of the Fitzroy and its main tributaries for a common 30-year period 1974-2003. Packet *et al.* (2009) used 11 years (spanning 15 years) of flood borne pollution data from the Fitzroy basin to identify a relationship between land use and pollutant generation and transport. SedNet/Annex catchment modelling has quantify the relative contribution of hillslope, gully and streambank erosion and potential land management practices to reduce sediment and nutrient loads within the basin (Dougall *et al.* 2009). A USLE C-factor was generated from a Ground Cover Index produced for Landsat TM (25m) imagery, with presence and absence of gullies mapped using Quickbird satellite images and aircraft-mounted Light Detection and Ranging (LIDAR).

Overview of erosion research

The Brigalow Catchment Study has shown that changing from brigalow forest to cropping and grazing has doubled runoff and increased peak runoff rates, with cropping marginally greater than cropping (Thornton *et al.* 2007). All plot/paddock scale studies in the Fitzroy have consistently shown the importance of managing both soil water deficit and surface cover on reducing the magnitude of erosion and water pollutants. The Capella study highlighted dryland cropping land is most susceptible to episodic erosion when crops are unable to be sown, and the subsequent long-fallow is conventionally tilled leaving soil exposed to the erosive forces of rainfall and runoff. Such conditions notably occurred in 1982 and 1994. Just 3 storms in 1983 contributed 30% (13.3 t/ha) of the soil loss before zero tillage was established and the soil was bare (Carroll *et al* 1997). Likewise, Dougall *et al.* (2009) found a similar episodic nature at the Gordonstone Creek Neighbourhood catchment where just 3 events produced 92% (60,000t) of the sediment export during the study. Overall, the lowest average annual runoff and soil loss is following wheat, when there is generally both a large soil water deficit and mass of crop stubble (90% soil cover). When the vertosol was dry and cracked almost all early summer rainfall infiltrates, this was evident in 1990-91 when following wheat harvest there was just 8 mm runoff from 250 mm of rainfall. Once cracks close, infitration rate, runoff and soil loss is determined by the amount of stubble protecting the soil from rainfall impact and surface runoff. This was illustrated at Moonggoo where an opportunity cropping regime actually grew 3 more crops (13 crops in 11 years) than a more conservative cropping system (10 crops), yet had greater runoff. The 3 extra crops were two winter chickpea, and mungbeans that produce relative low biomass with surface cover often <10% during the subsequent fallow (Neilsen per comm).

Many soils in semi-arid grazing lands are susceptible to developing low pasture cover or bare areas (scalds) under heavy grazing and have a low tolerance to soil erosion, due to low total water holding capacity and concentration of nutrients in the surface (Silburn *et al.* 2009). In grazing the effect of pasture cover on soil hydraulic properties and surface runoff is greater than in croplands, with a time lag between change in pasture cover and change in hydrologic response, the duration of this time lag is poorly understood, but may be up to 3 years (Waters 2004). At Keilambete on a red duplex soil, there was large erosion rates at low cover levels in comparison to Glentulloch, this was attributed to the low subsoil permeability and shallow A horizon, causing increased runoff and soil loss. Waters (2004) found pasture cover levels of approximately 60% need to be maintained on shallow red duplex poplar box/silver leaf ironbark soils, by maintaining cattle pasture utilisation rates between 25 % and 50 % of standing dry matter. Whereas, for the deeper poplar box duplex soils, >40 % pasture cover maintained erosion rates to acceptable levels. Likewise at the Springvale study runoff was strongly influenced by surface cover and was very high with low cover (200-300 mm/yr or 30-50% of rainfall). Runoff averaged 35 mm/yr or 5.9% of rainfall with >50% cover. All three grazing experiments show that managing grazing pressure and hence pasture dry matter and surface cover dramatically reduces erosion and runoff.

In furrow irrigation systems rainstorms caused most of the seasonal soil loss (Carroll *et al.* 1995), and sediment concentration from both rainfall and irrigation declined when cultivation ceased, furrows consolidated and when the cotton canopy provided surface cover. In addition Waters (2001) found that a wheat-cotton rotation reduced soil erosion by 70% and endosulfan concentrations by 40%, with 80% reduction of sediment loads when PAM was applied to irrigation water, and the use of vegetative strips trapped 65-85% of total endosulfan and 67% of chlorpyrifos in runoff. Coalmining landscapes created the greatest erosion rates from all land use monitored, particularly when there was a large bare surface area (>50%) exposed to the erosive forces of rainfall and overland flow. When soil was bare erosion rates were typically >70 t/ha, however once pasture (*Cenchrus ciliaris*) colonised erosion rates declined to negligible levels (<0.5 t/ha), even on steep slopes. Where pasture did not establish on spoil material, due to surface crusting, rates remained very large (>200t/ha).

At a sub-basin and basin scale Joo *et al.* (2000) estimated that most of the sediment load in the Fitzroy comes from the Nogoa and Comet sub-catchments, and for a given level of runoff, sediment concentration on average was highest for the Nogoa and Comet sub-catchments, and the lowest for the Isaac. Packett *et al.* (2008) found the higher the percentage of cropping land in a rainstorm event area, the greater the potential maximum pollutant concentration measured at the end of the Fitzroy. Nevertheless, the majority of the long-term average annual load is from grazing land, due to the large proportion of this land use in the basin. SedNet/ANNEX catchment modelling has identified hillslope erosion as the dominant source of sediment delivered to the stream network (67%), with gully erosion 26% and channel erosion 7%, and hillslope erosion contributed the largest proportion of both particulate phosphorus (63%) and nitrogen (55%). The modelling suggests the majority of the suspended sediment is generated from <30% of the Fitzroy landscape. When the SedNet modelling outputs are compared with Hughes *et al.* (2009) geochemical and radionuclide tracing work in the Theresa Creek catchment there is a good agreement on the spatial sources of suspended sediment, but large differences in the dominant sources of sediment (Dougall *et al.* 2009); highlighting the need for further research into tracing major sources of eroded sediment in the basin.

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