ALLUVIAL GULLY EROSION: A LANDSCAPE DENUDATION PROCESS IN NORTHERN AUSTRALIA

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1. Introduction

Recent aerial reconnaissance surveys and subsequent remote sensing mapping of Australia's tropical rivers identified alluvial gully erosion as a key sediment source (Brooks et al. 2007; Knight et al. 2007). Gully erosion is found to varying degrees within alluvial river types in northern Australia, but it is most extensive on alluvial plains of the larger rivers like the Mitchell, Leichhardt and Nicholson Rivers, draining into the Gulf of Carpentaria. However, very little is currently known about gully erosion processes in these landscapes (Figure 1).

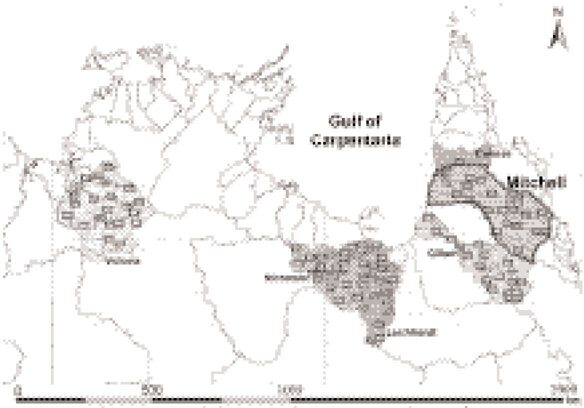

Fig. 1. Map of Catchments in Northern Australia showing the focus areas for a current mapping program. Boxes are remote sensing training sites.

2. Alluvial Gully Erosion Definitions

The definition of a gully is often ambiguous, but can be defined as an unstable eroding channel that expands upslope or laterally into previously un-channel surfaces (e.g., hillslopes, colluvium or alluvium) via surface or subsurface erosion (Schumm et al. 1984). The driving erosional forces of discharge and energy slope need to be greater than the resisting forces of boundary material (i.e., grain friction and cohesion, bed roughness, vegetation) for gully erosion to occur (Lane 1955). Gully complexes are here defined as actively eroding and expanding water catchments that contain a dense drainage network of micro- and meso-scale gullies nested hierarchically within larger macro-gully complexes. Alluvial gully complexes in northern Australian rivers develop in vast alluvial fan, terrace, and floodplains silt deposits of lower- and mid-catchment areas. They are broadly similar to bank gullies defined by Vandekerckhove et al. (2000), but very different in scale. The process of alluvial gully complex erosion appears to differ greatly in scale and process from the well documented, largely colluvial, gullies that abound in southern Australia (e.g., Prosser and Winchester 1996).

3. Alluvial Gully Erosion Processes

The high connectivity between alluvial gullies complexes and trunk rivers makes these features a significant sediment sources to the Gulf. New conceptual models of the processes driving these gullies, their morphology and the controls on their spatial distribution, are required if this process is to be adequately managed and parameterised into existing sediment budget models for northern Australia. A range of gully morphologies have been identified by remote sensing and ground reconnaissance (linear, continuous scarp, dendritic, amphitheatre) (Figure 2). In most of these gully forms, the active gully front is often parallel to the river channel, whereas erosion of the head scarp often migrates away from and perpendicular to the channel. The key feature of alluvial gully complexes is that multiple water sources contribute to erosion across the floodplain perirheic zone (sensu Mertes 1997), such as direct scour from river water, floodplain backwater from the main river, direct precipitation and runoff within the gully catchment, groundwater seepage at the gully head, and advected floodplain water (surface or subsurface) from distal sources.

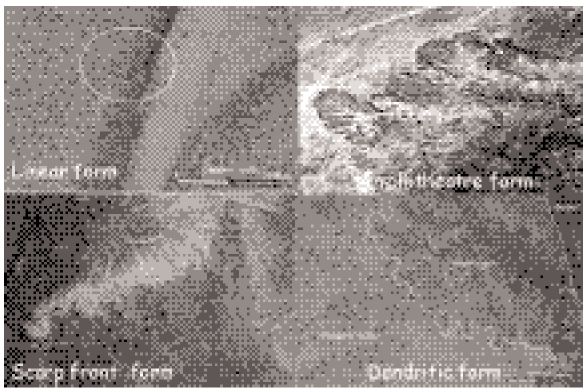

Fig. 2. Gully classification or typology from Brooks et al. (2007).

Our conceptual model outlines two dominant processes underpinning the array of gully forms: basal sapping and overland flow. The dominant process appears to be basal

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sapping, where saturated dispersible soils can erode in the absence of overland flow. Gully initiation, subsequent rate of activity, and morphological variability can be accounted for by the complex interplay between soil type, floodplain relief, vegetation, climate, fire regime, grazing pressure, river flow regime, inundation hydrology, and local rainfall within the context of these two primary driving processes. It is hypothesised that altered land use primarily associated with cattle grazing, altered fire regimes and increased road density, have accelerated gully erosion processes. In addition at the catchment scale, base level lowering of the channel relative to the alluvial surface appears to be the ultimate driver of gully activation.

4. Case Example: The Mitchell River Fan

The Mitchell River has a large catchment area (72,000 km^2) and drains from the western Great Dividing Range into the Gulf (Figure 1). The climate is seasonally wet with 95% of annual rainfall (800 to 2000mm) occurring from November to April. The lower Mitchell savannah plains consist of alluvial silts, sands and clays across a broad coalescing and ancient alluvial fan (Figure 3).

The major loci of deep, well developed gullying occurs within the upper, incised, and high-relief part of the Mitchell fan (M12 & M9 in Figure 3), and there is evidence to suggest a 2nd loci exists near the tidal interface (M2, M3), possibly driven by the hydro-isostatic adjustment identified by Rhodes (1980, p290) and sodic soils. In places, gullies of up to 5m or more in height (Figure 4) form continuous scarps along both high-floodplain margins for 10s of kms (Figure 5), locally occupying > 8% of the total alluvial land surface area. Preliminary field measurements recorded specific sediment yields of 1250 t/ha/yr from a single gully of around 1ha in size. Estimates of sediment production from the contemporary active floodplain within the Mitchell Fan (4200 km^2), suggests an annual sediment production rate of 11.5Mt/yr from gullying alone, equal to an average of 27 t/ha/yr across the fan.

Future research in the Mitchell will focus on additional on-the-ground quantification of alluvial gully erosion rates, processes, and driving factors (described above) at a subset of gully morphologies.

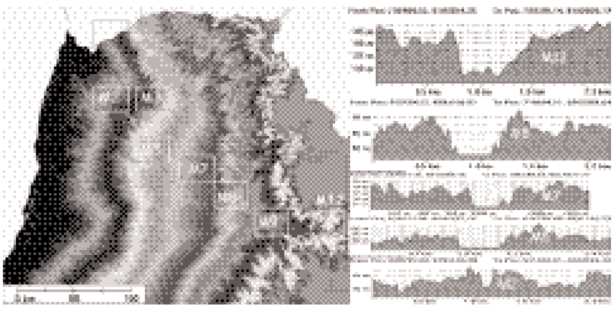

Fig. 3. 30m DEM of the Mitchell River alluvial fan showing zones of high, medium and low relative relief to the trunk river. Greyscale bands represent 10m contours.

Fig. 4. Ground photo of a gully head scarp in the Mitchell.

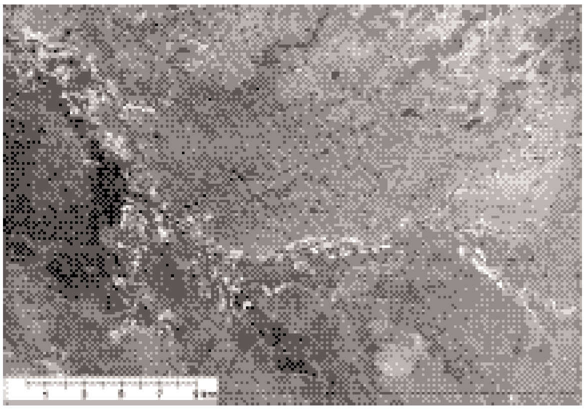

Fig. 5. ASTER image of M3 in Figure 3. Note white areas along river channels are gullies.

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