Understanding the natural variability of floodplain deposition in Australia’s Wet Tropics: Implications for the prioritization of management actions of sediment delivery to the GBR Lagoon.

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Abstract

This paper uses two examples from a larger study of floodplain chronostratigraphy on the Daintree and Mulgrave Rivers to address the importance of base line data from near pristine catchments in assessing management actions of the Reef Water Quality Protection Plan (RWQPP). The study examined long-term natural variability of sediment delivery in the Wet Tropics by investigating floodplain depositional sequences of the Daintree and Mulgrave Rivers using Optically Stimulated Luminescence dating. Chronology of these sedimentary sequences suggest that entire sections of floodplain have been stripped and reformed in a matter of centuries. Evidence of a major episodic stripping event approximately 300yrs ago potentially removed 661,000m^3 of sediment, to the GBR lagoon, from a 2km reach of the Daintree River. This implies that natural variability of sediment delivery to the GBR is far greater than that suggested to have occurred due to human landuse practices. Consideration of the effects that future climate change may have on these observed floodplain formation processes is essential for setting targets and prioritizing actions in terms of the RWQPP.

Introduction

The Great Barrier Reef (GBR) is the worlds largest coral reef system extending more then 2000km along the east coast of Queensland, Australia. Since European settlement the adjacent coastal catchments have been transformed by the widespread clearing of native vegetation, agricultural expansion and intensive grassing practices. Over 20 rivers drain into the GBR lagoon. The largest and subsequently most studied of these are the Burdekin and Fitzroy Rivers (Hutchings *et al.* 2005), with the smaller rivers of the Wet Tropics receiving less focused research efforts. Although Wet Tropics catchments are relatively small in comparison to other rivers draining to the GBR lagoon, localised effects of their sediment delivery to the near shore zone can be significant. The inner shelf is home to 4000km^2 of seagrass, dugong and turtle habitat, countless fisheries and substantial economic activities (Brodie, 2002). The impacts of terrestrial sediments to these areas have been extensively described (Wolanski and Spagnol, 2000; Wolnski and Duke, 2002; Wolanski *et al.,* 2003; Fabricius and Duke, 2004) and in response research has focused on quantifying the extent to which land use practices have contributed to the purported increase in terrestrial sediment supply to the GBR Lagoon.

In response the Queensland government partnered with the Commonwealth government to create the Reef Water Quality Protection Plan (RWQPP)

(Anon, 2003). The RWQPP was developed as a tool in which to support the prioritisation of management actions for pollution reduction, targeting key catchments with the aim to halt and reverse the decline in water quality entering the GBR within 10 years (Anon, 2003). In essence the plan lays out a number of strategies to prioritise management actions through the development of catchment scale water quality improvement plans that set targets to reduce sediment run off. The plan used a multi-criteria approach to assess and classify the relative impact of pollution from individual catchments to the reef (Greiner *et al.,* 2005). Although the classification criteria was quite rigorous in its nature it failed to take into consideration the natural variability of systems over space and time and the responses of these systems to climate change.

The greatest uncertainty in estimates of magnitude of modern increases in sediment yields to the GBR lagoon is related to pre-1850 inputs. It is commonly accepted that sediment loads to the GBR have increased between 5-10 times as a result of post-European agricultural expansion and landuse practices (Furnas *et al.,* 2003; McCulloch *et al*., 2003 and McKergow *et al*., 2005) but there is still relatively little export data from near pristine catchments. Current knowledge of sediment delivery rates to the GBR has largely been based on computer models quantifying the increase of sediment exports since European agricultural expansion (Belperio, 1983; Neil and Yu, 1996; Moss *et al*., 1992; Rayment and Neil, 1997; Furnas and Mitchell, 2001; Prosserr *et al*., 2001a; Brodie and Furnas, 2003; Furnas, 2003 and McKergow *et al*., 2005). These studies relied on limited data sets at regional scales and involved very few field observations of actual sediment and erosion processes.

In response to this increase in sediment yield there has been an overwhelming push for land managers to control erosion and sedimentary processes in river systems of the GBR Catchment. Hillslope erosion has been commonly excepted as the dominant source of sediments (Prosser *et al*., 2001b; Bartley *et al.,* 2004) but more recent studies have identified that bank erosion (Hateley *et al*., 2006; Bartley, 2008; Hughes *et al*., 2009) and gully erosion (Wasson *et al*., 2002; Brooks *et al*., 2007) are also major sources of sediment to GBR catchments. Floodplains are widely recognised as sediment sinks but are commonly overlooked as potential sources of sediments. Research has shown that catchments have a threshold level of sediment storage (Nanson 1986). Entire floodplains can be stripped during a single flood event once this threshold is exceeded, resulting in the equivalent of a century’s worth of sediment being delivered to the coast in a single event. Understanding the natural variability of floodplain formation and sediment movement through catchments is of broad significance in identifying areas of risk in relation to the RWQPP.

Prosser (1990) argued that it was necessary to look at floodplain chronologies of the Late-Quaternary when assessing the environmental conditions of natural and altered systems. The importance of reconstructing floodplain chronologies to facilitate present floodplain management has been highlighted in numerous studies of rivers on the East coast of Australia, (Brooks *et al*., 2003; Fryirs and Brierley, 1998; Nanson *et al.*, 2003; Nanson and Doyle 1999;

Nanson and Erskine, 1988; Nott *et al.,* 2002; Warner 1992; Young *et al*., 1986) however, there is a distinct gap in literature pertaining to north-eastern Australia. This study uses Optical Stimulated Luminescence dating techniques to investigate if floodplains are a suitable indicator of sediment loads from before European agricultural expansion, and the potential of floodplains to be a major source of sediments to the GBR lagoon.

Study Area

The Daintree River catchment (figure 1) covers an area 1332km^2 in the northern most extent of the Wet Tropics World Heritage Area. The Daintree River rises at approximately 1300m, flowing north across the Great Dividing Range before turning east to the coast just south of Cape Kimberley. The catchment is dominated by igneous and sedimentary rocks in the upper catchment and alluvial sedimentary deposits on the lower floodplain. The headwaters of the catchment are steep and dominated by precipitous slopes with gradients up to 10% and a floodplain sinuosity of 2.47 (Bartley *et al*., 2008). The lower valley is characterised by a discontinuous floodplain mosaic confined by bedrock spurs. The lower floodplain has an average width of 290m and is further restricted by remnant Pleistocene terraces (18-24ka) of a much larger system with greater capacity (Thomas *et al*., 2001). The floodplain is dominated by fine to coarse-grained overbank sediments forming a laterally stable floodplain. The average river width is approximately 83m in the upper floodplain reaches. Average rainfall recorded from the lower floodplain is ~3000mm per year and is expected to be greater in the steep upper catchment. The study area extends a 10km reach upstream of the Daintree Village with five field sites representing different floodplain development stages. A sediment budget constructed by Bartley *et al*., (2004) estimated a total sediment supply to the coast of 206,000t/yr with hillslope delivery the dominant source at 162,000t/yr followed by bank erosion 32,000t/yr, cane drains 12,000t/yr and with 8,000t/yr stored in floodplain sinks and <1000t/yr as within channel deposits.

The Daintree River was first settled between 1878 and 1880 and since less than 5% of the catchment has been cleared in the lower most extent of the floodplain margins, representing a near pristine catchment. Early settlers extensively logged the steep slopes of the lower valley for cedar until the early 1900's. Today sugar cane cropping and cattle grazing pastures dominate lower reaches of the floodplain. The upper catchment is largely pristine rainforest laying within the Daintree National Park. The estimated population of the catchment is less then 1000 people with the majority of these residing within the Daintree Village. The largest known flood in the Daintree River was recoded in 1895. Evidence from oral histories indicate that floodwaters peaked at over 15m above the current floodplain, washing away a house in the upper valley and killing six people.

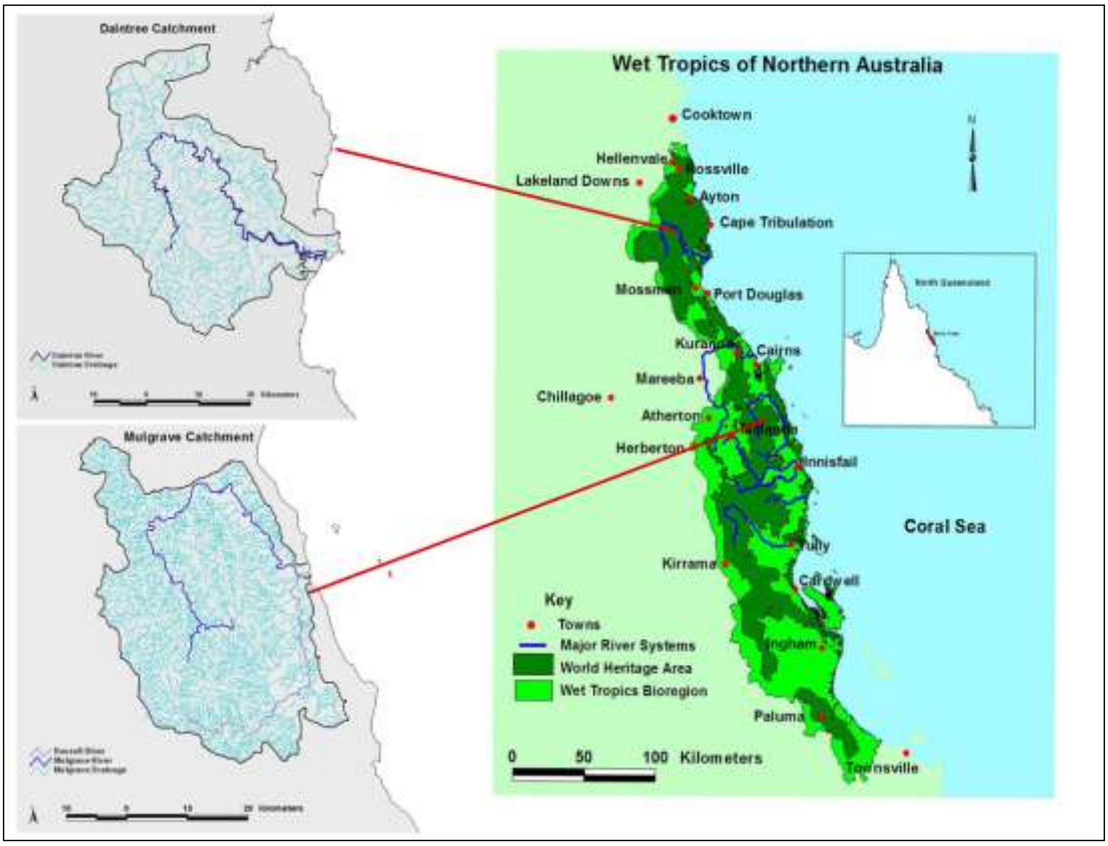

Figure 1. Location of the Daintree and Mulgrave Rivers in the Wet Tropics of Northeastern Australia.

The Mulgrave River catchment (figure 1) covers an area 810km^2 in the central eastern section of the Wet Tropics region of north-eastern Australia. The Mulgrave River rises in the Bellenden Ker Range and flows north across the escarpment, then east down the lower highland slopes. The river then flows across the flat coastal plain and turns abruptly south bordering the Malbon Thompson Range, after which it joins the Russell River to enter the sea at Russell Heads, 40km south of Cairns. The river has a total length of ~ 65km. The catchment straddles the highest part of the Great Dividing Range, within the Wet Tropics of Queensland World Heritage Area. The Mulgrave River floodplain lies in a narrow valley confined by coastal ranges. Coastal lowland tropical forests once covered the floodplain but now only a patchwork mosaic remains due to extensive clearing for agricultural expansion.

Tributaries of the headwaters of the Mulgrave River drain the eastern edge of the basalt-covered Atherton Tablelands before the main stream flows through the granites of the Bellenden Ker Range (1615m at its highest point) and across the metamorphics that dominate the lower reaches of the catchment (NRA, 2001). An extensive Late Pleistocene alluvial fan (Thomas *et al*., 2001; Nott *et al*., 2001) extends from foothills through the Mulgrave corridor and into the lower reaches where freshwater swamps, tidal estuaries and marine sand deposits dominate. Underlying geology of the Mulgrave catchment is dominated by the Palaeozoic Hodgkinson Province metamorphics and the Mareeba Granite, forming the Bellenden Ker massif which includes the

Malbon-Thompson Range and Mt Bartle Frere (Nott, 2003). These granites intrude the Hodgkinson metamorphics. Quaternary colluvial/alluvial deposits dominate the Mulgrave River corridor and the narrow floodplains of the Little Mulgrave River (Willmott and Stephenson, 1989).

Methods

Optical Stimulated Luminescence (OSL) dating techniques (Aitken, 1998; Wintle, 1997) were used to reconstruct floodplain chronologies for both the Mulgrave and Daintree Rivers. With advances in single grain OSL techniques (Jacobs *et al*., 2006) confidence can be given to applying this technique to younger fluvial samples (Olley *et al*., 2004). Samples were collected for OSL dating by driving steel tubes into augured holes and the cleared face of terrace features along transects parallel to the riverbanks on both rivers.

Results

Results of the OSL dating indicated that modern floodplains of the Daintree and Mulgrave Rivers are extremely young with basal ages of 600 and 700 years respectively. Late Pleistocene terraces dating between 18ka and 30ka confine the modern floodplain. Larger wider, deeper rivers formed these river terraces with greater capacity to transport sediment than today's river systems. The incision of these valleys was the result of a reduction in stream power some 14 thousand years ago (Thomas *et al*., 2001). The floodplain chronologies indicate cut and fill dominated floodplain sequences on the Daintree River throughout the Holocene with remnant terraces indicating marked phases of aggradation and incision.

Evidence on the Daintree River showed a phase of aggradation in response to the Holocene climatic optimum around 7-5 thousand years ago, followed by a marked absence of sediments between 4 thousand and 2.5 thousand years ago. There was a return to an aggradational phase 2.5 to 1 thousand years ago, followed by brief incision and further aggradation at 0.6 thousand years ago. Finally in the Daintree catchment, there was evidence of catastrophic stripping some 300 years ago followed by further rapid deposition. It is estimated that at transect four on the Daintree floodplain (figure 2), ~661,000m^3 of sediment were eroded from the floodplain around 300 years ago. At the same site, there is a further 1,244,123m^3 that could be potentially eroded from the floodplain if the river once again shifts back to an erosional phase as a result of future changes in hydrological conditions combined with the impacts of future climate change.

The age of the modern floodplain of the Mulgrave River (figure 3) was similar to that of the Daintree River, but there was a significant absence of any remnant terraces and a defined gap in the sedimentary record between 14 thousand years ago and 700 years ago. It is possible that these features have been stripped from the floodplain in either one large super flood or that a series of floods over a short period of time eroded large volumes of sediment.

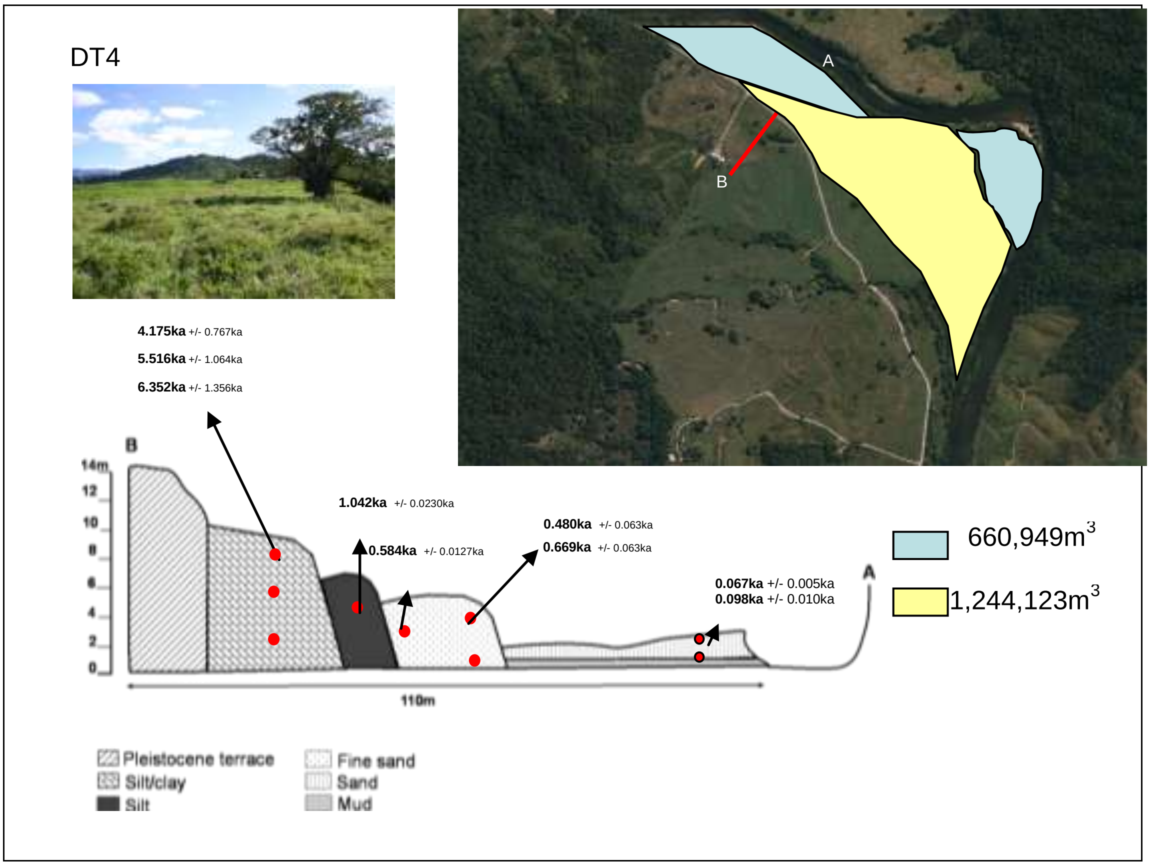

Figure 2. Cross-section of stripped floodplain at transect 4 on the Daintree River showing ages of the depositional and erosional phases of floodplain formation and giving an indication of the rapid deposition rates of sediment on the modern floodplain. The blue area shows area stripped and yellow indicates potential areas at risk.

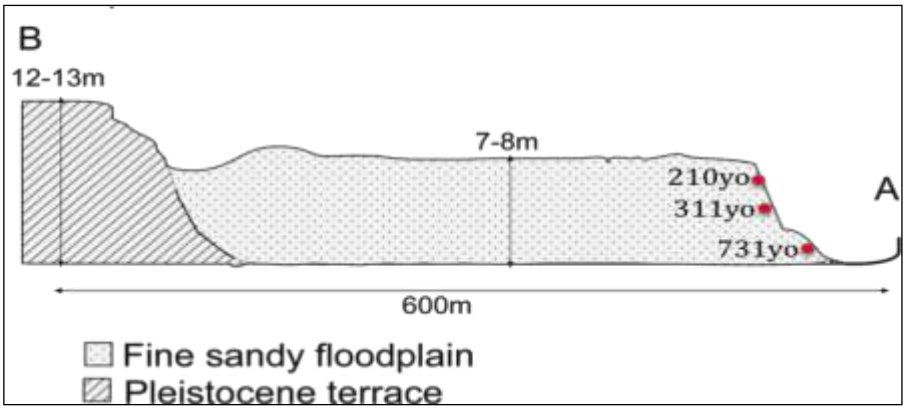

Figure 3. Cross-section at Greenpatch on the Mulgrave River indicates the contemporary floodplain is confined by a Pleistocene terrace with a distinct absence of sediments between 18ka and 731 years ago. Modern sediment accumulation of 7m has occurred over the last 700 years.

Policy Implications

The results presented on the Daintree and Mulgrave Rivers in this paper clearly indicate that the natural variability of potential sediment delivery to the GBR is an order of magnitude higher then previous estimates. Results indicate that floodplains are susceptible to rapid deposition followed by stripping of floodplain surfaces. These results contradict SedNet modelling (McKergow *et al.,* 2005) that reported over 90% of floodplains from rivers draining the GBR catchment accumulated sediments at a rate of less than 2mm/y or 2m over 1000 years with the majority having rates of less than 1m in 1000 years. Results presented in this paper indicate for the Daintree River that actual rates of floodplain accumulation could be as high as 5.5m over 600 years and with rates up to 2m over the last 60 years. A similar story can be seen on the Mulgrave River with up to 7m of accumulation over 700 years. Absence of sediments older then 1000 years on the contemporary floodplains of the Daintree and Mulgrave Rvers indicates that these floodplains are susceptible to episodic floodplain stripping events delivering large amounts of sediment to the system in a short period of time.

Examination of proxy records (Nott *et al* 2007*)* suggest the existence of centennial scale climatic variability in the magnitude of cyclones that could be driving observed patterns of floodplain development in the Daintree and Mulgrave Rivers. Terry *et al* (2004) found that there is a direct relationship between rapid floodplain deposition rates and the occurrence of cyclonic events in Fiji. It is possible that oscillations in the frequency of tropical cyclones and monsoonal activity are driving observed patterns of sediment deposition on the Daintree and Mulgrave River floodplains and this highlights the importance of understanding the long-term natural variability of these systems. Caution needs to be applied to the interpretation of sediment modelling results when prioritising management actions. While not deterring from the need to target known sub-catchment hotspots, it is also important to understand the underlying natural processes and their spatial variability between catchments.

This study also highlights some important water quality management issues that need to be taken into consideration by land managers when addressing actions of the RWQPP. Targets for the reduction of sediment loads to the GBR lagoon need to first consider the natural variability of floodplain deposition, catastrophic stripping events and implications that future climate change may also have on these systems. These challenges need to be addressed in policy and planning documents.

Detailed field investigations will provide the scientific basis for floodplain function models to aid in the identification of sub-catchment hotspots, identify potential lag times in sediment storage zones and aid in rehabilitating floodplain areas. This will assist in the development of realistic sediment targets to be developed in line with the RWQPP. These results will also aid in the development of Water Quality Improvement Plans which are listed as priorities under Strategy D ‘Planning for Natural Resource Management and Landuse’ under the RWQPP. In particular, results from the Daintree River can provide data for rigorous evaluation and potential calibration of SedNet modelled results for the Daintree catchment as outlined in the Douglas Shire Water Quality Management Plan (Action D4, RWQPP).

This study has allowed the examination of floodplain dynamics from a near pristine catchment, which indicated episodes of enhanced sediment and erosional activity prior to European disturbance of the area. Such episodes have not been previously considered. Results have shown that actual natural variation in sediment loads is far greater than previously reported for river systems in the Wet Tropics of Northern Queensland. Incorporation of this data will help meet the temporal and spatial deficiencies of current data sets for sediment and climate change models.

Conclusions

Results of this study suggest that Daintree and Mulgrave River floodplains are responding to cyclic shifts in monsoonal and cyclonic activity. The natural variability of pre-European settlement sediment deposition and erosion on floodplains of the Wet Tropics is much greater than previous estimates. The implications for potential sediment yields to the Great Barrier Reef from sudden floodplain stripping events could be catastrophic. With changing flood regimes under a future altered climate it is possible that these floodplain erosion thresholds could be exceeded sooner than might have otherwise been the case. A shift to a flood-dominated cycle of coastal river systems combined with the effect of European land-use practises will increase channel capacity, which could strip floodplains to accommodate these larger flood events. The resultant sudden large pulse of sediment delivered to these streams will have a dramatic impact on the instream ecology of these systems as well catastrophic effect to near shore marine environments. Understanding the natural variability of systems is important for future planning in the Wet Tropics of Northern Queensland.

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