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Alluvial gully erosion: evolution, processes and management

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Abstract

Gully erosion is a globally significant form of land degradation, adversely affecting agricultural and rangeland productivity as well as downstream ecosystems. In northeast Queensland, Australia, substantial investments in alluvial gully remediation are being made to improve water quality within catchments draining to the Great Barrier Reef World Heritage Area. However, understanding of alluvial gully evolution, processes, and management strategies remains limited. This PhD project aims to investigate the long-term evolution of alluvial gullies, contemporary erosion processes, and the effectiveness of remediation strategies, focusing on the Upper Burdekin catchment. The research findings will inform alluvial gully management and contribute to reducing sediment runoff into the Great Barrier Reef's lagoon.

Introduction

Gully erosion is a significant land degradation process that leads to loss in land productivity, damages infrastructure, and degrades downstream ecosystems (Poesen et al. 2003). In northeast Queensland Australia, gully erosion accounts for approximately 40% of the total suspended sediment (<63µm) load delivered to the Great Barrier Reef (GBR) lagoon, posing a significant threat to the reef's health (Waterhouse et al. 2024). Growing concern about the deteriorating health of the GBR has prompted millions of dollars of investment over the past decade to improve catchment-scale water quality through gully remediation and other land management practices (State of Queensland 2018).

In this region, gullies are typically classified as either hillslope gullies or alluvial gullies. Hillslope gullies are typically linear and more isolated incisional features eroding into colluvium and are primarily driven by concentrated overland flow processes (Poesen et al. 2002). In contrast, alluvial gullies are erosional features entrenched into vast alluvial landscapes not previously incised since initial deposition (Brooks et al. 2009). In the GBR catchment, early sediment budget models assumed hillslope gullies were the dominant sediment source to downstream waterways (McKergow et al. 2005), and as a result, remained the primary focus of gully erosion studies and management practices (Wilkinson et al. 2018). More recent studies, however, recognise alluvial gullies as a dominant source of fine sediment delivered to the GBR lagoon (Brooks et al. 2021).

Despite this recognition, there remains a limited understanding of long-term alluvial gully evolution, contemporary erosion processes and rates, as well as the effectiveness of common remediation strategies. A comprehension of long-term dynamics is key to address issues concerning whether the contemporary rates of gully erosion are within the normal range or are accelerated due to land use, climate change or other anthropogenic factors. This PhD project will contribute to addressing each of these key knowledge gaps.

Methods

The research is focussed in the Upper Burdekin, a sub-catchment of the Burdekin Basin, identified as a major source of fine sediment delivered to the GBR lagoons (Bainbridge et al. 2024) (Figure 1). On-ground field studies will focus on a group of alluvial gully systems deeply incised into the Quaternary alluvium within 1km of the Burdekin River (Figure 2). The predominant soil types are Brown Chromosols and Brown Sodosols, characterised by highly dispersive subsoil horizons. The region experiences a dry tropical climate with annual average rainfall of 628mm, 80% of which falls during the wet season (October to March).

To achieve project aims, a range of methods will be applied (Figure 3). To obtain the minimum age of gully initiation, sediment stratigraphy and Optically Stimulated Dating (OSL) will be conducted following the method described by Lee et al. (2011). Historical gully expansion and lifetime volumetric loss will be quantified using the method described by Daley et al. (2021). Past land-use and climate proxies of the area will be analysed to investigate the factors driving gully development (Lewis et al., 2021). Temporal variation of gully development will be assessed to examine the growth model (Nachtergaele et al., 2002). An empirical approach will be adopted to assess the dominant factors and processes driving contemporary gully development, incorporating hydrological and water quality monitoring, terrain analysis, and erosion pin measurements. The effectiveness of alluvial gully remediation will be determined through a Before-After-Control-Impact (BACI) approach as described by Brooks et al. (2024).

Results

The project is in the preliminary stage and results are not yet available.

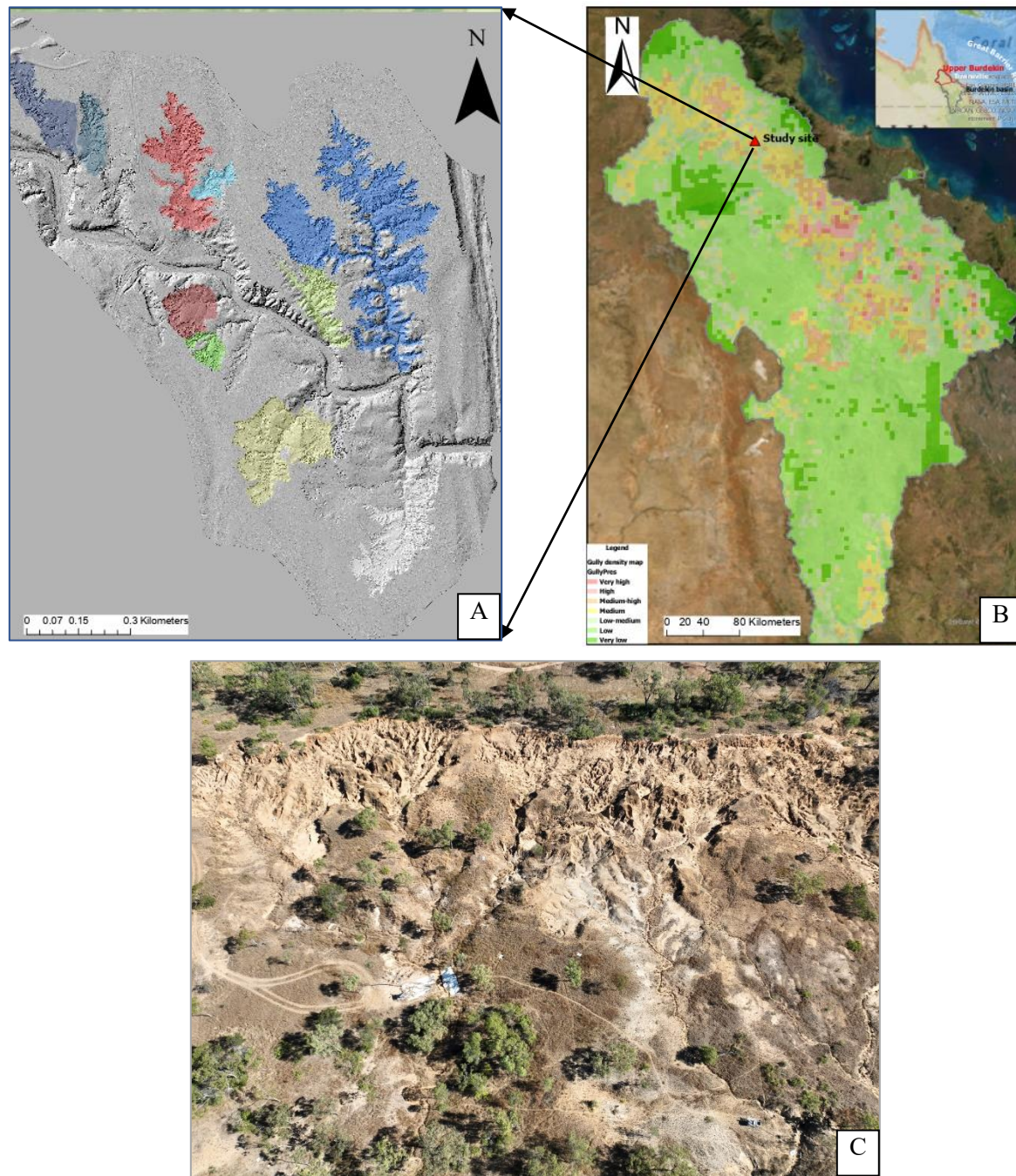


Figure 1 (A) Location map showing gullies in the study area. (B). Gully density map of the Burdekin catchment, modified from Tindall et al., (2014). (C) Picture showing an example of alluvial gully in the study area.

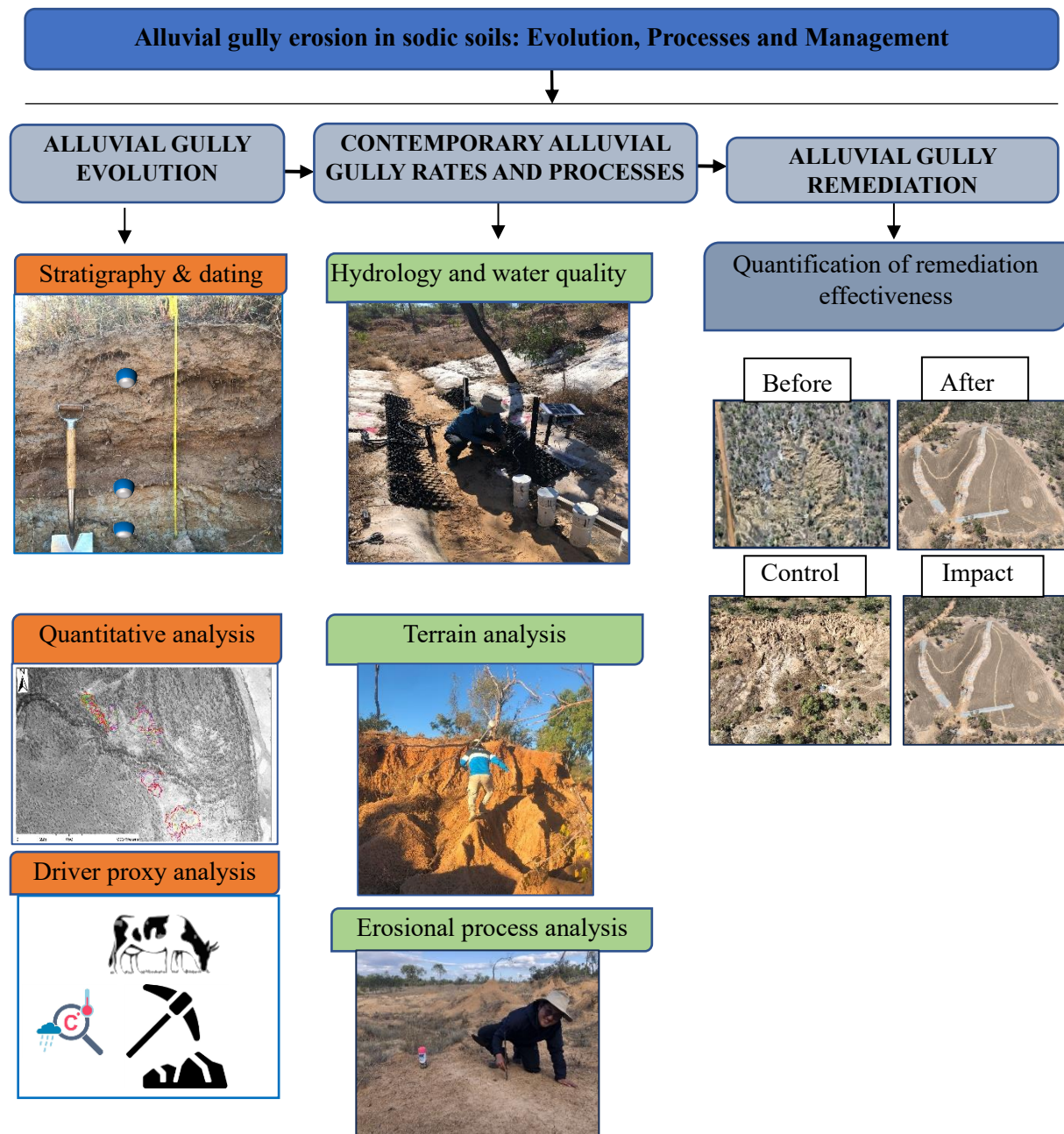


Figure 2. Schematic diagram showing different methods to be used for the study. Detail description in the text.

Discussion

The proposed research will enhance fundamental scientific understanding of alluvial evolution, contemporary processes, and remediation effectiveness. The study on long-term gully evolution will enhance understanding of key factors and processes influencing alluvial gully formation, long-term sediment yields, and potential future trajectories. The study on contemporary process and rates will enhance understanding into the current dynamics of alluvial gullies occurring in sodic soils, including an assessment of the quantitative relationship between different erosional processes and the sediment yield. The study on gully remediation will provide new insights into the effectiveness of various remediation approaches implemented within the alluvial gully system. The new data, knowledge and understanding generated

through this research will be of great value to a range of stakeholders involved in gully monitoring, modelling and management, both in Australia, and internationally.

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