8th International Symposium on Gully Erosion

Program

21-27 July 2019
Townsville Australia

Contents

1. Welcome 3
2. 8ISGE Committees 4
3. Conference Venue and Function Locations 5
4. Program 6
5. Our Sponsors Collection 15
6. Abstracts – Oral (by session) 16
7. Abstracts – Posters (alphabetical) 72
8. Attendees 119

1. Welcome

Welcome to Townsville and the 8th International Symposium on Gully Erosion.

Gully erosion is recognised around the globe as a significant source of sediment to stream systems, and a natural hazard that can be accelerated by climate change, extreme events, and human land-use. The scope of the 8th ISGE remains unique, in being focused on all aspects of this erosion phenomenon, which are represented by our four themes:

1. Gully erosion processes under climate and landuse forcing
2. Experimental and measurement techniques
3. Modelling, assessment and prediction
4. Management and prevention including social and economic aspects.

This will be the first ISGE in the southern hemisphere, and also the first ISGE to be held in the tropics – right next to the Great Barrier Reef. The previous ISGE was held in May 2016 at Purdue University in Indiana, USA. Earlier events in the series were in Belgium (2000), China (2002), USA (2004), Spain (2007), Poland (2010), and Romania (2013).

Gully erosion can be overwhelming for land holders to solve on their own. Sharing results of scientific studies in this symposium, and bringing together different disciplines to learn from each other, is how we can improve the understanding and management of gully erosion across the world.

In this region of Australia, gully erosion is an important issue because it is the largest source of fine sediments and associated nutrients to the Great Barrier Reef lagoon. Through catchment research, gully erosion control has become a priority of activities to improve coastal water quality. This has led to significant local interest in learning more about where and why it occurs, and about remediating, rehabilitating and preventing gully erosion. Many regions of the world share a story such as this.

A total of 129 people registered for the 8th ISGE, including 26 from China, 2 from Japan, 2 from India, 1 from Israel, 5 from Africa, 11 from Europe, 6 from North America and 76 from Australia.

Our program includes two full days of technical sessions followed by the mid-conference field trip and then a final day of technical sessions and workshops. Our thanks to the Scientific Committee for assisting with the preparation of the symposium program. The mid-conference field trip will take us to the large Burdekin River and a nearby 20 year research site where rehabilitation experiments have been underway. Getting into the field provides a great opportunity to discuss a wide range of research and management approaches with other participants. Some of you are joining us for a two-day post-conference field trip to some very large gullies and extensive remediation activities further afield in the Bowen River catchment.

I encourage you to make the most of this opportunity to meet others from afar. Please help us to make this the world's largest and friendliest gully erosion conference!

On behalf of the Organising Committee, I hope you enjoy your time in Townsville.

Scott Wilkinson

2. 8ISGE Committees

Organising Committee

Scott Wilkinson (Chair) (CSIRO)

Andrew Brooks (Griffith University)

Peter Gibson (NQ Dry Tropics)

Ian Rutherfurd (University of Melbourne)

Aaron Hawdon (CSIRO)

Tracey Rehbein (CSIRO)

Amy Warnick (CSIRO)

Scientific Committee

Robert Wells (Chair) (United States Department of Agriculture)

Sean Bennett (University at Buffalo)

Richard Cruse (Iowa State University)

Mary Nichols (United States Department of Agriculture)

Javier Casalí (Public University of Navarre)

Wojciech Zglobicki (Maria Curie-Skłodowska University)

Anita Bernatek-Jakiel (Jagiellonian University)

Valentin Golosov (Laboratory for Soil Erosion and Fluvial Processes)

Veena Joshi (University of Pune)

Yan Zhang (Beijing Forestry University)

Matthias Vanmaercke (University of Liège)

Zhengan Su (Institute of Mountain Hazards and Environment)

Carlos Castillo (University of Cordoba)

3. Conference Venue and Function Locations

4. Program

Sunday 21 July

Time	Details
15:00-17:00	Registration open - Rydges Southbank Convention Centre Foyer 23 Palmer St, South Townsville
17:30-20:00	Informal Networking Dinner, Townsville Yacht Club, 1 Plume St, South Townsville (optional and attendance only by those who registered)

Monday 22 July

Time	Details	
7:30-8:30	Registration open Rydges Southbank Convention Centre Foyer 23 Palmer St, South Townsville	
8:30-8:45	Welcome to Country	Brenton Creed Wulgurukaba Representative
8:45-9:00	Opening Address	Professor Paul Bertsch Queensland Chief Scientist
9:00-9:30	**Robert Wells**	**Keynote presentation: 7ISGE Review and Special Issue**
9:30-10:30	**Technical presentation Session 1** Chair: Scott Wilkinson	**Theme 1 – Gully erosion processes under climate and landuse forcing**
	Miguel Campo-Bescós	Towards a better assessment of the geometry of rills and gullies
	Yan Zhang	Rill and gully erosion on unpaved roads under an extremely heavy rainstorm on the hilly Loess Plateau
	Mary Nichols	Arroyo evolution in response to controlled floodplain runoff
	Anita Bernatek-Jakiel	Towards Better Understanding of Sediment Detachment from Soil Pipe Walls: a Case Study from the Bieszczady Mts., SE Poland
	Thomas Parkner	Landslide Activity as a Controlling Factor for Gully Development on Unstable Slopes in the Southern Mangaehu Catchment, North Island, New Zealand
10:30-10:50	**Morning Tea**	
10:50-11:50	**Technical presentations Session 2** Chair: Mary Nichols	**Theme 2 – Experimental and measurement techniques**
	Carlos Castillo	Recent evolution of gully networks under intensive agriculture in southern Spain
	Graeme Curwen	Sick of Digitising gullies? Try this semi-automated method
	Aaron Hawdon	An Assessment of Handheld Laser Scanning for the Rapid Survey of Gully Terrain
	Kevin Roots	An assessment of the Zeb-Revo laser scanner as a tool for monitoring gully erosion
	Henrique Momm	Automated Spatiotemporal Measuring of Ephemeral Gully Channel Lateral Expansion using Digital Photogrammetry in Laboratory Experiments
11:50-12:30	**Poster Session**	
Theme	**Presenting Author**	**Title**
1	Fils Makanzu Imwangana	Influence of infiltration at different pedological horizons on the process of triggering gully erosion in the Mont-Amba area (Kinshasa, DR.Congo)
1	Gang Liu	Quantifying successive development of interrill-rill-ephemeral gully erosion on hillslope
1	Mark Silburn	Which soils have the most gullies in the GBR catchments, Australia?
2	John Gallant	Lidar gully mapping in the Great Barrier Reef catchments

3	Mingchang Shi	Effect of Gully on Regional Soil Erosion
3	Joanne Burton	Sources of bioavailable particulate nutrients in a grazed rangeland, Bowen River Catchment, Australia
3	Chongfa Cai	Spatial distribution of Benggang in tropical and subtropical regions of south China
3	Ben Jarihani	Developing a multiple-parameter index of hydrological connectivity to identify erosion hotspots in the Upper Burdekin catchment
3	Jiang Qun'ou	Impacts of land use/cover change on soil erosion in Chaobai River Basin
3	John Spencer	A comparison of remote sensing techniques for measuring gully sediment yields and rehabilitation effectiveness
3	Justin Stout	Gully to stream channel transition zones and how to identify them
4	Ronald Bingner	Coordinated USDA–NRCS and ARS Ephemeral Gully Erosion Conservation Planning Technology
4	Andrew Brooks	One down, 200 to go: The effectiveness of large-scale alluvial gully rehabilitation in addressing Great Barrier Reef Water Quality
4	Carlos Castillo	Performance of a low-cost bioengineering approach for the rehabilitation of permanent gullies
4	Scott Wilkinson	A gully erosion control program to improve Great Barrier Reef water quality: Prioritisation and findings
12:30-13:20	**Lunch**	**Photo display**
13:20-14:00	**Matthias Vanmaercke**	**Keynote presentation: Modelling Gully erosion rates at regional and continental scales: Challenges and Opportunities**
14:00-15:00	**Technical Presentations Session 3** Chair: Carlos Castillo	**Theme 3 – Modelling, assessment and prediction**
	Miguel Vallejo Orti	Identification and monitoring of large gullies in Kunene Region- Namibia using Remote Sensing Products
	Yifan Dong	Different development erosion processes of valley floor and hillslope gullies indicated by different indexes in the black soil region of northeastern China
	Robin Thwaites	What Gully is That? Towards a Classification Scheme for Erosion Gullies in Queensland
	Mauro Rossi	Dynamic distributed gully erosion modelling and validation
	Shawn Darr	Improving gully density estimates for Great Barrier Reef catchments
15:00-15:20	**Afternoon Tea**	
15:20-16:20	**Technical Presentations Session 4** Chair: Zhengan Su	**Theme 4 – Management and prevention including social and economic aspects**
	Padmini Pani	Land reclamation and its Implications for Rural development: A Study of Chambal Badlands, India
	Yitbarek Tibebe Weldesemaet	Enhancing rural prosperity through gully rehabilitation; the case of Northern Ethiopia
	Xingyi Zhang	A novel reclaimed engineering for farmland damaged by gully erosion in Northeast China
	Sam Skeat	A production systems approach to point source sediment remediation - enhancing landscape function and farm resilience through erosion control
	Mike Berwick	Markets and science join forces to repair gullies
16:30	**Close**	
17:30-19:30		Behind-the-scenes evening at Reef Headquarters Aquarium Reef HQ, Flinders Street, Townsville Welcome by Dr David Wachenfield, Chief Scientist, Great Barrier Reef Marine Park Authority

Tuesday 23 July

Time	Details	
8:00-8:30	Registration open - Rydges Southbank Convention Centre Foyer 23 Palmer St, South Townsville	
8:30-8:35	Opening remarks	
8:35-9:15	**Susan Conway**	**Keynote presentation: What is eroding gullies on Mars?**
9:15-10:15	**Technical Presentations Session 5** Chair: Anita Bernatek-Jakiel	**Theme 1 – Gully erosion processes under climate and landuse forcing**
	Donghong Xiong	Changes in runoff energy, surface landform and sediment yielding during the bank gully erosion process in Dry-hot Valley Region, Southwest China
	Fenli Zheng	Apportioning contributions of individual rill erosion processes and their interactions on loessial hillslopes
	Glenn Wilson	Gully Formation due to Internal Erosion of Soil Pipes: Sediment Detachment and Transport in Soil Pipes
	E. V. (Tani) Taguas	Sediment transfer by rills and ephemeral gullies at the microcatchment scale: a study case to evaluate the impact of rainfall variability and management in a semi-intensive olive orchard in Spain
	Jack Koci	Linking gully erosion processes and hydrological connectivity in savanna rangelands tributary to the Great Barrier Reef
10:15-10:35	**Morning Tea**	
10:35-10:40		Introduction to Great Barrier Reef session
10:40-11:20	**Frederieke Kroon**	**Keynote presentation: Managing water quality in the Great Barrier Reef in the context of climate change and other disturbances**
11:20-12:20	**Technical Presentations Session 6** Chair: Javier Casalí	**Theme 4 – Management and prevention – GBR focus**
	Andrew Brooks	The significance of gully erosion as a dominant source of sediment pollution to the Great Barrier Reef; and the challenge ahead to reduce it
	John Day	Soil Conservation and Gully Erosion Control Projects in the inland Burnett Mary: Review 2013 to 2018
	Glenn Dale	Mt Wickham large-scale alluvial gully rehabilitation – approach and transferability
	Lynise Wearne	Innovative Gully Project – Finding cost effective and scalable solutions to reduce sediment into the Great Barrier Reef
	James Daley	Predicting future gully erosion from a single pass airborne LiDAR DTM: The Potential Active Erosion metric
12:20-13:20	**Lunch**	**Photo display**
13:20-14:00	**Greg Hancock**	**Keynote presentation: Lessons Learnt About Rill and Gully Erosion from a Landform Evolution Perspective**
14:00-15:00	**Technical Presentations Session 7** Chair: Matthias Vanmaercke	**Theme 3 – Modelling, assessment and prediction**
	Ronald Bingner	Enhanced Ephemeral Gully Erosion Technology Within AnnAGNPS to Assess the Impacts from Agricultural Management Decisions
	Javier Casali	Evaluation of AnnAGNPS for predicting ephemeral gully erosion in central Iowa (USA)
	Melanie Roberts	A mathematical model for the erosion of an ideal gully to inform interventions

	Ikenna Osumgborogwu	Ecogeomorphic drivers of gully-landslide interactions in the Ideato area of southeast Nigeria
	Mutian Yuan	Rainfall threshold of gully erosion under an extremely heavy rainstorm on the hilly Loess Plateau
15:00-15:20	**Afternoon Tea**	
15:20-16:20	**Technical Presentations Session 8** Chair: Yan Zhang	**Theme 2 – Experimental and measurement techniques**
	Nigussie Haregeweyn	Comprehensive gully erosion characterization, monitoring and modelling: case studies from three contrasting sites in the Upper Blue Nile basin
	Nicholas Doriean	Suspended sediment monitoring in ephemeral alluvial gullies: laboratory and field evaluation of available measurement techniques
	Robert Wells	Field scale evaluation of temporal erosion patterns using high spatial resolution drone imagery
	Hao Li	Evaluating gully wall slope angle impact on DEM error derived from structure-from-motion (SfM) photogrammetry using vertical images
	Rebecca Bartley	Measuring the effectiveness of gully remediation on off-site water quality in the Burdekin catchment, Queensland, Australia
16:20-17:20	**Poster session**	
Theme	**Presenting Author**	**Title**
1	Greg Hancock	Gully erosion and post-mining landscapes: modelling patterns and trends in an undisturbed catchment
1	Padmini Pani	Dynamics and Characteristics of Ravine: A Study of Semi-Arid India
1	Ian Rutherfurd	Gully rejuvenation by debris flows in forested catchments of southeast Australia: landscape change linked to drought, wildfire and ENSO
1	Jie Tang	Quantitative Analysis of Characteristics for Farmland Gullies in Northeast Black Soil Region of China
1	Matthias Vanmaercke	Does the topographic threshold concept explain the initiation points of sunken lanes in the European loess belt?
2	Ben Jarihani	Gully Networks Detection by integration of Machine Learning and Geographic Object-Based Image Analysis
2	Dan Yang	Impact of soil type and physicochemical properties on gully development within land consolidation terrace slopes in the Dry-hot valley region, China
3	Simon Walker	Multi-Resolution Mapping of Gully and Channel Extent and Future Risk from Digital Elevation Models
3	Mauro Rossi	Gully head modelling in Mediterranean badland areas
4	Rebecca Bartley	The effectiveness of gully remediation on runoff and sediment loss
4	Alexandra Garzon-Garcia	The effect of gully rehabilitation on carbon and nutrient export during a high-flow event at Crocodile Gap Rehabilitation site – Normanby catchment, Australia
4	Jianbin Guo	Study on soil and water conservation benefit in different vegetation types of karst area in Danjiangkou Reservoir Area in China
4	Rohan Lucas	Is it worth it? Where and when should we be investing in gully remediation
4	Lisa Hutchinson	Developing a Cost-Effective and Prioritised Approach to Gully Remediation in the Bowen, Bogie and Broken Catchments
4	Estela Nadal-Romero	Two examples from southern Spain of gullied areas affected by land use changes: implications in gully network
17:20	**Close**	

Wednesday 24 July - Virginia Park Field Trip

The Virginia Park Field trip is an all-day trip beginning at 7:00AM and concluding at 4:30PM. All attendees are required to wear closed shoes (no sandals, thongs or flip flops) as there will be some short walking (~100-200 m) through bushland.

Although it is winter time, it is recommended that attendees wear a wide brimmed hat, long pants and a long sleeved shirt for sun protection. Please bring your water bottle, and a snack box will be provided to each person before boarding a bus and lunch will be provided at the Virginia Park station homestead. Sunscreen and additional drinking water will be available at each stop.

Background

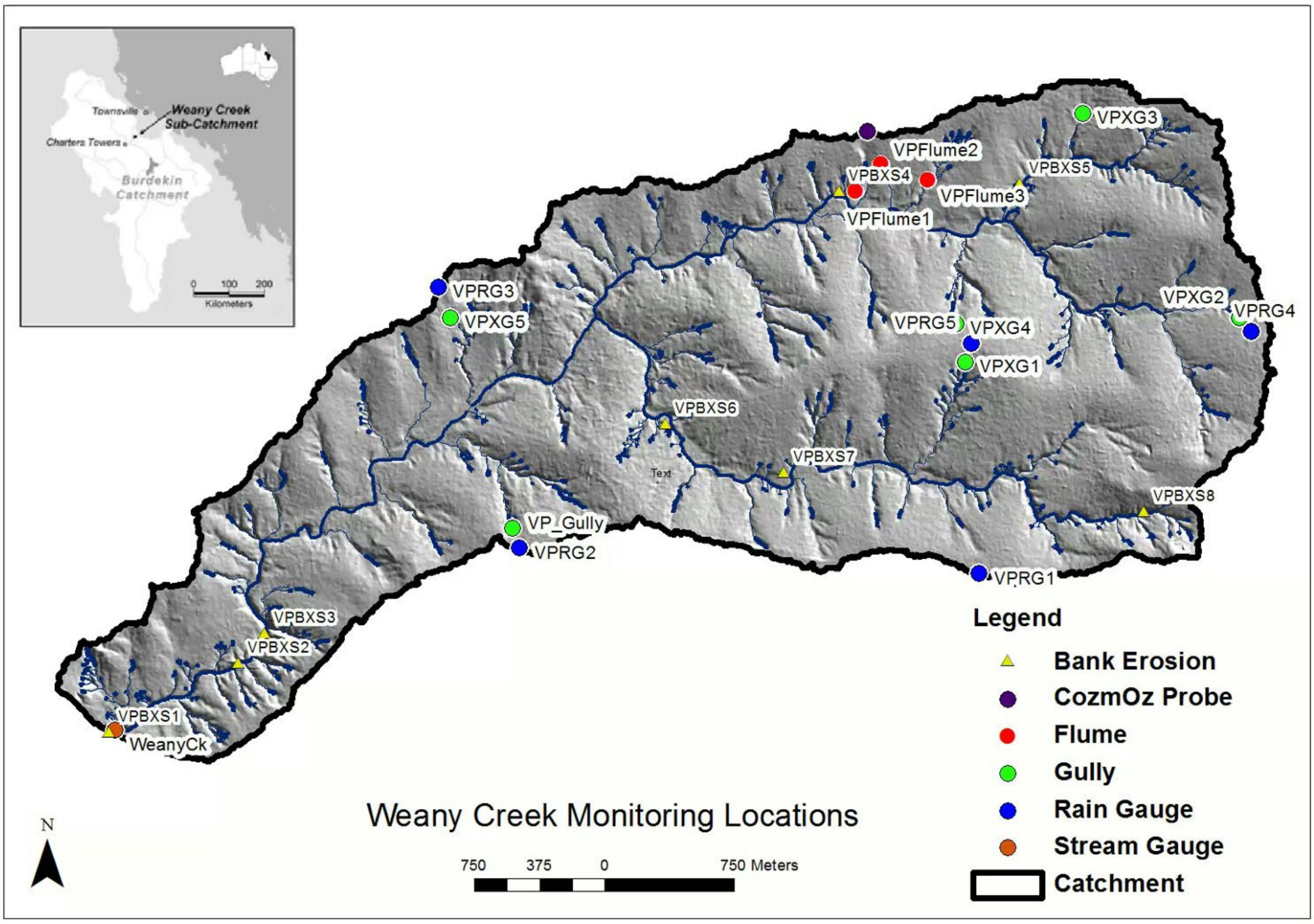
This tour takes us to the Burdekin River which is the fifth largest river catchment in Australia. It is an important regional water supply and the highest exporter of fine sediment to the Great Barrier Reef lagoon.

We will enjoy the hospitality of the Bennetto family, the owners of Virginia Park Station, a commercial grazing property within the Burdekin basin, and host to over 20 years of scientific research activity.

Here we will explore the gullies of the Weany Creek catchment to examine the spatial patterns and temporal dynamics of the landscape, measurement techniques, sampling approaches, instrumentation systems and modelling methods, and share some recent research results.

Participants will also gain insight to the challenges faced by land holders, approaches used by regional natural resource managers, and the value of long-term scientific research.

Figure 1 Weany Creek research catchment



Virginia Park Field Trip Summary Itinerary
(see separate Field Trip Program booklet for more details)

Stop	Time	Location	Notes
	7:00 AM	Assemble at Rydges Hotel	23 Palmer St, South Townsville QLD 4810
	7:30 AM	Depart Rydges	Discussion points on buses
Flood Markers	9:00 AM	Macrossan Bridge Scott Wilkinson (CSIRO)	Catchment Science in the Burdekin 1. Overview of research sites and programs across the region. 2. Recent floods, source tracing, sediment budget modelling and river load estimates.
1	10:00 AM	Virginia Park Station: VPG0/NESP Control 1. Anne Henderson (CSIRO) 2. Jack Koci (USC) 3. Rebecca Bartley (CSIRO)	Long term Gully Monitoring/NESP Control site 1. Monitoring methods – Gully Chronosequence – Erosion measurement, land condition, water quality 2. Structure from Motion survey methods 3. Program Overview – History of monitoring – NESP project
2	11:00 AM	Virginia Park Station: Weany Creek Gauge Aaron Hawdon (CSIRO)	Weany Creek Gauge – River monitoring purposes, techniques for remote locations. – Weany Creek Sediment budget. – Comparison with other study catchments.
3	11:30 AM	Virginia Park Homestead Rob Hunt (NQ Dry Tropics)	Meet and greet Bennetto family Grazing, gullies, soils and landholder engagement – overview of NQ Dry Tropics programs.
	12:00 PM	**Virginia Park Homestead**	**Lunch**
4 and 5	1:00 PM	**Virginia Park Station:** **Group 1:** VPG5/NESP Treatment: Scott Wilkinson (CSIRO) **Group 2:** VPFlume 1: Grazing management and Hillslope hydrology: Anne Henderson (CSIRO) Brett Abbott (CSIRO) Aaron Hawdon (CSIRO) (30 min each site and 30 min swap over)	**Group 1:** – Overview of gully remediation, evolution of gully 5 (projects focus through time). – Hillslope gully remediation / Reef Trust Toolbox. **Group 2:** – Changes in cover and pasture species, hillslope runoff and sediment loss at the site. – Impact of grazing practices on above – general context and regional assessment. – Cosmic-ray neutron soil moisture sensor
6	2:30 PM	**Virginia Park Station:** Grazing trials and practices Matt Bennetto (Virginia Park Station) Sam Skeat (NQ Dry Tropics)	**One Group** – Planned grazing practices that improve water quality. – Utilisation and recovery cycles. – Priority infrastructure requirements.
	3:00 PM	Depart Virginia Park Station	
	4:30 PM	Arrive Rydges	

Thursday 25 July

Stop	Time	Location	Notes
8:00am	Registration open - Rydges Southbank Convention Centre Foyer 23 Palmer St, South Townsville		
8:30-8:40	**Opening remarks**		
8:40-9:20	**Estela Nadal-Romero**	**Keynote presentation: Rethinking gullies and badlands dynamics: interactions between vegetation, water and soil erosion**	
9:20-10:20	**Technical Presentations Session 9** Chair: Robert Wells	**Theme 1 – Gully erosion processes under climate and landuse forcing**	
	Zhengan Su	Impacts of native vegetation on erosion rates and hydraulic properties of bank gullies in the Dry-hot Valley region of southwest China	
	Amir Mor-Mussery	The influences of dammed gullies on the ecology of a cultivated arid area, Project Wadi Attir (PWA): A case study	
	Yiyang Zhao	Thresholds conditions for rill and gully initiation on road surface on the Loess Plateau	
	George Olivier	The impact of ploughed contours on hillslope hydrology and gully erosion – a field-scale case study in the Swartland, South Africa	
	Guang-hui Zhang	Effects of vegetation restoration on soil erodibility and its temporal variation at steep gully slopes	
10:20-10:40	**Morning Tea**		
10:40-11:20	**Xiaobing Liu**	**Keynote presentation: Gully Erosion and Control Practices in Northeast China**	
11:20-12:20	**Technical Presentations Session 10** Chair: Scott Wilkinson	**Theme 4 – Management and prevention including social and economic impacts**	
	Matthias Vanmaercke	Gully prevention and rehabilitation: a review	
	Rebecca Watson	Understanding Demographics of Current Reef Trust II Participants Enables a Targeted Approach to Gully Remediation	
	S Kala	Mitigation of Soil Erosion and Management of Gullied Lands through Bamboo Based Bioengineering Technology in Central India	
	Alexandra Garzon-Garcia	Understanding the Sources of Bioavailable Particulate Nutrients from within Gully Systems: a conceptual framework	
	Ayalew Talema	Survival and growth analysis of multipurpose trees, shrubs and grasses used to rehabilitate badlands and gullies in the sub-humid tropics	
12:20-12:50	**Poster session**		
Theme	**Presenting Author**	**Title**	
1	Zhanli Wang	Modelling interrill and rill erosion processes on steep hillslopes	
1	Ji Xiaodong	Experiment on influence of vegetation coverage and rainfall intensity on the artificial slope soil loss	
1	Qingwei Zhang	Identifying sediment transport capacity of raindrop-impacted overland flow within transport-limited system of interrill erosion processes on loess hillslopes of China	
2	Mike Saynor	Method Development for Measuring and Monitoring Gully Formation Using Drones	
2	Qiong Zhang	Using rare earth elements to monitor ephemeral gully erosion processes	
2	Fenli Zheng	Discrimination of soil losses from ridge and furrow in longitudinal ridge-tillage	

Theme	Presenting Author	Title
2	Peter Zund	The optimum soil dispersibility measure
3	Robert Wells	Laboratory and field simulated gully erosion using a physically-based numerical model
3	Scott Wilkinson	Predictive modelling to understand areas at risk of gully erosion in basins draining to the Great Barrier Reef
3	Xihua Yang	Effects of DEM resolution on soil erosion modelling
3	Xuexia Zhang	Assessment of gully erosion susceptibility in Zoige wetland of China
3	Robin Thwaites	What is Where? Material Mapping Methods for Queensland Alluvial Gullies
4	Timothy Pietsch	Reef Credits Gully Methods
4	Matthias Vanmaercke	Prevention and Mitigation of Urban Gullies in D.R. Congo: Lessons learned from Failures and Successes
4	Jack Koci	Rehabilitation outcomes using check dams and livestock exclusion in hillslope gullies, northeast Australia

<table>
<tr><th>12:50-13:40</th><th colspan="2">Lunch</th></tr>
<tr><td rowspan="2">13:40-14:50</td><td colspan="2">Best Practice Workshops (Detail on following page)</td></tr>
<tr><td>Room 1
Defining best practice principles for rehabilitation, remediation and prevention
• Scenario of current challenges and approaches - large gully remediation (Damon Telfer)
• Introduction to workshop process (Ian Rutherfurd)
• Working in table groups</td><td>Room 2
Defining best practice principles for terrain measurement
• Current challenges and approaches
• Introduction to workshop process (Rebecca Bartley)
• Working in table groups</td></tr>
<tr><th>14:50-15:10</th><th colspan="2">Afternoon Tea</th></tr>
<tr><td></td><td>Defining best practice principles for rehabilitation, remediation and prevention
• Facilitator will recap after the break
• Prepare report-back material</td><td>Defining best practice principles for terrain measurement
• Facilitator will recap after the break
• Prepare report-back material</td></tr>
<tr><td>16:00-16:50</td><td colspan="2">Reconvene in Plenary
Each workshop table group will give a 4 minute report
A summary of workshop outcomes will conclude the session</td></tr>
<tr><th>16:50-17:00</th><th colspan="2">Program close</th></tr>
<tr><td>18:00</td><td colspan="2">Banquet Dinner at the Townsville Brewery, 252 Flinders St, Townsville
Dinner Speaker: Dr Paul Hardisty, Chief Executive Officer, Australian Institute of Marine Science</td></tr>
</table>

Best Practice Workshops

The meeting of the global gully erosion research community at the ISGE represents a unique opportunity to consolidate and update what defines best practice in research and management. These workshops will broaden understanding of new advances presented at the symposium, and facilitate forming collaborations on areas of mutual interest.

One simple definition of best practice is ‘what the experts said should have been done’ in a court case. Few successes or failures end up in court, and the resources available to solving an individual research or management problem are limited. However, there are clear principles by which best practice can be defined, which can provide guidance to humanity as it faces the challenges of gully erosion.

Our challenge is to work collaboratively to develop best practice principles that assemble meaning from the experiences we have developed in each site and region, in a range of environments and landscapes and land use contexts. Key questions will include defining how the symposium has changed our understanding of best practice and what we will do differently as a result.

Based on early expressions of interest the Organising Committee has developed two workshops which are aligned with two of the symposium themes:

1. Defining best practice principles for rehabilitation, remediation and prevention

   What processes do we go through in approaching the rehabilitation or remediation of a gully and why, what do we need to know, on what do the decisions depend, what defines the point beyond which there are diminishing returns?

2. Defining best practice principles for terrain measurement and analysis

   Terrain measurement has been revolutionised in the past two decades and continues to rapidly evolve. Erosion pins and optical levels have been joined by laser and photography techniques, airborne and ground based platforms for constructing digital elevation models and measuring change in terrain. Approaches vary in their speed, precision and cost. What are the fundamentals which underlie the options available? What guides our decision-making about when to apply each, can we map the strengths and weaknesses of common approaches?

We have two hours to achieve this challenge.
Each workshop will commence with a brief presentation by your facilitator to set up the workshop approach. The majority of work will be done in table groups. We will pause for a refreshment break mid-way, and come together for a plenary reporting session afterwards.

5. Our Sponsors

Gold

Proudly sponsored by

Silver

Bronze

Supporting

6. Abstracts – Oral

Gully erosion processes, disciplinary fragmentation, and technological innovation

Sean Bennett[1], **Robert Wells**[2]
[2]National Sedimentation Laboratory, USDA-Agricultural Research Service, Oxford, MS, USA.

(This abstract is reproduced from the introduction to the Special Issue of Earth Surface Processes and Landforms which was produced following the 7th ISGE: Gully Erosion: Integrating Monitoring, Modelling and Management).

The development and evolution of gullies on soil-mantled hillslopes can devastate agricultural regions and cause widespread soil and landscape degradation. Since 2000, international symposia have been organized to address gully erosion processes, and this paper and special issue provide additional context for the 7th International Symposium on Gully Erosion held at Purdue University in 2016. Several important themes of gully erosion emerged during this symposium that warranted additional discussion here. These topics include the importance and impact of technology transfer, disciplinary fragmentation as an impediment for research advancement, the difficulty in defining the erodibility of sediment within gullies, and the opportunities afforded by remote sensing technology. It is envisioned that such symposia will continue to enhance the capabilities of researchers and practitioners to monitor, model, and manage these important geomorphic processes and to mitigate landscape degradation.

Towards a better assessment of the geometry of rills and gullies

Elena Zubieta [1], **Javier Casalí** [1], **Carlos Castillo** [2], **Miguel Angel Campo-Bescós** [1], and **Rafael Giménez** [1]
[1] Public University of Navarre, Department of Engineering, Los Olivos Building, 31006 Pamplona, Spain
[2] University of Cordoba, Dept. of Rural Engineering, Campus Rabanales, Leonardo Davinci Building, 14071 Cordoba, Spain

The morphological characterization of eroded channels is essential in rills/gullies erosion studies. The most usual procedure employed to characterize these channels is the measurement of width and depth. With data on the length of the channel, volume estimations of the eroded soil can also be determined.

The most significant problem regarding this morphological characterization is the exactitude of the width and depth values of the channel. Width is usually defined from an imaginary line that connects both extremes of the cross section of the channel, where abrupt changes in slope occur. But these extremes are not always clear or evident. The same occurs with depth, generally defined as the vertical distance between the lowest point of the profile and the imaginary straight line that represents width. However, when the cross sections present irregular bottom, consideration of the minimum elevation point as representative of an entire section is questionable. Therefore the characterization of a cross section of an erosion channel, especially the determination of its width, is conditioned by the individual perception of the investigator. Repetitiveness of measurements is consequently affected. The latter could be rectified through the use of mathematical algorithms (e.g., Optimal Lid Method), which enable the objective morphological characterization of all types of cross sections.

But the only objective and unequivocal manner to define the morphology of an erosion channel is by overlapping, in any point along the bed, the elevation profiles before and after erosion. The section width is determined by the intersection points of both profiles, and the cross section is defined by the area between both profiles. Nevertheless, topographical information before the erosion process is rare.

The study presented herein carries out a detailed characterization of eroded rills from DEMs (from photogrammetry), before and after the formation of these channels. These rills were experimentally obtained in situ from different combinations of slope and flow. The morphological parameters therefore defined (width and depth) –reference values– were compared with those defined only from the rill's DEMs, according to the judgment of selected experts. These results were compared with those obtained from the Optimal Lid model. Hundreds of cross sections defined by different procedures were analyzed.

The first results demonstrate an important discrepancy between the experts consulted. The variation coefficient (CV) in the measurement of the width of the different sections was ca. 9%. Besides, the width average value determined by the experts was mostly and curiously overestimated in around 35% which determined an even higher overestimation of the cross section area (67%). This study quantifies, for the first time, the experimental error –and to a large extent, unnoticed– embedded in the definition of the width of erosion channels.

Rill and gully erosion on unpaved roads under an extremely heavy rainstorm on the hilly Loess Plateau

Yan Zhang[1, 2,] Yiyang Zhao[2], Baoyuan Liu[3*], Zhiqiang Wang[3], Shuai Zhang[3]

[1] Forest Ecosystem Studies, National Observation and Research Station, Jixian, Shanxi, China

[2] College of soil and water conservation, Beijing Forestry University, Beijing, China, 100083

[3] Beijing Normal University, Beijing, 100875

ABSTRACT

Severe soil erosion is common on the hilly Loess Plateau, and rainstorms often cause rill and gully erosion on unpaved roads built to carry traffic not only for farming but for petroleum and natural gas extraction operations. A heavy rainstorm and flood disaster occurred in the region on July 26–27th, 2017, inducing serious road erosion. Road erosion was investigated in two small watersheds close to the storm center, within which to measure rill and gully erosion on three types of road in the field and investigate the factors influencing that erosion with remote sensing images and GIS. Google images before the storm and UAV images after the storm were used to interpret land uses and to measure geomorphological and vegetation factors.

The results showed that: (1) In 579 road cross-sections within the 63 road erosion segments found along the 10.42 km length of roads surveyed, the average soil loss was 804.77 t/ha from main unpaved roads, 471.78 t/ha from secondary unpaved roads, and 147.46 t/ha from trails. (2) Gully erosion was predominant over rill erosion on all three types of road. Average rill erosion was 0.41 cm, 0.17 cm and 0.02 cm, in contrast with 4.88 cm, 3.15 cm and 1.05 cm of gully erosion on the main unpaved roads on secondary unpaved roads and trails, respectively. (3) The contributing area was dominant over other factors relating to road erosion under heavy rainfall and could explain 84.9% of the erosion from the road segment to which it drains based on linear regression analysis. Furthermore, a nonlinear regression model with the contributing area and road segment gradient as predictors was found to predict road erosion very well, with a coefficient of determination of 0.970.

Keywords: road erosion; rill; gully; rainstorm; drainage area; Loess Plateau

Arroyo evolution in response to controlled floodplain runoff

Mary Nichols

USDA-ARS Southwest Watershed Research Center, Tucson, USA

Arroyos are characterized by steep, vertical banks with high energy gradients along their incised channels. Once incised, arroyos widen through lateral channel bank erosion caused by both mass wasting and gullying. Gullies then continue to advance through the adjacent former floodplain as surface runoff cascades over the head and side walls. In southern Arizona, USA, many of the most productive grasslands are found on alluvial floodplains, and preventing their erosion is critical to ecosystem health and wildlife habitat, as well as to commercial ranching operations. Typically, bank erosion is controlled by constructing long, earthen berms on the former floodplain parallel to the incised channel to prevent runoff from reaching the channel bank. Managing and maintaining the berms are ongoing tasks. Although general models of arroyo evolution are available to describe expected changes, new information is needed to understand and manage arroyo evolution under conditions of controlled floodplain runoff.

In this study, rates of gully advance and channel widening in unprotected channel reaches were quantified in comparison with reaches that have been treated with lateral berms since the 1930s. The study reach is a 33 km long section of Altar Wash in the Altar Valley watershed, which is a semiarid basin that drains from the US-Mexico border north into southern Arizona. The watershed is bisected by an entrenched axial arroyo that formed in the early 1900's.

Remotely sensed data, including aerial photography and LiDAR point clouds, were used to inventory and map berms and gullies and to quantify multi-decadal rates of gully advance. This analysis was complimented with field measurements of gullies, channel geometry, and sediment. Approximately 65% of the overall channel reach is protect by earthen berms on at least one bank. A total of 44 earthen channel bank protection berms with an average length of 900 m (ranging from 54 - 5,246 m) were identified, and 50% of these berms are breached in at least one place. In protected channel reaches, lateral gully advance is controlled, and the threat of bank erosion from above is minimized. However, over the last few decades, channel sinuosity has increased and new discontinuous floodplains are forming on coarse sediment deposits within the arroyo. These deposits are a control on lateral channel position. Arroyo walls are now vulnerable to erosion from below as banks are eroded where channel meanders impinge on the channel bank. This new information is important because current management is focused on preventing surface runoff from reaching channel banks with minimal attention to the erosion threat from within the channel.

Towards Better Understanding of Sediment Detachment from Soil Pipe Walls: a Case Study from the Bieszczady Mts., SE Poland

Anita Bernatek-Jakiel[1], Jiří Bruthans[2], Michał Jakiel[1], Mateusz Stolarczyk[1]

[1]Institute of Geography and Spatial Management, Faculty of Geography and Geology, Jagiellonian University, Kraków, Poland
[2]Institute of Hydrogeology, Engineering Geology and Applied Geophysics, Faculty of Science, Charles University, Prague, Czechia

Gullies are initiated and transformed not only by surface erosion processes, but also by subsurface ones such as soil piping. Soil pipes develop under various climatic, lithological, pedological and land use conditions suggesting different mechanism that leads to soil dispersivity and erodibility. Until now, the processes involved in particle and aggregate detachment from soil pipe walls have not been well studied. Therefore, the aims of this study are (i) to recognize the factors responsible for cohesion in the tested soils (Cambisols and Gleysols), and (ii) to identify the processes which are likely responsible for disintegration of material. Once the material loses the cohesion, it can be easily eroded and transported along existing macropores, which may result in soil pipe formation.

The study area is located in the Cisowiec catchment, the Bieszczady Mts. (SE Poland), where soil pipes develop in Cambisols and Gleysols, characterized mainly by silt loam texture. The study involved fieldwork and laboratory analyses and experiments. Detailed terrain mapping was carried out in order to identify piping-related forms. Two soil profile pits were made in the sinkhole (i.e. the place of a pipe roof collapse), and one, as a reference, on the slope without soil pipes. The soil pits were excavated and described based on the FAO recommendations and the soils were classified using the WRB system. Additionally, the tensile strength was measured in the field. The main soil properties were analysed in the laboratory using standard pedological methods (i.a., soil structure, consistence, content of coarse fragments, colour, soil texture, bulk density, total porosity, pH, $CaCO_3$ content, organic matter content, exchangeable cations).

Disintegration of soils in water in atmospheric pressure was tested under various moisture conditions prior flooding by water, Wallers solution and Wallers solution without sodium bicarbonate. Samples were flooded and it was observed whether the material disintegrates, how fast, how large are the resulting particles and if particles disintegrate into angle of repose or the lumps keep subvertical or vertical sides underwater.

The cohesion of tested soils may be caused by the organic matter content, polyvalent metal cations such as Ca^{2+}, Fe^{3+}, and Al^{3+}, oxides and hydroxides of Fe and Al, Ca and Mg carbonates, and clays. The results have suggested that the removal of FeO_x and $Fe(OH)_x$ may be responsible for the loss of cohesion. The anoxic water may dissolve and leach Fe and Al along dominant flow paths leading to the disintegration and increase of macropore/pipe diameter. In future, the clay minerals will be analysed in order to show their role in soil aggregate stability.

The study is supported by the National Science Centre, Poland within the project SONATINA 1 (2017/24/C/ST10/00114) and the PROM Programme – International scholarship exchange of PhD students and academics financed by the Polish National Agency for Academic Exchange.

Landslide Activity as a Controlling Factor for Gully Development on Unstable Slopes in the Southern Mangaehu Catchment, North Island, New Zealand

Thomas Parkner[1]

[1]University of Tsukuba, Tsukuba, Japan

The East Coast of the North Island of New Zealand is a region sensitive to gully erosion and landsliding characterized by high natural erosion rates magnified by rapid anthropogenic activity. In this region, the highest values for specific soil loss by gully erosion were documented worldwide. The term gully complexes was coined there for such gullies which are initiated by incision of water erosion and further enlarge by mass movements due to oversteeping gully walls. Gully development was analysed in terms of the factors land use change, rainfall intensity, material, and topographic thresholds. As gully erosion occurs in a landscape affected by widespread landsliding, in this study, the effect of landslide activity is related to gully development.

The study area includes nine steep headwater catchments in the Southern Mangaehu Catchment located in the East Coast Region of the North Island, New Zealand. The areas of the steep catchments range between 1.1 and 25 ha. Bedrock consists of Cretaceous, highly crushed and sheared mudstones and sandstones. Native forest was removed at the beginning of the 20th century for pastoral farming with shrubs invading since 1990s and partial plantation in eucalyptus in 2011.

Aerial photography taken in 06.1939, 04.1957, 09.1971, 06.1988, 05.2005, and 01.2012 were interpreted and digital elevation models were extracted from the aerial photography from 1957 using ERDAS to map landslide distribution before the gully erosion phase starting shortly before the earliest photography of 1939 and to analyse the development of gullies and gully complexes.

Mapping results show that the steep study area was affected by the landslide types slumping, flows, and deep-seated slides prior to the current gully erosion phase. Six initial, linear gullies with typical widths of 5 m and lengths from 91 to 221m were present on the imagery of 1939. Except of one catchment, all others were eroded by gullies during the study period. Only two out of the eight gullies developed into gully complexes in seven decades. The other six linear gullies were either a) destructed by large-scale deposits of slides or flows, or, b.) temporarily infilled and later re-incised to similar size, or c.) remained at a similar size due to continuous material supply by flow deposits. These results indicate that next to the controlling factors land use, rainfall, and material the factor landslide activity needs to be added to understand gully development on unstable slopes. The reactivation degree of older landslide deposits determines whether linear gullies are destructed or are competent to develop into larger gully complexes.

Comprehensive gully erosion characterization, monitoring and modelling: case studies from three contrasting sites in the Upper Blue Nile basin

Nigussie Haregeweyna, Mesenbet Yibeltalb, Muatu Liyewb, Atsushi Tsunekawac, Mitusru Tsuboc , Ayele Alimaw Fentac, Derege Meshesha Tsegayed, Matthias Vanmaerckee

[a]International Platform for Dryland Research and Education, Tottori University, 1390 Hamasaka, Tottori 680-0001, Japan

[b]The United Graduate School of Agricultural Sciences, Tottori University, 1390 Hamasaka, Tottori 680-8553, Japan

[c]Arid Land Research Center, Tottori University, 1390 Hamasaka, Tottori 680-0001, Japan

[d]College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia

[e]Department of Geography, Université de Liège, Belgium

We studied the morphological characteristics, long term dynamics and potential controlling factors of gullies found in three agro-ecologies of the Upper Blue Nile basin, Ethiopia: highland (Guder), midland (Aba Gerima), and lowland (Dibatie) sites.

About 94 gullies distributed in the three sites (Aba Gerima = 33, Guder = 36, and Dibatie = 25) were morphologically characterized using field measurements in 2017 & 2018. The characterization was complimented with the assessment of gully development over the last 57 years using remotely sensed data. Moreover, gully head retreat and sediment yield rates were investigated for 56 active gully heads over the period 2006/7 – 2016/17 using high resolution satellite images. The significance surface and/or subsurface processes in controlling the gully development is discussed.

Gully length and gully surface area showed strong correlation with gully volume, implying that the significance of gully head retreat over gully bank and bed erosion. There has been significant expansion of gully networks in all the three sites over the last 57 years. However, the extent is more localized in low-lying areas in Dibatie sites, in contrast, gullies in Aba Gerima occur more or less uniformly across the landscape, while Guder exhibits intermediate situation, implying variation in sensitivity of the landscape across the sites. Similarly, there is significant variation in gully-head retreat and sediment yield rates where retreat rates ranging from 0.76 m yr-1 in Guder to 3.42 m yr-1 in Dibatie with corresponding sediment yield of 8.73 and 49.33 t ha-1 yr-1.

The climate expressed in number of intense daily rainfall events (>20 mm d–1) was found weakly correlated with gully density across all the three sites. In terms of land use, a general inverse relationship between gully density and area coverage of vegetation land use types was observed with the exception of Guder site. The possible reason for the exception in Guder is attributed to the nature and characteristics of the dominant Acacia decurrens vegetation in Guder site. The land under Acacia vegetation is characterized by low undergrowth and compacted soil surface that resulted in high sediment starved surface runoff, which could have huge potential to cause gully incision and sediment transport once the flow enters into the gully network.

Surface processes for gully initiation seem more dominant in Guder while subsurface process in Dibaite sites. This is evidenced in the relationship between contributing area, A, and local slope, S, across the three sites, where for a given contributing area, A, more steeper local slope S is needed in Guder, followed by Aba Grima and Dibatie to initiate gully erosion.

The subsurface process seems to be strongly controlled by piping especially in Dibatie and to a certain extent also in Guder. This piping is commonly triggered by three distinct processes: action of termites combined with soil tension crack in Dibatie, distinct variation in soil infiltration characteristics along the soil profile in Guder, where more impervious soil is overlain by loose colluvium deposit. Improved understanding of the gully erosion process and mechanisms in contrasting environments help develop tools that accurately predict gully erosion in this and other similar environments.

Keywords: gully morphological characteristics, gully head retreat, sediment yield, sediment- starved runoff, piping

Sick of Digitising gullies? Try this semi-automated method

Graeme Curwen[1,2], James Daley[1], Justin Stout[1], Andrew Brooks[1], Robin Thwaites[1]

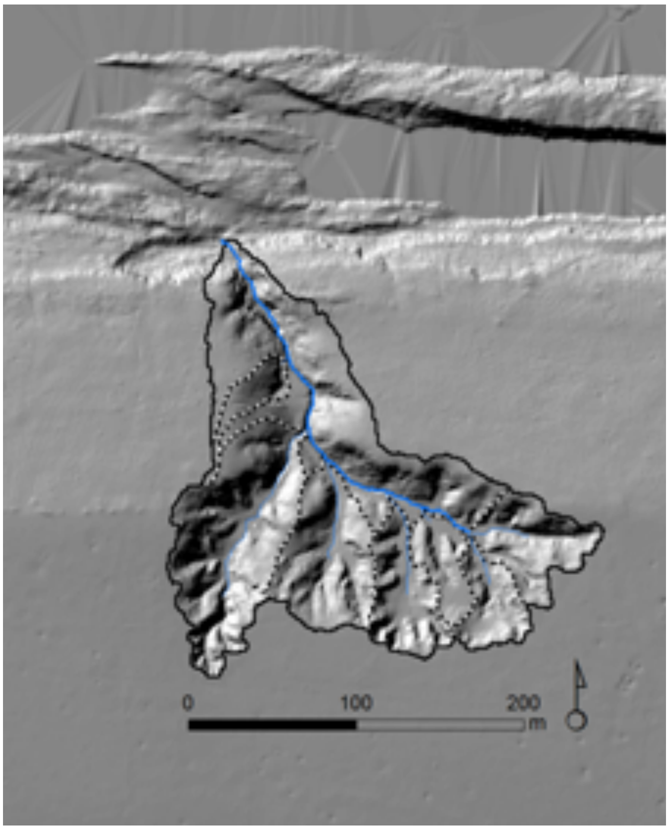
[1]Griffith Centre for Coastal Management, Griffith University, Gold Coast, Australia

[2]Australian Rivers Institute, Griffith University, Brisbane, Australia

The contribution of gully erosion to Great Barrier Reef (GBR) water pollution is currently derived from modelled outputs. Presence/absence mapping at a100m grid scale across GBR catchments is providing a critical first-step to mapping gully density, but the approach has limited ability to differentiate gully form and sediment yield. However, to meet sediment reduction targets, land managers require a prioritisation process for gully remediation and potential sediment yield categorisation that allows individual high yielding gullies to targeted. Consequently, accurate delineation of gullies, with metrics about their form and behaviour, is increasingly recognised as a requirement to improve models and management prioritisation. Whilst a fully automated method is still elusive, this presentation sets out a semi-automated method to map gully erosion from high resolution topographic data that significantly reduces processing time and increases mapping objectivity.

Initially, a multi-directional hill-shading method produces accurate boundaries of gullies and stream banks with slope break-lines in "flat" alluvial surfaces and hillslopes. Input parameters are adjusted according the background/residual terrain to appropriately delineate boundaries. Hydrological analysis within a shaded-edge boundary produces 'gullysheds' consistent with management objectives for gully remediation. Gullysheds represent the boundary of hydrologically consistent contribution zones which represents the potential eroded area at any scale. Based on initiation thresholds for flow lines, a set of mapping units at different scales are produced: gullies, gully sub-systems, and gully systems. Within the gullysheds, actively eroding areas have been identified and quantified using terrain analyses and bare-earth imagery. Attached to each unit is a suite of metrics to determine potential erosional activity and allow the classification of gully type as a function of sediment yield potential.

Using this semi-automated mapping toolbox, we provide a reproducible method to rapidly identify and classify gullies across large spatial areas, and a starting point for managers to begin identifying gully systems which should be targeted for immediate remediation for sediment reduction to environmental assets. To test the method's robustness across different landscape settings, we mapped gullies across 650 km2 of the Burdekin and Bowen River basins, Australia. We found the method provides accurate delineation of both alluvial and hillslope gullies, even within complex landscapes that incorporate a variety of terrain forms. Comparison of our results with field mapping and ground-truthing showed a high degree of similarity between the methods, although the semi-automated mapping displays a better delineation of soft edges (low-angled slopes) than was detectable in the field. A limitation of this method is that very shallow erosional features such as scalds are not readily included. Additional analysis of high-resolution multispectral imagery and bare-earth is required to define these areas. Also, shallow gullies and drainage features within residual soils on steeper bedrock-dominated slopes require a modified approach.



An Assessment of Handheld Laser Scanning for the Rapid Survey of Gully Terrain

Aaron Hawdon[1], Anne Henderson[1], Rebecca Bartley[2], Thomas Lowe[3], Scott Wilkinson[4] and Brett Baker[1]

[1] CSIRO Land and Water, Townsville,

[2] CSIRO Land and Water, Brisbane,

[3] CSIRO Data61,Pullenvale,

[4]CSIRO Land and Water, Canberra,

The health of the Great Barrier Reef is being adversely affected by fine sediment exported from adjacent catchments. Australian State and Federal Governments have allocated millions of dollars to address gully and streambank erosion which is a major source of these fine sediments. Design of gully rehabilitation is assisted by data on changes to gully depth, volume and wall angles. One approach is to undertake repeat (event based or annual) terrain surveys to quantify changes in gully topography. Several approaches currently exist for terrain analysis, however, many of the techniques are either too slow for large areas, or lack the accuracy needed for erosion detection in smaller gullies.

This study investigated the potential of a Zebedee handheld laser scanner (HLS) to undertake rapid and accurate gully surveys. The system combines Simultaneous Localisation and Mapping technology with a mobile spinning laser and has a stated accuracy of ~30 mm.

Between 2015 and 2018, HLS surveys were undertaken at a long-term gully erosion monitoring site to develop an appropriate survey technique and post processing methodology.

The data were then evaluated against coincident real-time kinematic (RTK) GPS surveys to assess the suitability as a standard method of terrain survey.

Annual RTK GPS cross section and headcut survey points formed the reference dataset and were used to extract coincident points from HLS data. The Root Mean Squared Error's (RMSE) of elevation points from both sets were similar (HLS 46 mm and RTK GPS 46 mm) when compared against those of independently surveyed control points. The 573 elevation points collected from the coincident cross section surveys had almost a 1:1 linear relationship and RMSE of 84 mm. There was also a strong linear relationship for headcut retreat with a RMSE of 19 mm. The HLS data that was used for the RTK GPS comparison then formed a reference set to compare the variability of individual HLS surveys conducted on the same day. The range of RMSE's from the 9 surveys conducted was between 30 mm and 76 mm.

We found that it was not necessary to make any significant change to the HLS manufacturer's recommended survey technique, confirming that 100 linear metres of gully (width ~5m) can be surveyed with two passes taking approximately 20 minutes, with an additional 5 minutes required for setup. Refinement to processing routines did not significantly decrease processing time (still around 3 hrs) but has greatly improved accuracy

in comparison with the initial (2015) analysis. The strengths of the HLS surveys are the speed of data collection, high point density which captures terrain detail, and relatively low errors that are comparable with other methods of terrain survey.

An assessment of the Zeb-Revo laser scanner as a tool for monitoring gully erosion

Kevin Roots

Department of Natural Resources Mines and Energy, Rockhampton, QLD, Australia

Handheld mobile LiDAR (Light Detection and Ranging) systems offer an alternative approach for capturing detailed terrain data to quantify the volumes of sediment lost from eroding gullies. While aerial LiDAR systems allow for the capture of data over large areas, the costs associated with the capture and processing of aerial LiDAR can be high. The vertical perspective of aerial LiDAR also limits the capture of data from undercuts and crevices. Terrestrial LiDAR systems can typically capture data with a higher point density than aerial LiDAR, thereby recording more detailed site information. However, traditional tripod-mounted terrestrial LiDAR systems are limited by their fixed line-of-sight data capture requirements. As such, the surveying of complex gully terrains with a tripod-mounted terrestrial LiDAR is a time-consuming process, necessitating the equipment to be repeatedly set up at different points within the gully system. Conversely, handheld mobile LiDAR systems allows for a faster survey rate than tripod based terrestrial LiDAR systems.

As handheld mobile terrestrial LiDAR technology is relatively new, there is still a level of uncertainty about the levels of accuracy and precision of the data captured from gully environments. As such, a study was conducted between 2017 and 2018 to assess the suitability of the Zeb-Revo mobile laser scanner, a hand-held fully mobile terrestrial LiDAR unit, as a tool for monitoring gully erosion. The point cloud data captured with the Zeb-Revo was used within the 3DReshaper terrain modelling software to construct bare-earth Digital Terrain Models (DTM). The volume of the gully void within each DTM could then be calculated as a means of quantifying change over time.

Preliminary field tests indicate the repeatability of the data captured with the Zeb-Revo to be high, with the volumes calculated from sequential same-day scans deviating on average less than 2% from the mean, with a 2.46% maximum deviation from the mean in areas of moderate ground cover.

Tests to compare data captured with the Zeb-Revo to data from aerial LiDAR and Total Station surveys indicate similar levels of accuracy. The total gully volume calculated on an aerial LiDAR DTM was 1.4% greater than that calculated from the Zeb-Revo. The cross-sectional area calculated over two transects on the Zeb-Revo DTM deviated from that calculated from Total Station surveys by 1.4% and 0.07%.

Overall, when used within the operational limitations of the equipment, the Zeb-Revo has proven to be a very efficient and effective tool for the convenient multi-temporal capture of accurate morphological data from eroding gullies.

Recent evolution of gully networks under intensive agriculture in southern Spain

Carlos Castillo[1], Henrique Momm[2], Rob Wells[3], Ron Bingner[3], Rafael Pérez[1]

[1] Department of Rural Engineering, University of Córdoba, Spain

[2] Department of Geosciences, Middle Tennessee State University, Murfreesboro, Tennessee 37132, USA

[3] National Sedimentation Laboratory, Agricultural Research Service, USDA, Oxford, Mississippi 38655, USA

Many areas around the world under intensive agriculture are suffering acute environmental impacts. Gully erosion represents one of the major challenges on those farms where a combination of intense rainfall, low vegetation cover and steep topography leads to concentrated flow erosion. The management operations associated to this production system not only establishes favourable conditions for this type of water erosion but also determines directly the evolution of drainage networks when earthmoving and filling operations are applied. The aim of this study is to investigate the topographic and anthropic factors driving the recent dynamics of permanent gully networks in a medium-scale basin under intensive cropland and olive orchard agriculture.

The Galapagares watershed (80 km^2 drainage area) is located in the Campiña landscape (vertic soils, rolling topography) close to Córdoba city (~20 km) in southern Spain. For all gully networks (defined as those channels showing a Strahler-order under 4), two analyses were carried out: a) a static analysis, involving a topographic assessment of gully networks characteristics using a 2x2 m DEM; b) a dynamic analysis across a 20-years period of study (1997-2016) through the manual digitization of gullied areas based on available ortho-photography.

A Geographical Information Systems (GIS) tool was implemented in the basin using QGIS for a systematic study of all gully watersheds. The topographical assessment provided a useful classification of gully watersheds regarding drainage area size and slope as a first indicator of erosion vulnerability. We evaluated the accuracy of different topographic indices to gully initiation (e.g. AxS and CTI) leading to an optimal definition of gully networks. Regarding the dynamic analysis, we found significant uncertainties in the digitization process of orthographies due to the varying quality of the images and the difficulty involved in the delimitation of gully channel boundaries. Contrasting tendencies in gully network evolution were found between plan-area growth rate and the impact of filling operations, both of them influenced by the amount of previous rainfall depth and the farming practices of the owners. Most of the gullies were found to suffer either partial or complete filling especially after dry periods, with only a few of them apparently not impacted by the human factor. Finally, an empirical model for incremental gully growth is proposed based on topographic factors, rainfall amount and initial gully area. We believe these findings will support stakeholders by providing a vulnerability index of gully watersheds and a straight-forward tool for estimating gully erosion in this area.

Modelling Gully erosion rates at regional and continental scales: Challenges and Opportunities

Matthias Vanmaercke[1], **Sofie De Geeter**[1], **Jean Poesen**[2]

[1]University of Liège, Department of Geography, Clos Mercator 3, 4000 Liège, Belgium

[2]KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Heverlee, Belgium

Gully erosion is a dominant geomorphic and soil degradation process in many regions worldwide. Depending on the geographical setting, gullies can be easily held responsible for 30% to 90% of the total mass of sediments exported from river catchments. Furthermore, gullies strongly increase runoff and sediment connectivity, leading to a further indirect increase in catchment sediment yields. As such, gully erosion often induces a plethora of problems, including the direct loss of soil and land, water reservoir capacity losses, increased flooding risks, but also decreased crop yields, damage to infrastructure and casualties. Several studies indicate that gully erosion will strongly increase in the near future in most areas (and especially in Africa) as a result of increasing land use pressure and expected increases in rainfall intensity. Being able to quantify and predict gully erosion is therefore of essential importance, including for the development of suitable land use and catchment management strategies. Nonetheless, our ability to do so currently remains very limited, especially at regional to continental scales. Several site-specific models have already been proposed. However, their applicability to larger areas is generally hampered due to data constraints and/or the limited range of environmental conditions for which these models have been calibrated.

We therefore discuss some recent advancements in the development of tools that allow to predict average gully erosion rates (GE, [t km-2 y-1]) at regional to continental scales. Similar to the Revised Universal Soil Loss Equation, we aim to develop a model that provides realistic and meaningful estimates of gully erosion at annual to decadal time scales (allowing scenario analyses) while keeping the data requirements as low as possible. To achieve this goal, we propose a model structure where GE is simulated as the product of the gully head density of an area (expressed as the number of gully heads per km^2) and the average retreat rate of each gully head. With respect to the latter, a review and meta-analyses of measured gully headcut retreat rates (GHR) worldwide, shows that average GHR is mainly controlled by the area contributing runoff to each gully head and, especially, a measure of mean rainfall intensity (i.e. RDN: the Rainy Day Normal). The combination of both factors allows to explain nearly 70% of the observed seven orders of magnitude variation in GHR worldwide.

Given the very strong observed correlation between RDN and GHR, our analyses also show that gully erosion rates are likely very sensitive to climate change. To develop a model that can predict the spatial variation in gully density at continental scales, we constructed a database of >1600 study sites across Africa where all individual gully heads were mapped based on available aerial photos (resulting in > 44 000 individually mapped gully heads). Overall, gully head densities in Africa vary between zero and 1500 gully heads per km^2. Statistical analyses show that this density is mainly explained by differences in vegetation cover, topography and soil characteristics. A regression model based on these variables explains ca. 50% of the observed variation in gully density.

A potential avenue to further improve the accuracy of gully density predictions is likely to apply a method that combines the slope-area threshold concept for gully head initiation with a simple runoff model. First analyses indicate that this is feasible at the continental scale, using currently available datasets. Such approach would not only permit to better account for the spatial patterns and interactions between the factors controlling gully initiation. It would also likely allow to improve the prediction of GHR and directly couple both model components into an integrated model that predicts total GE.

Overall, our results indicate that especially GHR exerts a strong control on total average GE. Given that GHR can already be predicted to a reasonable extent, this suggests that the development of a model that can simulate regional and continental patterns of gully erosion rates is becoming feasible. Nonetheless some important challenges remain. These include: differentiating between active and none-active gully heads; accounting for the large temporal variability that typically characterizes gully erosion rates; incorporating the contribution of ephemeral gullies as well as other gully erosion subprocesses (such as piping, gully widening, gully deepening) to total GE; and quantifying both the direct and indirect impacts of gully erosion on catchment sediment yields.

Identification and monitoring of large gullies in Kunene Region-Namibia using Remote Sensing Products

Miguel Vallejo Orti [1,2], **Eva Corral-Pazos-de-Provens**[3]

[1]Department of Geo-Spatial Sciences and Technology, Namibia University of Science and Technology, Namibia

[2]3D Geospatial Data Processing Group, Institute of Geography, Heidelberg University, Germany

[3] Departamento de Ciencias Agroforestales, Universidad de Huelva; Huelva, Spain

Namibia is a semi-arid country highly dependent on agriculture and natural resources where land degradation already affects many of their regions. One of the most critical overlooked environmental problems in Namibia is soil gully erosion, resulting in enormous ecological, economical and even cultural negative impacts. Standardised techniques to identify and monitor the development and consequences of gullies is crucial to better understand accelerating factors and to plan remediation strategies.

This research develops methods to i) detect large gullies by analysing their geomorphological characteristics through the analysis of TANDEM-X, to then ii) calculate erosion rates in the gully surroundings estimating relief displacement using RADAR Sentinel-1 DinSAR techniques and thereafter iii) monitor changes in vegetation patterns through inter and intra annual analysis in the evolution of NDVI calculated from Sentinel 2 datasets.

The results show that DEM analysis on TanDEM-X imagery allows the detection of large gullies at pixel level (12 m spatial resolution) with a TA above 80% (UA> 50% and PA> 50% for gully class) ensuring a Cohen Kappa of at least 50%.

On the other hand, DinSAR applied on Sentinel 1 dataset with 1.5 years temporal shift shows differences in altitude changes in the gully erosion zones up to 10 cm (Vertical/Vertical-VV and Vertical/Horizontal-VH Polarizations), nevertheless, to be able to quantify precisely the absolute soil gain or loss per spatial unit, it is necessary to discern between pixel altitude changes derived from local erosion and regional terrain subsidence. It can also be observed that active erosion sections of large gullies in arid regions have an average annual value of NDVI inferior than adjacent areas and they present a lower NDVI variability between months within the same year.

Using this knowledge as a reference point, future works will focus on conducting identification and exhaustive historical analysis of the evolution of great gullies in Kunene Region in Namibia to unravel the relationship of gully dynamics with climatic and human factors, while understanding how land degradation affects the traditional ways of life of those communities living and farming close to large gullies, for example the Himba and Herero communities in Opuwo areas.

Different development erosion processes of valley floor and hillslope gullies indicated by different indexes in the black soil region of northeastern China

Yifan Dong[1,3], Yongqiu Wu[2], Wei Qin[3]

[1] Yunnan Key Lab Int Rivers & Trans Boundary Ecosec, Kunming 650091, Yunnan, Peoples R China

[2] Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China

[3] State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing, 100048, PR China

Over 295 000 gullies have developed in the black soil region of Northeast China, and approximately 80% were observed in cropland, which caused intensive land degradation that threatens crop production in this region. There are two important issues for predicting gully erosion which have often been ignored in previous studies: 1) the different development processes of valley floor and hillslope gullies, and 2) how to define the gully erosion rate.

In this study, the topographic changes of five active gullies (two valley floor gullies and three hillslope gullies) that formed between 1997 and 2002 in Heshan farm were continuously monitored for three to six years (Fig 1). The measurement were conducted by RTK GPS and the precision of the DEMs reached the 0.01 m level.

The valley floor gullies showed intensive headcut retreat and were prone to show deposition in the years with moderate rainfall. The widening and deepening in the middle parts were the key locations of soil loss in the hillslope gullies, and the volumes increased steadily during the periods observed.

Four different indexes were adopted to indicate the gully erosion rates in terms of volume: the volume change per year (GERv), volume change per length/area changes ($\Delta V/\Delta L$, $\Delta V/\Delta A$) and the increasing ratio (IRv). All the indexes of the valley floor gullies showed significant parabolic relationships with the maximum rainfall (Rmax), except for $\Delta V/\Delta L$ ($0.93<R2<0.99$, $P<0.01$, n=10), while for the hillslope gullies, IRv, GERv and $\Delta V/\Delta A$ showed exponential growth relationships, with a compound index Rg being equal to the product of the logarithmic values of the snowfall (Sf), erosivity of the runoff generation rainfall (EI30runoff) and the Rmax of each year (R2=0.58, 0.50 and 0.60 respectively, $P<0.01$, n=14). The IRv showed a better ability than the other indexes to indicate gully erosion rates, which reduced the influence of the different initial sizes of the gullies.

What Gully is That? Towards a Classification Scheme for Erosion Gullies in Queensland

Robin Thwaites, Andrew Brooks, John Spencer, Tim Pietsch

Griffith Centre for Coastal Management, Griffith University, Gold Coast, Australia

The renewed focus on gully erosion management in GBR catchments, and across Queensland more generally, has highlighted the need for a common nomenclature and classification to help communication between various workers and stakeholders. The major purposes considered for such a scheme are:

a. to provide a scientific framework for gully description, classification, and management;
b. to provide a generic communication tool that simplifies the complexity of materials, form, and processes associated with gullies;
c. to help identify and target resources to the gully systems that are producing the greatest sediment and nutrient loads to the reef;
d. to provide a desktop and field tool for prioritising gully systems for rehabilitation in future
e. to greatly aid the process of catchment modelling for sediment flows and erosion sources.

To these ends we are developing a comprehensive generic classification to aid land resource managers and authorities, as well as researchers and other stakeholders, in their investigation of gullies. A comprehensive database and repository of gully data is a requisite component to this scheme.

The approach requires a spatial/desktop component as well as a field-based component. The spatial component is based on 1 m resolution LiDAR-derived topographic data coupled with other 2-D spatial data layers. A database framework has been developed around the data recording requirements of the classification, though not exclusively.

The conceptual approach to the classification can be summarised as:

- attribute-based;
- morphological: form/material;
- scale-dependent;
- flexibility in application;
- both quantitative and qualitative
- digitally based.

The structure is loosely hierarchical in the Remote (spatial/desktop) Component, with modifiers to the core classifier criteria. This is developed in parallel with the Field Component, of a field-scale observational structure of soil materials and erosion activity.

An initial indication of the scale of investigation and scale of system being identified is crucial. An essential decision must also be made on whether the system/feature is defined as a gully (system) or not (i.e. a stream channel).

Currently the framework has four main 'Classifier' components:

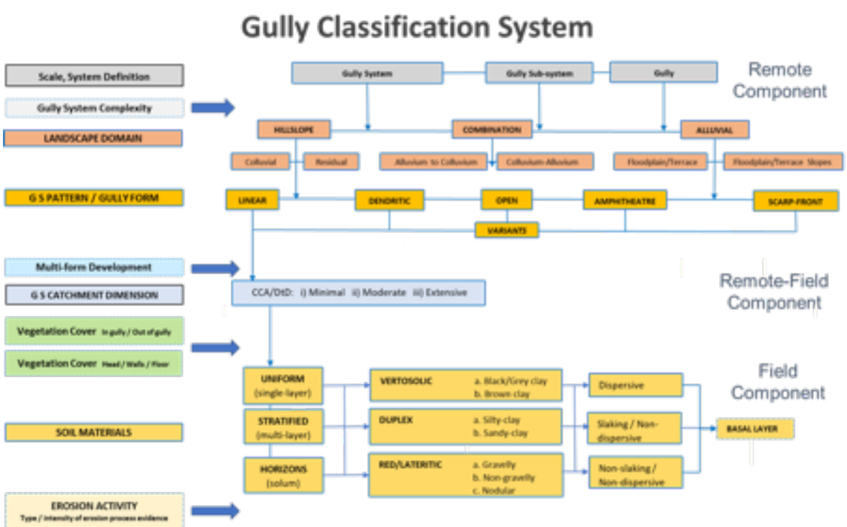
I. Scale of application
II. Geomorphic setting: 'Landscape Domain'
III. System morphology: 'Gully System Pattern'
IV. Soil material types: 'Soil Materials'

With six 'Modifiers' for:

i. Climate-rainfall region
ii. Complexity of the system
iii. Multi-form/multi-phase development
iv. Catchment dimension
v. Vegetation cover
vi. Dominant erosion activity

Essentially, the system describes five gully types in three landscape environments of three soil material forms in a stated level of complexity of form.

The multiple purposes to which the typology is to be put complicates the concept of a simple framework. Some classification examples are discussed further whereby the Remote Component can overcome the multiple scale issues and be able to mesh adequately with the local scale, Field Component, approach.



Dynamic distributed gully erosion modelling and validation

Mauro Rossi[1], Margherita Agostini[1], Narges Kariminejad[2], Mohsen Hosseinalizadeh[2], Hamid Reza Pourghasemi[3], Dino Torri[1]

[1]Insituto di Ricerca per la Protezione Idrogeologica (IRPI), Consiglio Nazionale delle Ricerche (CNR), Perugia, Italy

[2]Desert Control & Management, Gorgan University of Agricultural Sciences & Natural Resources, Iran

[3]Department of Natural Resources and Environmental Engineering, College of Agriculture, Shiraz University, Shiraz, Iran

Gully erosion is a significant geo-hydrological phenomenon occurring worldwide. Such phenomena contribute significantly to the soil erosion on a catchment and to its morphological shaping. In so doing, it impacts all the processes acting in a hillslope. Being one of the principal processes of soil erosion, gully erosion will play an important role in worsening the effects of climate and land use changes in the near future. Therefore, the prediction of the spatial and temporal occurrence of these phenomena is an interesting problem both for the scientific world and more in general for the society.
In this work we model gully erosion on different study areas, using a distributed pixel-based model. The LANDPLANER model was used for the purpose, mainly due to its ability to deal with scenario-based analysis and due to the limited requirements of input data in its basic configuration, which include a DEM and a land cover map to derive the parameters of the runoff through the Curve Nuumber method.
The twofold erosion modelling schema integrated in LANDPLANER, namely a quasi-static topographic threshold approach and a dynamic simplified erosion index, were tested in some study areas, considering the local morphological, climatological and Land Use/Land Cover conditions. We propose a framework to derive such dynamical model input data to better characterize the spatial and temporal occurrence of gully phenomena. Open source (SENTINEL-2) and commercial satellite (WorldView 3) data are used for the purpose and with the main objectives to perform long term, seasonal, event and scenario-based modelling analyses. Modelling results were validated using geomorphological and gully phenomena inventories, using different spatial criteria and different performance metrics. We maintain that the tested modelling and validation approaches can be easily replicated and applied in other different study areas to better characterize the spatial and temporal occurrence of gully erosion phenomena.

Improving gully density estimates for Great Barrier Reef catchments

Shawn Darr[1], **Margaret Barker**[2], **Donald Malcolm**[3], **John Ross**[4]

[1]Qld Department of Natural Resources Mines and Energy, Toowoomba, Australia

Gully erosion is a significant contributor to anthropogenic sediment loads that are delivered to the Great Barrier Reef (GBR). Substantial investments are being made to reduce these human induced loads. To enable targeted investment of gully remediation and the subsequent modelling of these remediation practices, improved mapping of gully location, density, geometry and activity rates across all GBR catchments is required. Efforts to date have concentrated on compressively mapping gully erosion for a single catchment or limited geographic extent or have modelled gully density by extrapolating a small number of sample sites across large areas.

This paper describes the approach developed to rapidly map gully and associated channel erosion and quantify its severity across all GBR catchments (423 000 km2). High resolution imagery and a grid based approach was used to map the presence or absence of gully erosion within grid cells. Further desktop analysis and field work captured gully and channel geometry, gully stability, and gully fragmentation and connectivity to stream networks.

Results show catchments within the Burdekin basin typically have the highest average gully densities. Both the Fitzroy and Burnett basins have lower average gully densities but do contain catchments that have significant areas of high gully density. In contrast the wet tropical catchments have very low gully densities.

These results are an improvement on the only other broad scale gully density data produced for the entire GBR. Our data shows there is a greater range of gully densities across the GBR including much higher maximum gully densities and produces an estimate of total gully length four times greater than the previous estimate produced using a modelled approach. Our data also shows there are significant areas with no gully erosion in contrast to the previous estimate that shows very few areas have no gullies. Results indicate that this process is able to map broad areas at a scale that assists the identification of gully hotspots and enables targeted investments, improves inputs for water quality modelling and identifies priority areas for targeted detailed mapping.

Land reclamation and its Implications for Rural development: A Study of Chambal Badlands,India

Padmini Pani

Centre for the Study of Regional Development Jawaharlal Nehru University New Delhi
Padminipani.jnu@gmail.com Padmini@mail.jnu.ac.in

Agriculture is the main source of livelihood in rural India. Agriculture productivity depends on land quality, particularly in a rainfed region. Therefore, in India being the agrarian economy, the land is primary assets for regional development. The land degradation and inappropriate land reclamation in rural India have multifaceted impacts. The objectives of this study are to understand the dynamics of land degradation over the decades and to map the trajectory of degraded land reclamation and its implications of sustainable rural development? To fulfil these objectives the major land reclamation activities have been identified over the decades through field survey, FGD, and from history and literature. It has been analysed that the primary activity is land levelling. Based on remote sensing data analysis it has been found that around 600 km^2 area have been levelled since 1974. The most of land levelling taking place invariably in individual level which are not sustainable.

To understand the sustainability and rural development scenario of the region based on the degree of degradation and levelling nine villages household survey and FGD have been carried out. The Primary Census data of 2011 also have been analysed for the all 799 census villages of the entire ravine affected district Morena, to get a clear picture and to compare the socio-economic conditions of affected and nonaffected villages in the study district.

It has been found that the total degraded ravine area has been reduced substantially due to the high rate of land levelling practices by the locals. However, in the same period, it has been observed the ravine formation processes are active in different parts. It has been found that the impact of land levelling has significant off-site implications too. Apart from the loss of productivity and change in cropping pattern, the social segregation, shifting of villages are the problems in the study region. The loss of common land, changes in river systems due to high siltation, increasing man-animal conflict and disturbing ecological balance are the result of land levelling in the study region. The environmental impact of the degraded area will not only result in disturb social harmony but also increase conflicts and cause distress migration. A more holistic approach towards the land degraded area will minimise the effects of soil erosion. Therefore, we can conclude that all short-term benefit is not the right step for the development mainly for the vulnerable ecological region. The value of every landscape cannot be reduced to its value in economic terms.

Keywords: Land degradation, land levelling, sustainability, rural development, Chambal Region

Enhancing rural prosperity through gully rehabilitation; the case of Northern Ethiopia

Yitbarek Tibebe Weldesemaet[1]

[1]Watersheds Organizational and Livelihoods Affairs Support, Local Non-Governmental Organization P.O.Box-34793, Addis Ababa, Ethiopia

Gully rehabilitation schemes are considered as the potential approaches for reinstating previously degraded landscapes, thereby contributing to the local households' economic prosperity. Despite such qualitative assertions, the quantitative accounting of rehabilitated gullies and their economic contribution to rural households' income is hardly ever assessed in Ethiopia. Therefore, this study quantified the net economic return of rehabilitated gullies to local households, by comparing the cost of rehabilitating the gully; with the economic return generated by valuing its ecosystem services. Data were obtained from a biophysical assessment; household survey supported by secondary information from relevant local offices a model rehabilitated gullies from Northern Ethiopia.

The study findings showed that the rehabilitated gullies ecosystem services are marketable which can generate USD 364,320 in just 4 years after the rehabilitation; providing each household with a share of USD158 yr-1. The projected maximum economic return estimated from the rehabilitated gullies will be about, USD 2,369,360 increasing the share of each household to USD 1,030. Moreover, if these households decide to rehabilitated and manage their entire surrounding gullies, in about 20 years they can expect a per household share of USD7,600 yr-1.

This estimated benefit is attainable because the rehabilitation programme organised rural beneficiary households into formal institutions with management and utilisation bylaws, thereby ensuring their sustainable pathway to prosperity. This indicates that the economic return of rehabilitating gullies is attractive enough to motivate community and/or their government's investment while also serving as a potential indemnity for financial intermediaries to extend investment loans. In maximising the realisation of this benefit, it will require thorough research for the development of markets for different bio-geographic zones as well as link these services to international protocols, global warming, and world trade. Moreover, such economic return can be sustained if rehabilitation efforts are complemented with evolving appropriate working plan prescriptions.

Key Words: gully, ecosystem services, rehabilitation, economic return, Ethiopia

A novel reclaimed engineering for farmland damaged by gully erosion in Northeast China

ZHANG Xingyi[1], QI Zhi[2], ZHANG Shengmin[3], LI Hao[1], HU Wei[1], DING Chao[2], HAN Xing[2]*

[1]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, 150081, Harbin, China; [2]College of Resources and Environmental Sciences, Jilin Agricultural University, 130118, Changcun, China; [3]University of Chinese Academy of Sciences, 100049 Beijing, China

ABSTRACT

Gully erosion has been recognized throughout history as a major land degradation process and in many cases has been directly linked to unsustainable land management. Gully erosion stands out as one of the worst aspects of farmland degradation, which induced the loss of arable soil and the obstacle of tractor travel. Hence gully erosion greatly harmed the ability of crop production and agroecosystem. Based on the requirement of agricultural sustainable development in the Molliosls area of Northeast China, an innovative reclamation engineering for farmland damaged by gully erosion derived from straw filled was set up. The basic design principle of the reclamation engineering is the disappearance of the gully by the gully body filled straw and gully surface covered soil. A drainage system consisted of conceal conduit and seepage pit was established under ground. A continues conceal conduit wrapped by geotextile was laid on the center bottom of gully, and the seepage pit was interval constructed cross the gully. The stream on the surface of rehabilitated gully got into the conceal conduit through two paths, one is from the infiltration of gully surface covered soil to straw layer, then concentered to the conceal conduit; another one is from seepage pit to the conceal conduit. Most of the stream was drained out the field from underground, which greatly decreased the power of the surface water flow. No new gully would be formed on the surface of rehabilitation gully area. The dominant technic of the reclamation engineering is to change surface water flow to underground drainage.

The reclamation engineering consists of gully reshaping, conceal conduit laying, straw bundling, straw bundle stacking, surface earthing, earth bund constructing, seepage pit building and exit protecting. Gullies formed in the field could be disappeared by the reclamation engineering. Agricultural machine could travel freely, and the land could be rehabilitated. Small gully or the brand of median and large gully with the depth lower than 2 m could be reclamated by this engineering. Up to now, more 300 gullies has been rehabilitated by the national projects of gully control, Mollisols land protection and land arrangement in the Mollisols area of Northeast China, and more than 100 hectare farmland has been rehabilitated. More than 0.2 million gullies in the northeast of China could be reclaimed by the engineering. Approximate 0.14 million hectare farmland could be rehabilitated, 0.6 billion kg grains increased each year.

Key words: A novel engineering; Mollisols area; gully; farmland; reclamation

The construction of gully reclamation

A production systems approach to point source sediment remediation - enhancing landscape function and farm resilience through erosion control

Sam Skeat[1], Neil Cupples[2],

[1]Grazing Project Officer, NQ Dry Tropics, Townsville, Australia
[2] Soil Conservation Officer, NQ Dry Tropics, Townsville, Australia

Point source sediment erosion from grazing lands is a major environmental issue affecting the Burdekin Catchment, with over 60% of the source catchment modelling fine sediment outcome being attributed to gullies. Experience in the Burdekin Catchment suggests that treating gully erosion, as a singular degradation issue, is only temporarily successful unless the commercial grazing management of the area is simultaneously improved. Better long-term results may be achieved through an integrated approach to planned grazing and erosion management where the focus is on reinstating landscape function. The primary focus of this treatment style is the application of planned grazing to adjust the timing and intensity of grazing while integrating erosion control structures to reinstate the natural processes that influence how water flows through the landscape. These structures are used as a complimentary measure to prolong water interaction with the landscape both above and below the ground. Initial prioritisation of works and grazing systems assessment enables cost/benefit analysis to provide significant production benefit to the landholder with the least amount of earthworks and expense, increasing motivation for the landholder to maintain the works as part of the productive landscape their business manages.

Managing the intensity and timing of grazing and rest develops a positive feedback loop within the grazing system. The pasture community adapts to the grazing pressure/resting cycle by developing more species diversity, resulting in pastures that have shown to be more resilient and have a higher plant density which in-turn increases water infiltration, limits soil exposure and slows runoff. The placement of erosion control structures has inherent risks of failure during intense rainfall events, initial settlement and becoming overwhelmed with sediment. By designing interventions that both protect against erosion (slow and disperse flow) and act as water retention features, growing periods can be prolonged and erosion risk further reduced throughout the year. Critical to the success of these measures is the identification of sites where landscape traits can manage the flows and prolong water interaction with the landscape both above and below the ground.

Initial local results indicate that the application of planned grazing practices in combination with targeted on-ground works can enhance the grazing business, regenerate the landscape and reduces sediment loss. These sites have demonstrated that planned grazing combined with erosion intervention can turn marginal, degraded land into highly productive land over the space of approximately 8 years.

Markets and science join forces to repair gullies

Mike Berwick AM, Senior Advisor to GreenCollar Group
Andrew Brooks, Griffith Centre for Coastal Management, Griffith University, Gold Coast, Australia

The commercial world and science have come together to find solutions to remediating gully erosion that is contributing > 40% of the anthropogenic sediment load to the Great Barrier Reef (GBR). The Reef 2050 Plan developed by the Australian and Queensland Governments to help protect this World Heritage asset, has set a target of 50% reduction of the anthropogenic sediment load, and if this target is to be achieved it cannot be done without making major inroads into sediment pollution sourced from gully erosion. Repairing erosion gullies is expensive, it provides little benefit to the graziers on whose properties the gullies occur, so there is no substantive incentive to repair them, the cost is usually well beyond their reach anyway and government investment alone is insufficient compared to the scale of the problem. Environmental markets are a means to attract investment to ecosystem repair, but investors want to know what they are getting for their money – what is the $/tonne of sediment prevented from reaching the reef and how much does that contribute to the Reef targets? A simple and obvious question that any investor, in government or the private sector, would reasonably ask – I need to know the outcome before I invest. Whether for sediment, nutrient or pesticide pollution, the correlation between an activity and an outcome, eg ground cover and the pollution load in grazing systems, is the critical but difficult question.

The Reef Credit has been devised as a measurable and verifiable unit of water pollution reduction reaching the reef. Environmental market expert, GreenCollar, in partnership with the wet and dry tropics Natural Resource Management groups (Terrain and North Queensland Dry Tropics) have established the components required to create a functional market: the governance (rules, secretariat, oversight), accounting (measurement and audit), reporting and sourcing Reef Credit supply and demand. The Griffith University team has been engaged by GreenCollar to co-author the Gully Methodology (described elsewhere at this symposium) – how to measure and/or model the fine sediment exported from eroding gullies to the reef, estimating the reduction in pollution from remediation, monitoring to validate the estimates and third party audit. In this presentation we will outline how the emerging market instrument is to work and explain the accounting behind the Gully Methodology.

In conclusion the process of developing this market-based mechanism has highlighted critical knowledge gaps in measuring, modelling and monitoring pollution loads that are needed to attract government, private and philanthropic investment to improve water quality entering the GBR Lagoon from the catchments draining to it.

What is eroding gullies on Mars?

Susan J. Conway[1]

[1]Centre National de Recherche Scientifique, Laboratoire de Planétologie et Géodynamique, Université de Nantes, France

Gullies on Mars were first reported by Malin and Edgett in 2000 and were initially interpreted to result from groundwater flowing out from beneath the martian surface. Mars is believed to have been hyper-arid for the last billion years and so the possibility that aquifers could exist on Mars, providing a potential oasis for life, was big news. In the years that followed it was found that the location of martian gullies on isolated topographic highs and their latitude-dependant distribution and orientation argued for a climatic trigger in their formation, with researchers preferring melting of snow and/or ground ice, rather than aquifer outburst. Now, repeat observations have revealed that sediment transport is occurring in gullies today and that those transport events tend to occur at the coldest times of year, when the temperature can be more than 100°C below the freezing point of water, implying that the involvement of liquid water is highly unlikely. Carbon dioxide ice condenses onto the martian surface in winter and has therefore been linked to the activity seen in martian gullies. In our recent work, my collaborators and I have been further exploring the role that sublimating carbon dioxide ice could play in mobilising sediment flows in martian gullies.

I will describe ongoing work by myself and collaborators outlining the recent results from topographic analysis, numerical modelling and laboratory simulations under martian conditions and give insights into the processes that could be eroding martian gullies today and in the past.

Examples of gullies on Mars, each scale bar is 300 m long. Left to right HiRISE images: ESP_019033_2495 gullies on crater wall with frost in alcoves, ESP_014153_1430 gullies on crater wall with sinuous channels and recent deposits, ESP_014067_1150 gullies on rippled sand dunes, ESP_020957_1290 gullies on crater wall with sandy deposits. Image credits: NASA/JPL/University of Arizona.

Changes in runoff energy, surface landform and sediment yielding during the bank gully erosion process in Dry-hot Valley Region, Southwest China

Donghong Xiong[1], Baojun Zhang[2], Zhengan Su[1]

[1] Key Laboratory of Mountain Hazards & Earth Surface Processes, Institute of Mountain Hazards & Environment, Chinese Academy ofSciences, Chengdu 610041, China

[2] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Research Center of Soil & Water Conservation and Ecological Environment, Chinese Academy of Sciences, Yangling 712100, China

Gully erosion is one of the major contributors to severe land degradation in the Yuanmou Dry-hot Valley Region, Southwest China. Gully headcut, a typical morphological characteristic of bank gully, whose heights would influence on the runoff hydrodynamics and thus affect the landform changes and sediment yielding. It is, therefore, of great significance to determine the changes of runoff hydrodynamics and surface landform, and their effects on the sediment yielding, and also the effects of headcut height on them during the bank gully erosion process.

To quantify the changes in flow energy, sediment yield and surface landform impacted by headcut height during bank gully erosion, five experimental platforms were constructed with different headcut heights ranging from 25 to 125cm within an in situ active bank gully head. A series of scouring experiments were conducted under concentrated flow and the changes in flow energy, sediment yield and surface landform were observed. The results showed that great energy consumption occurred at gully head compared to the upstream area and gully bed. The flow energy consumption at gully heads and their contribution rates increased significantly with headcut height. Gully headcuts also contributed more sediment yield than the upstream area. The mean sediment concentrations at the outlet of plots were 2.3 to 7.3 times greater than those at the end of upstream area. Soil loss volume at gully heads and their contribution rates also increased with headcut height significantly. Furthermore, as headcut height increased, the retreat distance of gully heads increased, which was 1.7 to 8.9 times and 1.1 to 3.2 times greater than the incision depth of upstream area and gully beds. Positive correlations were found between energy consumption and soil loss, indicating that energy consumption could be used to estimate soil loss of headcut erosion. Headcut height had a significant impact on flow energy consumption, and thus influenced the changes in sediment yield and landform during the process of gully headcut erosion. Headcut height was one of the important factors for gully erosion control in this region. Further studies are needed to identify the role of headcut height under a wide condition.

Keywords flow energy consumption; sediment yield; surface landform change; bank gully erosion; Dry-hot Valley region

Apportioning contributions of individual rill erosion processes and their interactions on loessial hillslopes

Chao Qin[1,2], Fenli Zheng[1,3*], Glenn V. Wilson[4], Xunchang J. Zhang[5], Ximeng Xu[6]

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A & F University, Yangling, PR China

[2] State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, PR China

[3] Institute of Soil and Water Conservation, CAS & MWR, Yangling, PR China

[4] USDA-ARS National Sedimentation Laboratory, Oxford, USA

[5] USDA-ARS Grazinglands Research Laboratory, El Reno, USA

[6] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, PR China

Channels (rill, ephemeral gully, gully and river channel) exhibit a continuum of sizes and flow magnitudes. Rill erosion, as the initial stage of channel erosion, accounts for > 80% of total eroded sediments on hillslopes in many parts of the world. Previous researches often regard rill erosion as an entirety or focus on individual rill erosion process separately. But few attentions have been paid to the contributions of individual processes including rill headcut advance, bed incision, sidewall expansion and their interactions to the over-all rill erosion. Thus, simulated upslope inflow experiments were designed to investigate the impacts of individual processes involved and their interactions in rill erosion under four inflow rates (1.0, 2.0, 3.0 and 4.0 L min−1) and two slope gradients (15° and 20°). Photogrammetry and manual sampling were used to measure hillslope morphology variation and sediment delivery.

The results show that headcut advance, bed incision and sidewall expansion interact with each other and exhibit both independent and dependent features across spatial and temporal scales. Headcut advance interacts with bed incision and sidewall expansion before rill head advancing to a critical slope length. Initial rill depth and width are determined by initial headcut morphology. Bed incision and sidewall expansion dominate rill erosion before and after the non-erodible layer is exposed to concentrated flow, respectively. Headcut advance contributed the largest amount of rill erosion (44%-68%), followed by bed incision (27%-44%) and sidewall expansion (3.8%-12%). Headcut advance contributed more (63%-83%) to total rill width increment while bed incision contributed larger percentage (51%-65%) to total rill depth increment. Prediction equations for length, width and depth of a single rill on a loessial hillslope and empirical equations of rill erosion for the individual erosion processes were fitted and validated. Quantification and understanding of the contributions of individual rill erosion processes provides the necessary scientific basis for the development of process-based rill erosion models, and then, for preventions of soil losses and land degradation.

Gully Formation due to Internal Erosion of Soil Pipes: Sediment Detachment and Transport in Soil Pipes

G.V. Wilson[1], Ximeng Xu[2], J. Wang[3],R.R. Wells[4], John L. Nieber[5], G.A. Fox[6], Fenli Zheng[7] and M. Ursic[8].

[1]USDA-ARS, National Sedimentation Laboratory, Oxford, MS, USA;
[2]Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, PR China;
[3]Huazhong Agricultural University, Wuhan, Hubei Province, 430070, PR China;
[4]USDA-ARS, National Sedimentation Laboratory, Oxford, MS, USA;
[5]Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC, USA;
[6]Bioproducts and Biosystems Engineering, University of Minnesota, St. Paul, MN, USA;
[7]Institute of Soil and Water Conservation, Northwest A & F University, Yangling 712100, Shaanxi, PR China;
[8]USDA-ARS, National Sedimentation Laboratory, Oxford, MS, USA;

ABSTRACT
Internal erosion of soil pipes can be a very important process in gully erosion as well as other mass failure events such as landslides and levee/dam breaching. Flow through preferential flow paths such as macropores can be rapid enough to exceed the soil critical shear stress and cause detachment of particles from the walls of the flow path, i.e. internal erosion. Development of a soil pipe from enlargement of a macropore results in more rapid flow and thus greater internal erosion, particularly mass failure of aggregates from pipe walls and roofs. If the sediment transport capacity of the pipe is exceeded, the pipe will plug causing back-pressure to build up within the soil pipe, which can foster gully formation and expansion by pipe collapse. However, limited research has been conducted on particle and aggregate detachment within soil pipes or transport of sediment through soil pipes. The objectives of this work were to (i) determine the rates of the sediment detachment in soil pipes as a function of flow rate during natural flow events in situ and (ii) determine the conditions under which the sediment transport capacity of soil pipes is exceeded and pipes clog resulting in pressure buildups that can lead to hillslope instability. Discontinuous gullies formed by soil pipe collapse at GCEW were equipped with H-Flumes instrumented with ultrasonic sensors and pressure transducers to monitor flow rates through the soil pipes. Discrete suspended sediment samples were collected from soil pipe flumes during flow events and composite bedload sediment transport samples collected after each event. Laboratory sediment transport experiments involved injection of sediment at steady concentrations and flow rates into a 100 cm long artificial soil pipe using various sediment sizes (aggregates to very fine sands) and sediment concentrations and the soil water pressures monitored above and below soil plugs formed when the transport capacity was exceeded. This presentation will present recent results from the field and laboratory measurements and recommendations for future research on sediment detachment and transport in soil pipes.

Sediment transfer by rills and ephemeral gullies at the microcatchment scale: a study case to evaluate the impact of rainfall variability and management in a semi-intensive olive orchard in Spain

E.V. Taguas[1], J. Rebolledo[1], G. Guzmán[1,2] T. Vanwalleghem[1], and J.A. Gómez[2]

[1]University of Cordoba, Rural Engineering Department. ETSIAM. Campus Rabanales, Edif. Leonardo Da Vinci, 14014 Córdoba (Spain). Ph. +34 957 218533; juanelitorebo@hotmail.com, evtaguas@uco.es; ag2vavat@uco.es.

[2]Institute for Sustainable Agriculture (CSIC). Alameda del Obispo s/n, 14004, Córdoba (Spain). E-mail: gemaguzmandiaz@ias.csic.es, joseagomez@ias.csic.es

Erosion associated with concentrated flow in Mediterranean cultivated areas is considered as a major process of land degradation. In this work, the features of rills and ephemeral gullies generated in an olive orchard catchment of 6.4 ha, where tillage operations were usually applied, were measured and compared with sediment loads at the catchment outlet. The specific objectives were: 1) to quantify the rills and ephemeral gullies measured in the catchment for inter-tillage periods where different hydrological features (precipitation and erosivity) and management schemes were observed; and 2) to assess the contribution of concentrated flow to measured sediment discharge at the catchment outlet by considering the impact of cover crop strips during the last period.

The cross-sectional measurements of depth, width, shape, length and location of rills and ephemeral gullies in the catchment were carried out through a GPS survey. Each were measured 4 times between April 2009 and March 2014. During the first three campaigns, the management was conventional tillage; however, in September 2014, cover crops (Bromus rubens L.) were seeded in some lanes of the catchment following the most approximate contour direction. A gauge station with a flume at the catchment outlet captured rainfall, runoff and sediment discharge measurements.

The quantitative and statistical analyses consisted of evaluating and correlating the hydrological features associated with the measurement period (cumulative erosivity and precipitation, number of erosive events with maximum intensity of 10 minutes and the corresponding return period) with the rills and ephemeral gullies generated (number, total volume and length, shape and mean length, width and depth) and the total runoff and sediment loads in the catchment.

The mean volume of rills and ephemeral gullies for the 4 surveys was equivalent to 8.1 t·ha-1 and 3.3 t·ha-1, respectively; whereas, the mean total sediment discharge for the same period was of 9.5 t.ha-1. Soil losses associated with the rills only showed an acceptable correlation with 10 minute maximum intensity, ranging between 1 and 20 t·ha-1. The impact of cover crops during 2014 was particularly notable on rill discontinuity and sediment trapping as observed in the field; however, few erosive events happened during the period. Active sediment dynamics are expected in the catchment, derived from a sequence of events with high precipitation (not particularly intense), which improve the connectivity of rills generated in the lanes to the stream. Despite the reduction of rill connectivity and sediment discharge due to the use of a cover crop, the farmer decided not to maintain it because of management inconveniences.

Linking gully erosion processes and hydrological connectivity in savanna rangelands tributary to the Great Barrier Reef

Jack Koci[1], Roy C. Sidle[1,2], Ben Jarihani[1], Matthew J. Cashman[3]

[1]Sustainability Research Centre, University of the Sunshine Coast, Maroochydore DC, Queensland 4558, Australia
[2]Mountain Societies Research Institute, University of Central Asia, Khorog GBAO 736000, Tajikistan
[3]US Geological Survey, MD/DE/DC Water Science Center, Baltimore, Maryland 21228, United States

ABSTRACT

Gully erosion is a globally significant land degradation phenomenon which reduces water quality, decreases agricultural and rangeland productivity, and damages infrastructure. Gullies are a particularly significant issue in the dry-tropical savanna rangeland catchments tributary to the Great Barrier Reef (GBR) World Heritage Area, northeast Queensland, Australia, providing the primary sources of sediment and particulate nutrients (e.g., nitrogen and phosphorus) to the coast, and key contributors to the declining health of the reef ecosystem. Limited understanding of the key hydrological and geomorphological processes involved in gully initiation and expansion constrain effective gully management.

This study sought to improve understanding of hydrogeomorphic processes driving hillslope gully erosion in the Upper Burdekin catchment, using low-cost aerial (via Unmanned Aircraft System, UAS) and ground-based (via handheld digital camera) structure-from-motion with multi-view stereo photogrammetry (SfM). UAS and ground-based platforms delivered accurate topographic models of four hillslope gully systems, with overall root mean square elevation errors of 0.06 - 0.12 m and 0.03 - 0.08 m for the two methods respectively, facilitating temporal gully change detection.

High resolution mapping of hydrological flow pathways enabled spatially explicit prediction of where gully extension is likely to occur as a result of overland flow. The points where modelled flow pathways intersect gullies corresponded to observed geomorphic change. Application of an index of hydrological connectivity clearly demarcated parts of the hillslope most connected to the gully network. Bare and scalded areas, roads, and cattle trails are identified as important runoff source areas and hydrological conduits driving gully extension. Key within-channel erosion processes include mass wasting, particularly at the gully head; rilling and fluting along the gully sides; and bed scour. Median linear, areal and volumetric headcut (n = 21) retreat rates between 2017 and 2018, were 0.2 m, 0.8 m2, and 0.3 m3, respectively. This study provides valuable new insights into key gully erosion processes in savanna rangelands and demonstrates how low-cost UAS and ground-based platforms can be used to aid in the modelling and management of hillslope gully systems.

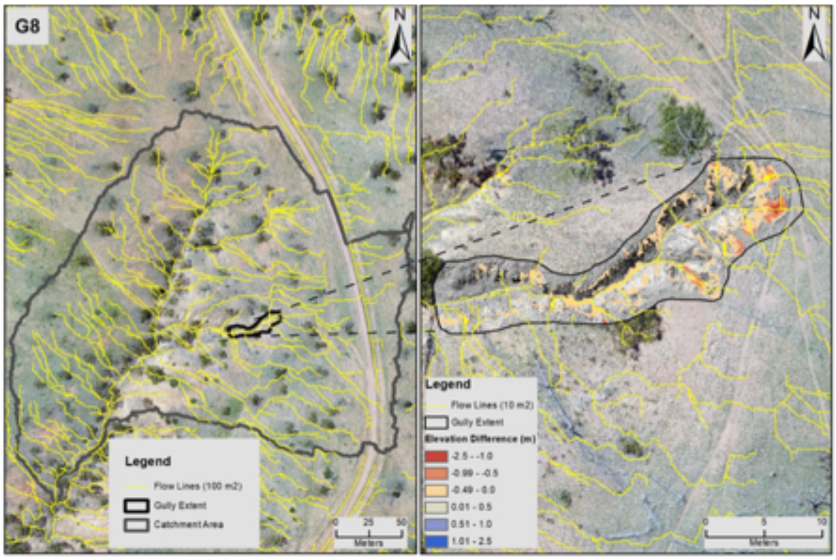


Figure 1. Major hydrological flow pathways (contributing area > 100 m2) (left panel), and minor hydrological flow pathways (contributing area > 10 m2) and gully geomorphic change between 2016 and 2018 (right panel).

The significance of gully erosion as a dominant source of sediment pollution to the Great Barrier Reef; and the challenge ahead to reduce it

Andrew Brooks[1], John Spencer[1], Graeme Curwen[1,2], Nic Doriean[1,3] Tim Pietsch[1], Robin Thwaites[1], Shawn Darr[4].

[1]Centre for Coastal Management – Griffith University, Gold Coast, Australia

2Australian Rivers Institute – Griffith University, Brisbane, Australia

3Environmental Futures Research Institute – Griffith University, Gold Coast, Australia

4Qld Department of Natural Resources, Mines, and Energy – Toowoomba, Qld.

Sediment and associated nutrient runoff from catchment erosion is a major threat to the Great Barrier Reef (GBR) resilience. Sediment tracing evidence suggests that channel and gully erosion are the source of 90+% of fine sediment pollution to the Great Barrier Reef in many catchments, while modelling suggests gullies contribute, approximately 40% and streambank (channel erosion) around 40%. Understanding the breakdown of these two primary sources, and their precise location is fundamental to targeting management effort. Whilst sediment tracing can help to target the sources at the sub-catchment scale, locating specific gullies for management requires that the precise location is mapped, and the sediment yield is quantified.

Broad-scale mapping of gully density in the GBR catchments is ongoing. Recent 100 m grid-cell presence/absence mapping completed for about 55% of the 437,354 km2 GBR catchments, suggests there are about 89,000 km of gullies from the mapped portion. Extrapolating these data to the remaining unmapped portions of the catchment, means the total length of gullies could be in the order of 160,000 km. However, it is apparent that this dataset is highly negatively skewed by small linear gully features, given that the average widths of all gullies is estimated to be only around 3.5m. By using these estimates and translating them into a more meaningful surface area metric, this equates to about 56,000 ha for the entire GBR, or 0.13% of the total land surface area.

Whilst this area estimate might seem like a daunting management task, the dominance of small, linear gullies and channels in this dataset suggest the total sediment budget is likely dominated by contributions from a relatively small proportion of the larger, more active alluvial gullies.

High-resolution gully mapping (from 1m LiDAR DEMs) has been undertaken only on a small proportion of the GBR catchments (< 2000 km2) to date. Where it has been undertaken the evidence suggests that the large, active gullies are probably in the order of 10% or less of the total mapped gully population. Sediment yields derived from LiDAR DEM and airphoto reconstructions from large alluvial gully sites are significantly higher than the average yields derived for the full dataset, 317 t/ha/yr +/- 170 1SD, for the Strathalbyn site, which has approximately 60 ha of gullies concentrated in 550 ha. By contrast, average yields for the majority of gullies are estimated to be 46 t/ha/yr. At equivalent rates to Strathalbyn, 1 Mt/yr would be sourced from 3,150 ha of gullies. This provides some context for the potential areas of gully that are required to be rehabilitated across the GBR. These data highlight the need to accurately map gullies and differentiate gullies according to their area, type and specific sediment yields.

Soil Conservation and Gully Erosion Control Projects in the inland Burnett Mary Review 2013 to 2018

John Day[1], Dominique Glasgow2

[1]Burnett Mary Regional Group, Wondai, Australia.
2Burnett Mary Regional Group, Wondai, Australia.

PURPOSE

The program aim was to provide advice and support to landholders to optimise the sustainable management of their land through best practice soil conservation techniques. The program has been active in various incarnations over the past 5 years and has had direct interaction with more than 130 landholders. The review of the work is to benchmark the progress, assess the methods used and record the sustainability of structural erosion control works thus far.

MATERIALS AND METHODS

The process for the selection of projects was based on severity of the erosion site, length of time since completion and rehabilitation methodology used. To reduce bias due to construction variation the full range of rehabilitation methodologies used were targeted.

From 55 funded projects 25 projects were reviewed. The review process used field visits, measurements from Google Earth pro, Qld Globe and QImagery, photo and video before and after. A short, focused survey was conducted with participants to gauge satisfaction and estimates of soil loss since completion.

To estimate the extent of soil loss prior to the intervention measurements were taken from historical Google and QImagery archives.

RESULTS AND DISCUSSION

The total soil loss estimate prior to intervention from all sites = 66,142tonnes. Total estimated tonnes per year being eroded away prior to intervention = 3,868tonnes/annum. Total estimated tonnes per year still eroding post intervention at all sites combined = 45.5tonnes. Annual saving = 3,822.5tonnes from a total project treated area of 470ha. The total cost including landholder contribution = $320,594, (public funds alone $187,304.90). The cost of the soil saved annually is approximately $84/tonne. If we consider the dollar contribution from the government alone the cost is $49 spent for each tonne of soil saved

These results are on the bottom of the range of costs per tonne of sediment highlighted on page 25 of "Understanding the economics of grazing management practices and systems for improving water quality run-off from grazing lands in the Burdekin and Fitzroy Catchments", ($81 to $217 per tonne) 9 case studies. These results are reinforced by survey results.

- 95% (18 out of 19) respondents indicating their erosion projects were a success,
- 53% of respondents felt they had no soil lost since project completion and a further 21% felt it was very minimal,
- 100% of participants believe they are more skilled and confident to do erosion control work alone,
- 100% will do more erosion control work.

CONCLUSIONS

The five-year soil conservation program has provided strong evidence that on ground works involving a diversity of rehabilitation interventions, including gully head stabilisation, can produce cost effective, sustainable reductions in soil loss. The support of and experienced soil conservation officer is essential.

Mt Wickham large-scale alluvial gully rehabilitation – approach and transferability

Glenn Dale, Neil Halpin[1,3], Peter Wilkinson[1,3] ,Laura McCallum[1,3], Ian Robb[1,3], Ben Silverwood[1,3]

Rohan Lucas[3], Vanessa Warrington[3,4]

Andrew Yates, Matt Miles[5], Lisa Hutchinson[5]

The large-scale gully remediation component of the NQ Dry Tropics' Landholders Driving Change (LDC) Project aims to achieve cost-effective gully rehabilitation to reduce sediment export and improve Reef water quality in the Burdekin region.

Remediation of a 16ha alluvial gully at Mt Wickham represents the first large-scale alluvial gully rehabilitation project within the LDC program.

Mt Wickham is a highly active gully, with fine sediment less than 20µm contributing approximately 40% of total sediment, well above the regional average. Signs of early gully erosion are evident in aerial photos from 1951. The gully has since grown exponentially in area ($r2 = 0.94$), and is currently estimated to export 2,200 to 3,900 t/year of total sediment (876 to 1,556t/yr fine sediment).

In line with the objective of developing a cost-effective approach to gully rehabilitation that is transferable across the Burdekin and other Reef Catchments, a rehabilitation approach was designed and implemented based on:

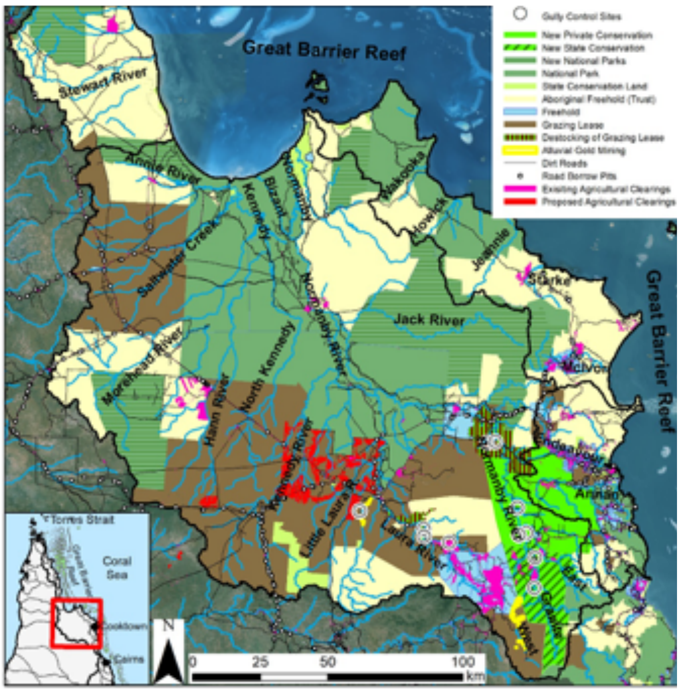
- Detailed site survey and characterisation to provide a confident understanding of site characteristics and processes driving erosion;
- Development of a conceptual model describing relevant gully erosion influences;
- Design and specification of a package of interventions aimed at targeting site characteristics and erosion processes;
- Engagement of local contractors to undertake gully remediation works and build capacity through understanding of gully erosion process and the basis for targeted interventions.

A process-based conceptual model was applied to the design of gully interventions, mirroring the Universal soil loss equation where:

- Erosivity = Fluvial
- Geotechnical = Slope, slope length, slope shape
- Pedological = Erodibility (but has cross-over with Crop management)
- Biological = Crop management
- Managerial = Practice control factors

This model reflects a matrix of exposure by vulnerability, providing a framework equivalent to the process of conventional risk assessment (likelihood x consequence) and, hence, a risk-based framework for prioritising gully rehabilitation works. It also provides a framework for development of a process-based, decision support system, providing the capacity to capture learnings from Mt Wickham and subsequent gully rehabilitation projects, facilitate transferable, cost-effective gully rehabilitation, and provide confidence to support investment in a greatly expanded program to achieve meaningful Reef water quality improvements and Reef water quality targets.

The process of design and implementation of a cost-effective gully rehabilitation approach at Mt Wickham will be discussed, and early performance of rehabilitation works following record 2018/19 rainfall events will be presented. The capture of learnings into an enduring and transferable decision support system will be discussed.



Innovative Gully Project – Finding cost effective and scalable solutions to reduce sediment into the Great Barrier Reef

Lynise Wearne[1], Damon Telfer[2], Sunny Behzadnia[3]

[1]Greening Australia, Brisbane, Australia
[2]Fruition Environmental, Townsville, Australia
[3]Greening Australia, Townsville, Australia

The Innovative Gully Remediation Project is a collaborative project supported by the Queensland Government's Reef Innovation Fund and Greening Australia's Reef Aid Program. The purpose of the collaboration is to develop cost-effective and scalable options for the reduction of sediment and particulate nutrient export to the Great Barrier Reef (GBR) lagoon ecosystem from alluvial gullies in grazing landscapes. The project is specifically focused on trialing methodologies (and relating that to cost effectiveness) that can be replicated in or transferred to other areas of the Burdekin and within other GBR catchments. The project site (Strathalbyn) is located within the Burdekin River catchment (catchment area ~ 130,000 km2) which is estimated to deliver about 47% of the total suspended sediment load to the GBR. Strathalbyn contains 65 hectares of alluvial gullies, 32 km of gully scarp and 9 km of gullies in length. Recent research reveals that in excess of 935,000 tonnes of fine sediment (< 20μm) has been exported to the GBR from the alluvial gullies that make up the Strathalbyn project area.

Remediation of gully complexes as part of the project at Strathalbyn has demonstrated to date effective methodologies for addressing sediment mobilization. Phase 1 (2017) works resulted in one treatment site (direct remediation of 1.5ha); and Phase 2 (2018) resulted in five additional treatments (direct remediation of 12.5ha). Treatments differ according to rock capping extent and thickness (e.g. 100mm vs 200mm); no rock capping (instead using coil netting to stablise the soil); the inclusion of porous check dams in some treatments; and varying grazing regimes.

An estimated 4000 tonnes per year of fine sediment has been reduced from the first two phases of works. These yields are expected to increase to > 5000 tonnes per year once the 2019 remediation works have been completed.

A range of monitoring techniques have been implemented to determine reduction of sediment and particulate nutrient loads to the GBR and the costs of achieving those reductions based on different interventions. Phase 1 works were competed in 2017, and the initial results showed a great than 97% reduction in suspended sediment concentration between the treated and untreated alluvial gullies. Monitoring was limited within the Phase 1 works due to limited rainfall and equipment failure, therefore results were considered as preliminary only. Phase 2 works have resulted in additional monitoring, extended to now measure both sediment and bioavailable nutrients. Monitoring to date of the Phase 2 works (as well as Phase 1 works) includes samples from across 7 events, with a total of 110 samples from all treatment and the control gullies. Flow data (and depth of flow data) was recorded, as well as a solid rainfall dataset on site. The current paper will present the findings of the Phase 1 and Phase 2 works, including the water quality results, and the response of the remediation works following a number of high rainfall events. In addition, the 2019 works program will be discussed.

Predicting future gully erosion from a single pass airborne LiDAR DTM: The Potential Active Erosion metric

James Daley[1], Justin Stout[1], Andrew Brooks[1], Graeme Curwen[1, 2]

[1]Griffith Centre for Coastal Management, Griffith University, Gold Coast, Australia
[2]Australian Rivers Institute, Griffith University, Brisbane, Australia

argeting and prioritising gully management requires an understanding of the location of gullies at high resolution, coupled with some measure of relative erosion susceptibility between gullies. Multi-temporal spatial datasets provide an ability to derive historical areal growth of gullies (aerial imagery) and erosional/depositional characteristics (LiDAR DEM of difference - DoD), yet these analyses require repeat datasets and highlight past erosion. Previous studies have utilised terrain derivatives to map gullies from a single LiDAR-derived digital terrain model (DTM). Here we take this approach a step further and identify at fine scale (1 – 2m) specific areas of erosion within individual gullies. This approach enables us to derive a measure of relative activity between similar types of gullies at a regional scale, and to predict future potential active erosion. Importantly, we demonstrate this can be achieved from single pass LiDAR.

We present a method for mapping potential active erosion (PAE) and apply this within gullies of the Bowen River basin, Australia. Primarily, slope and curvature and roughness values were analysed as predictive variables for erosion. Surface roughness, as a function of the standard deviation in total curvature, explained 86% of the variance in erosion. Data was filtered to the limit of detection was filtered from the analysis and divided into training and test datasets (75:25 accordingly).

We used a moderate gaussian Support Vector Machine with 95% PCA to classify the data into erosional/non-erosional. Multiple high resolution (1 m) DTMs are available for this location and provide an opportunity to validate the method through comparison with volumetric change derived independently from multi-temporal DoD analyses. The method achieved a true positive erosion classification >0.8.

Further validation was provided by field observations at 230 randomly sampled locations across several gully systems within the region. The method predicted highly active surfaces with a 0.91 correlation, while areas of relatively flat, residual topography exhibiting scalding or minor deflation were less detectable (0.29). Further work is required to integrate additional remotely sensed data to improve detection under such conditions. The current approach is limited by the reliance on surface expression of erosion, ie increased roughness, and the limit of detection in LiDAR. Fig. 1 further demonstrates the inability to model headscarp retreat, although this could be anticipated given the high proportion of activity within that area of the gully. While we present a binary measure of erosion, it provides a metric of the relative activity between gullies, either between similar types or localities; an important characteristic for comparison. The metric is also useful in identifying relatively inactive gullies which may otherwise have the general appearance of a gully in spatial datasets.

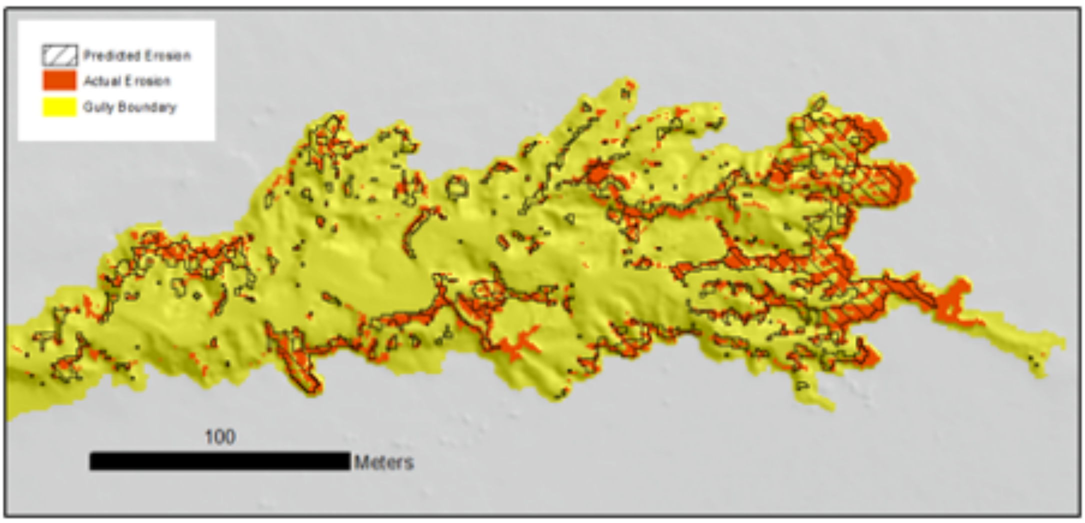


Fig 1. Example of predicted erosion using surface roughness in the 2010 DTM compared with the actual erosion extracted from a DEM of Difference (2010-2017) using 0.35 m threshold for detection

Lessons Learnt About Rill and Gully Erosion from a Landform Evolution Perspective

Garry Willgoose[1], Greg Hancock[2]

[1]Centre for Water Security, Faculty of Engineering and Built Environment, The University of Newcastle, Callaghan, Australia

[2]Centre for Water Security, Faculty of Science, The University of Newcastle, Callaghan, Australia

Incision as a result of fluvial erosion is an important mechanism to model when simulating landform evolution. In this talk we will discuss incision mechanisms, some of the drivers for it, some of the mechanisms that suppress it, and some of the associated implications for the dynamics of sediment transport and sediment mass balance downstream. Most of our recent thinking and experience has been driven by a need to model, and calibrate to field data, rill and gully erosion on rehabilitated mines sites. A further issue is assessing erosion for covers over hazardous wastes like mine tailings and low-level nuclear waste. That said, there are still lessons applicable to more natural environments.

The first aspect of this talk will be about what aspects of the physics of erosion are needed to trigger gully erosion. This is about more than just shear stress threshold exceedance but a focus on the incision process itself. Once we look at this carefully it will be apparent that coupled with the processes that cause incision there must be a range of processes that stop incision because the incision processes are not self-limiting. Once started rills and gullies will grow infinitely if the incision processes are the only ones in operation. Some of these rill suppressing processes have been well studied under the heading of inter-rill erosion. Other limiting processes are related to the shape of the landform and how downstream deposition areas are linked geomorphically to the upstream gullies. This can be important in our unnatural man-made landforms. One process that we've spent considerable time studying is the process of armouring because it appears to be a dominant mechanism in mine wastes. Mine wastes tend to be quite rocky and once the fines have been stripped out and the bottom of the gully has 100% armour cover they tend to stabilise. Subsequently they only erode as a result of weathering breakdown of the rock armour on the gully bottom, an erosion mechanism we call "weathering-limited erosion". This concept also applies to natural systems where the gully erodes to bedrock or some resistant base (e.g. plough pan) which limits further development.

The second aspect of gully erosion we will discuss is the sediment mass balance downstream of the eroding gully head. If the gully is actively advancing upslope it is delivering sediment load from the gully excavation to the gully downstream, while if the gully head has stabilised then there is no additional load from the gully head. There will still be sediment load being delivered to the gully from upstream of the gully head but not specifically from the excavation of the gully head. This change in the sediment load downstream has implications for the evolution of the gully downstream of the gully head, both the cross-sectional geometry and long profile of the gully. Specifically, when the gully head stops advancing upslope the sediment load being delivered to the gully will be reduced leading to a higher erosion potential within the gully downstream, which may destabilise what was previously a stable gully downstream of the head. This interaction between the advancing/stable gully head and the downstream gully stability as a result of sediment mass balance has been relatively poorly recognised. There is little data on this mechanism. We believe it is important for the downstream geometry of the gully particularly for mining applications where there is the potential that a gully will penetrate a cover over hazardous waste.

The work here is placed in the context of both geomorphic theory and numerical modelling. In particular, Landscape Evolution Models (LEMs) and the recent Soilscape Evolution Models (SEMs) have the ability to model both fluvial and diffusive processes as well as armouring in a digital elevation model framework. These models provide qualitative and quantitative insights into complex non-linear systems such as gullies. This talk will highlight the capabilities of such models.

Enhanced Ephemeral Gully Erosion Technology Within AnnAGNPS to Assess the Impacts from Agricultural Management Decisions

Ronald Bingner[1], Robert Wells[1], Henrique Momm[2]

[1]USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi, USA

[2]Middle Tennessee State University, Department of Geosciences, Murfreesboro, Tennessee, USA

Concentrated runoff increases erosion and transfers fine sediment and associated agrichemicals from upland areas to stream channels. Ephemeral gully erosion on croplands in the U.S. may contribute up to 40% or more of the sediment delivered to the edge of the field. Typically, conservation practices developed for sheet and rill erosion are also expected to treat ephemeral gully erosion, but science and technology are needed to account for the separate benefits and effects of practices on each of the various sediment sources.

Watershed modeling technology has been widely developed to aid in evaluating conservation practices implemented as part of a management plan, but typically lacks the capability to identify how a source, such as sheet and rill erosion, ephemeral gully erosion, edge-of-field erosion, or channel erosion, is specifically controlled by a practice or integrated practices. By using watershed modeling technology to understand how a source is controlled from one or more practices, an optimal combination of integrated practices can be designed that has the least impact on agricultural productivity and provides the greatest economic benefit, while having the most impact on improving watershed water quality.

The U.S. Department of Agriculture's Annualized Agricultural Non-Point Source pollutant loading model, AnnAGNPS, has been developed to determine the effects of conservation management plans and provide sediment tracking from all sources within the watershed, including sheet and rill, ephemeral gully, and channel erosion.

This study describes recent enhancements to ephemeral gully erosion capabilities within the AnnAGNPS model and discusses research needs to further improve these components for integrated conservation management planning. Conservation management planning by agencies within the U.S. and by international organizations needs a systematic approach when determining the extent of ephemeral gully erosion impacts on a field, watershed, or national basis, and/or to predict recurring or new locations of ephemeral gullies prior to their development. This technology provides the capability to separate the impact of ephemeral gullies on erosion from other sources and then evaluate the impact of targeted practices to control erosion at the source and subsequent downstream resources.

Evaluation of AnnAGNPS for predicting ephemeral gully erosion in central Iowa (USA)

Eduardo Luquin[1], Richard Cruse[2], Ronald Bingner[3], Robert Wells[3], Henrique Momm[4], Miguel A Campo-Bescós[1] Javier Casalí[1]

[1] Dep. of Engineering; IS-FOOD Institute (Innovation & Sustainable Development in Food Chain) – Public University of Navarre, Pamplona, Navarra, Spain

[2] Dep. of Agronomy – Iowa State University. Ames (Iowa), United States

[3] National Sedimentation Laboratory USDA-Agricultural Research Service. Oxford (Mississippi), United States

[4] Dep. of Geosciences, Middle Tennessee State University, Murfreesboro, United States

Ephemeral gullies are important erosion features and are frequently identified as the most relevant sediment sources in agricultural areas. Despite their importance, watershed models including an ephemeral gully (EG) erosion component are scarce and/or have not been properly evaluated in agricultural watersheds. The objective of this study was to evaluate the USDA (United States Department of Agriculture) AnnAGNPS (Annualized Agricultural Non-Point Source pollution model) capability to simulate EG erosion in two agricultural watersheds in Iowa. AnnAGNPS incorporates TIEGEM (Tillage-Induced Ephemeral Gully Erosion Model) that simulates EG erosion by the formation of a plunge pool and its subsequent headcut migration processes. The study area was located within the Walnut Creek watershed, Iowa (US) where EGs formed in two intensively monitored experimental sub-watersheds named Basswood 6 (B6, 0.94ha) and Interim 3 (I3, 0.95ha), each with similar topography, soils and farming management. The cropping system consists of a no-tilled corn-soybean rotation; gullies were filled by the farmer in 2012, 2015 and 2016. An ISCO 6712 automated water sampler and a fiberglass H flume were located at the watershed outlet to monitor runoff 2007-2015. Close-range photogrammetry techniques were used for spatiotemporal measurement of EGs. Photographs were taken using a calibrated Nikon D7000 camera with a 20-mm fixed lens and ground control points were surveyed using a RTK-GPS for sub-sequent analysis and geo-referencing of the photos. Gullies were measured at least once in 2013, 2014 and 2018. For a preliminary evaluation of the model, simulated runoff was manually calibrated to the monthly observed record using the SCS curve number and goodness of fit, and gully volumes were calibrated to the 2018 photogrammetric record using critical shear stress and EG width function.

Runoff CNs that showed the best goodness of fit statistical values were 77 and 64 for B6 and I3, respectively. In both watersheds, the best EG volume estimations were obtained using the Non-submerging Tailwater algorithm (B6: 2.14 m^3 vs measured 2.2 m^3 and I3: 1.38 m^3 vs measured 1.6 m3). Critical shear stress was 4.611 N/m2 and Nickpoint Erodibility was 1.04E-05 Mg/N/sec for both gullies. In I3, the model slightly overestimated EG length (44 m vs measured 30 m). Whereas in B6, the length was slightly underestimated (49.5 m vs measured 56 m). Overall, preliminary results showed a good approximation between simulated and observed values for runoff, EG volume, and dimensions. However, a more complete evaluation of the model is needed. The model evaluation should include a sensitivity analysis of EG component parameters (e.g. Headcut Detachment Coefficient) on EG dimensions.

A mathematical model for the erosion of an ideal gully to inform interventions

Melanie Roberts

Australian Rivers Institute, Griffith University, Nathan, Australia

The Great Barrier Reef (GBR) is under threat. After climate change, water quality is recognised as the greatest stressor on the GBR. Sediments eroded from the catchment are transported to the marine environment, leading to poor water quality in the GBR lagoon. Suspended sediment reduces light availability and impedes seagrass growth. Sedimentation can bury coral polyps, cause tissue necrosis, and reduce the recruitment and survival of coral larvae leading to coral reef decline. Sediment can also transport nutrients into the lagoon, potentially leading to eutrophication, algal blooms, and Crown of Thorns Starfish outbreaks. Gullies, particularly in grazing areas, have been identified as leading contributors to sediment reaching the GBR lagoon, despite occupying a small proportion of the landscape. Reducing gully erosion is critical to improving water quality of the GBR, however the current pace of change is insufficient to achieve water quality targets. To guide investment, improved mathematical models of gully erosion are sought that can better assess the efficiency of remediation actions.

Building on the work of Hairsine and Rose, we developed a process-based model to describe the erosion of sediment from an ideal alluvial gully. We explore this model from the lens of supporting investment decisions to remediate gullied landscapes and demonstrate how the model can be applied in this context. Our new model has several advantages over the Dynamic SedNet model currently used by many to support intervention decisions for the GBR.

The Dynamic SedNet model, having been developed to operate at large spatial and temporal scales, provides minimal opportunity to explicitly represent different management actions at a scale targeted to reduce gully erosion. The user must therefore incorporate the effects of intervention as a modifier to the calculated erosion rates. This arrangement is less than ideal, and is outside of the framework for which the SedNet model was originally developed. Moreover, the spatial and temporal averaging incorporated into SedNet limits its ability to reflect the variability in erosion arising from different gullies.

In contrast, our process-based gully model is able to reflect different interventions, allowing for direct experimentation to inform how different interventions would influence erosion. This model also allows for gully diversity to be better reflected, as the effectiveness of management actions varies between gullies. We initially consider gully diversity due to soil properties and macro topographic features. Our initial focus has been to capture the key driving processes of erosion necessary to represent management interventions for an ideal gully. Future work will focus on exploring these simplifications against observed erosion events, to determine where greater process detail in the model is required. Our objective is to develop the simplest model possible that can still capture the key features of erosion under different interventions.

Ecogeomorphic drivers of gully-landslide interactions in the Ideato area of southeast Nigeria

Ikenna Osumgborogwu[1], John Wainwright[1], Laura Turnbull-Lloyd[1]

[1]Geography Department, Durham University, Durham, United Kingdom
ikenna.e.osumgborogwu@durham.ac.uk

Gully erosion and landsliding are significant hazards; some landslide events occur as a result of extreme gullying; in turn the irregular surfaces created by landslide scars encourages the concentration of runoff, thus, increasing runoff erosivity and subsequent initiation of new gullies. Ecogeomorphic processes are commonly at the centre of these interactions, yet have been poorly studied.

This paper presents the first results of an on-going applied geomorphology project with the overarching aim of improving understanding of gully-landslide interactions using case studies in southeast Nigeria. Our methods include – use of remotely sensed data, geomorphological fieldwork and community participatory science. Remotely sensed data are used for gully mapping and they include QuickBird (0.65 m resolution) satellite imagery, over an 11 year period (2006 – 2017), 30 m ASTER DEM and Structure from Motion (SfM) photogrammetry. Fieldwork involves ground-truthing satellite imagery and afford the opportunity for SfM photogrammetry which will inform landslide identification and mapping within selected gullies. This process allow the estimation of soil loss due to landsliding and reveal geomorphic characteristics of gullies where landsliding occurs.

The Ideato area of southeast Nigeria comprises two Local Government Areas, Ideato North with a landmass of 190 km2, a 2017 estimated population of 222,091 and Ideato South, covering 88 km2 of land and a 2017 population of 226,971. Three ecogeomorphic factors were considered – changes in; population density, vegetation and land-use. In December 2006, land area covered by gullying was 0.14 km2 and 0.02 km^2 in Ideato North and South LGAs respectively. In December 2017, a total of 0.26 km^2 and 0.11 km^2 of land was covered by gully in Ideato North and South LGAs; an increase of 46.2% and 81.8% in 11 years respectively. Population density increased from 822 people km^2 to 1169 people km^2; an increase of 29.7% in the North and an increase from 1814 to 2579 people km^2 in the south; a 29.7% increase. Impervious surfaces increased by 3 km^2 while there was negative change in NDVI in an area of 23.3 km^2 in Ideato North. Negative NDVI values covering 4.7 km^2 of area was also recorded in Ideato South while impervious surfaces increased by 1.4 km^2. The desk-based study showed only weak relations between gully sites and proximity to rivers, and slope angle and thus demonstrating the need for more detailed process-based analyses in the field.

Keywords: Gully erosion, ecogeomorphology, population density, land-use change, vegetation change

Rainfall threshold of gully erosion under an extremely heavy rainstorm on the hilly Loess Plateau

Mutian Yuan, **Yan Zhang***

College of soil and water conservation, Beijing Forestry University, Beijing, China, 100083

ABSTRACT

Gully erosion is common on the Loess Plateau, and sediment production of gully erosion accounts for more than 50% of the total erosion of the whole watershed. As a driving force of gully erosion, rainfall threshold is particularly critical, but most of the previous studies were based on laboratory control experiments or long-term measurement of annual changes. There is a gap on the influence of rainfall spatial change on gully erosion under a rainstorm. A heavy rainstorm and flood disaster occurred in the region on July 26–27th, 2017, inducing intense gully erosion. Rainfall amount distribution in an area of 41207 km2 were interpolated based on 34 recording stations with rainfall range from 22.5 mm to 252. mm. UAV measurement technology was used to sample and shoot 217 catchments along three survey transections from the rainstorm center to the periphery. The UAV image was compared with the high-resolution remote sensing image before the rainstorm to examine newly occurred gully erosion after the rainstorm and access the influences of the land uses. The length, width, area and volume of each gullies were measured with DSM derived from UAV image. Relationships between gully density and rainfall amount were analyzed using correlation and regression analysis.

The results showed that: 1) A total of 502 gullies were formed by the rainstorm in the sampled catchments. At the storm center with 252mm rainfall, gully erosion, gully areal and linear density reached 4926.91 m3/km2, 1223.44 m2/km^2 and 999.02 m/km^2, respectively. Gully erosion, gully areal and linear density decreased with rainfall amount decreasing form storm center to the periphery. 2) Vegetation restoration from cropland to forest and grassland has a positive impact on reducing the gully erosion. The soil loss, gully areal and linear density in vegetation restoration catchments decreased by 50.94%, 47.34% and 42.37%, respectively, compared with those in the cultivated catchment. 3) Based on the exponential curves fitting the relationships between gully erosion and rainfall amount, the rainfall thresholds for gully occurrence was higher in 66 cultivated catchments than that in 151 vegetation restoration catchments.

Keywords: storm; rainfall threshold; gully erosion; vegetation restoration; Loess Plateau.

Automated Spatiotemporal Measuring of Ephemeral Gully Channel Lateral Expansion using Digital Photogrammetry in Laboratory Experiments

Henrique G. Momm[1], Robert R. Wells[2], Ronald L. Bingner[2]

[1] Dept. of Geosciences, Middle Tennessee State University, Murfreesboro, TN, USA.
[2] National Sedimentation Laboratory, USDA-Agricultural Research Service, Oxford, MS, USA.

Ephemeral gully evolution in agricultural fields is controlled by concentrated flow processes that incise into soil strata, headcuts migrate upstream, and channel sidewalls fail leading to lateral expansion. Specific conditions may occur where headcuts develop and migrate upstream and channel becomes restricted in depth by the presence of an erosion-resistant/non-erodible soil layer. As a result of these conditions, channel lateral expansion becomes the dominant physical process in the evolution of the gully. This phenomenon was replicated using laboratory experiments with the ultimate goal of developing an improved understanding of channel lateral expansion as impacted by terrain slope, soil erodibility, and overland discharge. This study focused on developing efficient and accurate methods for quantifying gully channel width evolution at high temporal (from 3 to 300s) and spatial resolutions (5mm intervals). Previous work utilized a single image analysis approach based on spectral discontinuities (two-dimensional analysis). This study implemented photo-pairs and photogrammetric technology to develop three-dimensional point clouds for subsequent spatial characterizations of channel sidewalls. A total of 20,376 point-clouds were generated depicting 45 experiments of 3 soils, 3 slopes, 3 discharge, and 2 replications.

Experiments were carried out in a small, non-recirculating, tilting hydraulic soil flume (3.89-m long, 0.61-m wide and 0.3-m deep) where the slope (1%, 5%, 11%), discharge (0.00025, 0.00067, 0.00108 m^3/s) and photogrammetry temporal resolution could be adjusted. Custom computer scripts were developed to automate the photogrammetry analysis in multiple linked steps involving: photo database development, determination of ground control points, photo internal orientation, photogrammetry processing and point cloud generation, point clouds filtering, raster grids generation, channel edge identification, channel edge post processing, and output generation. Point clouds were generated using structure from motion technology. Selected experiments were used to evaluate the accuracy of the image processing procedure. Ten time periods for each of the selected experiments were processed using operator-guided classical photogrammetry and the generated point-clouds were post processed using the automated edge-detection and manual GIS-based digitizing. Quantitative comparison of the three methods indicated high agreement between methods. These processing methods serve as template for future laboratory and field methods where high volumes of photogrammetric data needs to be processed and converted into geomorphologic information quickly and accurately.

Suspended sediment monitoring in ephemeral alluvial gullies: laboratory and field evaluation of available measurement techniques

Nicholas J.C. Doriean[1,2], Andrew P. Brooks[2], John R. Spencer[2], David T. Welsh[1], Peter R. Teasdale [3,4], and William W. Bennett[1]

[1] Environmental Futures Research Institute, School of Environment and Science, Griffith University Gold Coast campus, Queensland 4215, Australia

[2] Griffith Centre for Coastal Management, Griffith University Gold Coast campus, Queensland 4215, Australia

[3] Natural and Built Environments Research Centre, School of Natural and Built Environments, University of South Australia, South Australia 5095, Australia.

[4] Future Industries Institute, University of South Australia, South Australia 5095, Australia.

Australian State and Federal governments have identified gully erosion as a key focus area for monitoring and management as part of their initiatives to improve coastal water quality in the Great Barrier Reef (GBR). This has led to a significant increase in monitoring effort applied to measuring sediment water quality associated with gully erosion. The methods currently being used (autosampler, rising stage sampler, and turbidity logger) to monitor key water quality parameters in gullies were designed to be used in rivers and streams. However, gullies have unique hydrological and operational challenges, and their effect on the accuracy of these monitoring techniques has not been evaluated. Here we aim to systematically evaluate the capabilities and limitations of sediment water quality monitoring and analysis techniques commonly used to monitor sediment water quality associated with gully erosion in the GBR catchments, as well as evaluate the newly-developed pumped active suspended sediment sampler (PASS) sampler for this purpose.

Laboratory and field evaluations of these techniques showed that most methods, including the PASS sampler, collected representative samples of both suspended sediment concentration (SSC) and particle size distribution (PSD). Gully characteristics (e.g., channel depth, soil type, and catchment size) strongly influenced the accuracy of the different monitoring methods. For example, the automatic sampler had significant negative bias to SSC and PSD when suspended sand (> 10% of sample) was present during a flow event, particularly if the autosampler was elevated (>1.5 m) above its intake. The ability of each method to collect a representative sample was also strongly influenced by outside factors, such as, backwatering, insect infestation, and channel bed aggradation or scouring. These factors combined with the limitations and advantages of the methods evaluated in this study should be considered for future water quality monitoring activities associated with gully erosion.

Field scale evaluation of temporal erosion patterns using high spatial resolution drone imagery

Robert R. Wells[1], Henrique G. Momm[2], Carlos Castillo3, Ronald L. Bingner[1] and Dalmo Vieira[1]

[1] National Sedimentation Laboratory, USDA-Agricultural Research Service, Oxford, MS, USA.

[2]Dept. of Geosciences, Middle Tennessee State University, Murfreesboro, TN, USA.

[3] Dept. of Rural Engineering, University of Cordoba, Cordoba, Spain.

Hugh Hammond Bennett, a notable soil conservationist in the US, once wrote that soil erosion was a “national menace”. At the time (Dustbowl Era), rates of soil erosion were growing exponentially in the US and the fight continues to this day. Although numerous conservation measures and planning strategies have greatly reduced the amount of sediment moving within the landscape, there are still unresolved questions concerning initiation of particle motion, susceptibility to erosion, total soil loss, sediment transport and general measurement theory. As the struggle to overcome these adversities lingers, many advancements have been achieved in our understanding of erosion theory. Both empirical and process-based formulations have helped glean insights into fundamental processes and offered the promise of erosion prediction. This study is another link in the chain, attempting to accurately quantify temporal surface deformation as impacted by natural rainfall on agricultural landscapes. Imagery was captured within seven agricultural fields (six in Iowa and one in Minnesota), ranging in size from 0.6 to 3.6 hectare (1.6 to 8.8 acre), after planting and approximately one month later, subsequent to a series of recorded rainstorms. Considering the small scale in topographic variation between two surveys, extreme efforts were applied to image processing and geospatial registration. Advanced models for camera calibration from Micmac open-source photogrammetry software package were used to account for complex distortion patterns in the raw image data set. The undistorted images were then processed using Agisoft Photoscan for camera alignment, model georeferencing and dense point cloud generation (millions to billions of points per survey), from which digital elevation models (DEMs; 10 to 57 million cells) were produced in CloudCompare. The accuracy of the 3-D models was ~1.5 cm when compared to control/bench points and DEMs of temporal difference were produced to obtain erosion/sedimentation estimations for each field. The high-resolution DEMs offered insight to farmer activities and natural (i.e. erosion/sedimentation/plant growth) activities. In some cases, farmer activity had more impact on the landscape than the rainstorms. Interrill and concentrated flow (rill and ephemeral gully) erosion were easily discernable, providing a snapshot of ephemeral landscape development including: integrated sediment source delivery to concentrated flow channels; headcut dimensions and locations; and channel incision, sinuosity, widening and depositional patterns. Investigations of this type support the continued development and validation of U.S. Department of Agriculture prediction technology (e.g. AnnAGNPS and EphGEE) needed for effective conservation practice management planning.

Evaluating gully wall slope angle impact on DEM error derived from structure-from-motion (SfM) photogrammetry using vertical images

Hao Li[a], Huaicai Zhen[b], Wei Yang[c], and Xingyi Zhang[a]

[a]Key Laboratory of Mollisols Agroecology, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Harbin, China
[b]Northeast Agricultural University, Harbin, China
[c]Heilongjiang Academy of Hydro Science, Harbin, China

ABSTRACT

Detection of digital elevation model (DEM) error is a fundamental task in structure-from-motion (SfM) geomorphological survey such as that used for gully erosion. A network of tie points created from identifying and matching corresponding features in different images is applied for DEM products, and this process could be substantially affected by camera view angle in unmanned aerial vehicles (UAV). For gully erosion research, gully bank slope angle reflects view angle effects on DEM error when using vertical images for SfM-DEM products. The objectives of this research are to examine (1) How different gully bank slope gradients affect DEM error; and (2) to what extent will such DEM error vary with flight height. The SfM surveys of two cropland gullies (gully_b and gully_m) with three flight heights (10m, 20m and 50m) using phantom4 UAV and RTK were obtained in the Mollisol region of Northeastern China, where gully erosion is threating food security. Benchmark terrestrial laser scanner (TLS) data were acquired simultaneously for DEM error detection. The average gully wall slope ratio (horizontal: vertical) of gully_b and gully_m were around 1.8:1 and 1.1:1. The gully wall slope gradient was obtained from the TLS-DEM and then classified with the unit of degree. The gully wall area in percentage per slope class (Ap) was calculated. The elevation errors per slope class between SfM- and TLS-DEMs were compared in terms of mean absolute error (Em with unit of cm) and total absolute error in percentage (Et). The Et was obtained by multiplying Em with Ap.

The results show that average elevation errors between SfM- and TLS-DEMs were around 10 cm. The Em increased exponentially with gully wall slope gradient (Fig.1 a). The Em increased 5 cm to 10 cm from 0 to 60 degrees, while it increased sharply to 80 cm near 90 degrees. In previous studies of DEM error from TLS data, error increased linearly with slope gradient, addressing strongly gully bank slope effect on elevation errors of SfM-DEM. For gully_b, more than 50% of the gully bank area slope was concentrated between 20 to 30 degrees, and that for gully_m was 0 to 20 degrees. For the Et value of gully_b, more than 50% was concentrated between 0 to 30 degrees, and that for gully_m was between 20 to 50 degrees (Fig.1 b). Similar with TLS-DEM error investigated previously, SfM-DEM can lose validity in regions of steep topography. If we assume that the DEM error of area with more than 60 degree be reduced to be similar with that less than 60 degree, i.e. reduced from c.50 cm to c.8 cm, then the Et could only be reduced around ten percent, since such region with more than 60 degree occupied only five percent of the whole gully. This implies limited benefits of oblique aerial photography in gully erosion research.

Keywords: elevation error; DEM; structure-from-motion; gully erosion; UAV

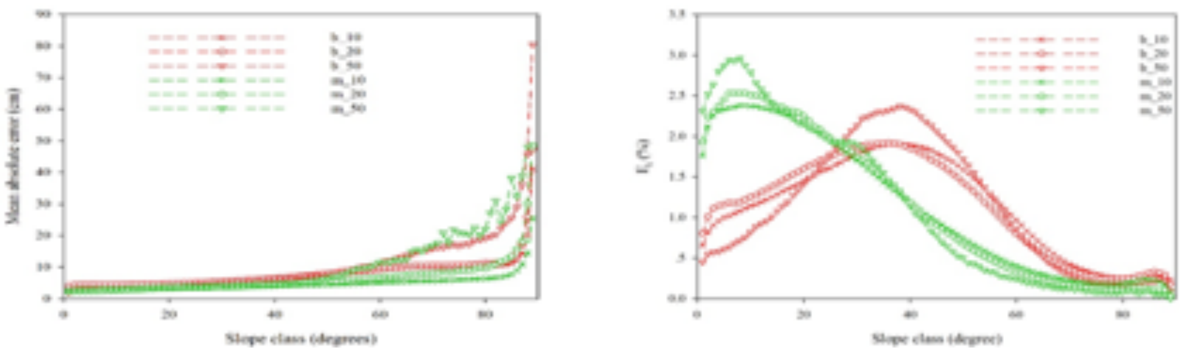


Figure1. Em and Et distribution with slope class (a, Em; b, Et)

Measuring the effectiveness of gully remediation on off-site water quality in the Burdekin catchment, Queensland, Australia.

Rebecca Bartley[1], Aaron Hawdon[2], Anne Henderson[2], Scott Wilkinson[3], Nick Goodwin[4], Brett Abbott[2], Brett Baker[2], David Boadle[2] and Kahlytah Ahwang[2]

[1] CSIRO Land and Water, Brisbane

[2] CSIRO Land and Water, Townsville

[3] CSIRO Land and Water, Canberra

[4] Queensland Department of Environment and Sciences

While gully erosion only impacts ~0.1% of the Great Barrier Reef (GBR) catchment area, it contributes ~40% of the excess soil erosion into the GBR. Gully remediation is therefore potentially an efficient method for reducing excess sediment loads, however, the approaches for reducing this erosion source are not well tested in this environment. Given the significant Government investment in GBR water quality improvement focused on reducing gully erosion, there is an urgent need to formerly evaluate remediation options from this erosion source.

This study was designed to evaluate the effectiveness of a range of remediation options for gullies within rangeland systems. Paired gully sites (treatment and control) were identified at five properties in the Burdekin basin. The remediation options implemented on the treatment gullies include a mixture of fencing, livestock exclusion, sediment trapping structures (within the gullies), gully reshaping, chemical treatment of the soil and hillslope vegetation management.

To quantify the effectiveness of the various treatment options, data were measured on (i) vegetation cover, biomass and species composition on the hillslopes above each gully as well as within the gullies, (ii) changes in gully erosion rate were conducted using repeat surveys of gully morphology using terrestrial laser scanning or airborne Lidar, and (iii) water quality and quantity monitoring including measurements of water stage, runoff volume, turbidity, sediment and nutrient concentration and particle size.

Water quality samples from these sites have also been shared with other projects looking at the bio-availability of nutrients, geochemical tracing and nutrient isotope analysis.

We have treatment response data from four of the five study sites, with at least two wet seasons of measurement data for each site. The initial results suggest that vegetation response is slow, even with reduced grazing pressure, and all sites have poor vegetation cover and biomass. Grazing management alone does not appear to improve water quality, however, porous check dams (or PCDs), in combination with stock exclusion fencing, appear to have a statistically significant impact on the amount of vegetation (% cover and/or biomass) that stabilises gullies floors and walls. This, in turn, appears to have significantly reduced the total suspended sediment (TSS) (and total nitrogen, TN) concentrations within the gullies treated with PCDs, although several more years of average to above average rainfall is required to validate this finding. Re-shaping and chemical treatment of sodic soils shows early indictors of effectiveness for the larger gullies in deep alluvial soils. Changes in the particle size of sediment have been variable between the treatments and measuring changes in runoff (and thus loads) is challenging in these climatically variable environments.

Rethinking gullies and badlands dynamics: interactions between vegetation, water and soil erosion

Estela Nadal-Romero[1]

[1]Instituto Pirenaico de Ecología (IPE-CSIC), Zaragoza, Spain

Although badlands and gullies occupy a relative small fraction of the world, those places present the highest erosion rates worldwide. Erosion processes determine vegetation establishment, playing a vital role for restoration of badlands and gullies systems. In that sense, badlands are suitable areas for studies of plant colonization, but the interaction between vegetation and water erosion is complex in those areas. Literature has mainly focused on quantifying soil erosion rates by using a wide variety of methodologies (erosion pins, gauging stations, photogrammetry, etc.), identifying hydrological processes, and understanding the interactions between badlands and plant cover dynamics. Accordingly, the aims of this presentation are (i) to review and summarize the current knowledge about badlands and gullies dynamics, identifying interactions between vegetation, water, and soil erosion processes; (ii) to discuss ongoing and emerging questions and challenges not previously addressed.

Although badlands and gullies are ubiquitous processes all around the world, further efforts are still needed for improving our knowledge, as well as for identifying further research questions on badland dynamics in the particular context of Global Change. Some examples are the following: How do the interactions between vegetation and erosion work in these eroded areas? Which is the role of endemic species in badland areas? What can we do to reduce sediment yield from gullies and badlands areas? Would it be necessary to restore all gullies and badlands areas? Can we quantify soil erosion rates due to piping processes? And finally, what is the fate of badlands and gullies under a context of Global Change?

Acknowledgement: This research was supported by the ESPAS project (CGL2015- 65569-R, funded by the MINECO-FEDER) and the “Geoenvironmental Processes and Global Change” group (E02_17E, Aragón Government and the European Social Fund, ESF-FSE).

Impacts of native vegetation on erosion rates and hydraulic properties of bank gullies in the Dry-hot Valley region of southwest China

Su Zheng'an[1], Zhouyao He[1,2], Xiaoyi Wang[1,3], Tao Zhou[1,4]

[1] Key Laboratory of Mountain Hazards and Earth Surface Processes, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, China

[2] Forestry College, Sichuan Agricultural University, Chengdu, China

[3] College of Water Conservancy and Hydropower Engineering, Sichuan Agricultural University, Ya'an, China

[4] University of Chinese Academy of Science, Beijing, China

Gully erosion is a type of soil degradation that occurs in a wide variety of environments around the world, yet the erosion rates and hydraulic properties of the concentrated flow in gully headward erosion have received minimal attention. To quantify the impacts of native vegetation (i.e., Heteropogon contortus and Agave sisalana) on the spatial and temporal variation of the erosion rates and hydrodynamic properties of the concentrated flow at the gully heads in the Dry-hot Valley region of southwest China, a series of scour experiments, which lasted 120 min, were run using flow discharges of 90 L min-1. We employed in–situ bank gully field flume experiment with upstream catchment areas with grass (GLG, G1 and G2) or bare land (BLG, G3) that drained down to bare gully headcuts. Meanwhile, Heteropogon contortus and Agave sisalana were set in the upstream catchment area and gully bed of gully 4 (G4), respectively. G3 was set as blank control group, while the grass in the G2 was one year older than that in the G1. Native vegetation clearly affected bank gully soil erosion rates. Meanwhile, as the vegetation grew, the erosion rates declined significantly. The amount of erosion in G4 was lower than G1, indicating that native vegetation in gully bed was significantly decreased soil erosion in the gully heads. Meanwhile, a declining power function trend ($p \leq 0.1$) was observed with time in soil erosion rates for both upstream catchment areas and downstream gully beds. Non-steady state soil erosion rates were observed for the headcut due to abrupt collapse. In response to this flow discharge, the concentrated flows were turbulent and supercritical in the upstream areas and gully beds of G3. Flow energy consumption (ΔE) and Darcy–Weisbach friction factor (f) for G1, G2, and G4 were significantly higher than those for G3, while flow rate, Froude number (Fr) and Re for G1, G2, and G4 were significantly lower than those for G3, respectively. Compared to other gully heads, ΔE and f was highest in the G4. As the experiment progressed, the hydrodynamic properties (i.e., Re, flow rate, and ΔE) in the gully beds and upstream areas increased logarithmically ($P < 0.1$). Finally, a significant correlation was found between the soil loss and flow energy consumption, which indicates that the flow energy consumption is a useful parameter for explaining the temporal variations of the soil loss during headward erosion. In Conclusion, increasing vegetation cover in upstream catchment areas and gully beds of bank gullies is essential in the dry-hot valley region of Southwest China.

The influences of dammed gullies on the ecology of a cultivated arid area, Project Wadi Attir (PWA): A case study

Amir Mor-Mussery[1], Jonathan M. Laronne[2]

[1]The Department of Soil and Water Science, Faculty of Agriculture, Hebrew University of Jerusalem, Rehovot, Israel

[2]The Department of Geography and Environmental Development, Ben Gurion University of the Negev, Beer Sheva, Israel

The combination of loess soil, an arid climate and intensive and continuous cultivation may promote incision and gully erosion. Whereas most studies focus on geomorphological aspects of gully erosion, only a few deal with ecological influences. In order to determine the ecological processes of gullies, we studied a hilly loess area adjacent to Hura Beduin municipality, northern Negev, named Wadi Attir. The area is rain-fed and cultivated for grazing and winter cereals using intensive tillage, resulting in dense gullies' density and a hilly topography. Two sets of gullies were chosen for the study, one 'natural' with no human interference, and the other with dammed terraces creating unique water catchments termed 'limans'.

In the untreated gullies, five ecological flows can be distinguished: (i) Flow of soil organic matter (SOM) and sediments (mostly clay) from the surrounded field through the slopes into the channel. Slopes with a slight incline or dense cover of harvester ant nests may stabilize it, and encourage shrub settlement and thereby preventing bank erosion. (ii) Flow of SOM and sediments from the gully head-cut to the confluent with the Wadi. This flow is intensive in the initial gully state (Sidorchuk, 2006) resulting in lack of sediments and clay along the channel, while a stabilised state (Sidorchuk, 2006) will lead to accumulation of SOM and sediments in plots along the channel, as well as settlement of vegetation. This may enhance the gully stabilisation. (iii) Bi-directional flow among neighbouring landforms and initial units of gully may lead to head-cuts and sinuosities with unique local ecological patterns. (iv) Flow of sediment from an adjacent loess area into the gully in a stabilised state may lead to the formation of widespread-sloped areas and, later on, promote rocky-karst desertification. (v) Bi-directional flow in gullied plots, naturally settled by ecosystem engineers (harvester ant nests, shrubs, planted trees) will lead mostly to local influences on the fertility and stability. Our study also indicates that the gully may serve as a 'hot bed' for rare species that had previously spread in this area.

Two additional flows of biomaterial have been identified in the limans chains: (i) Flow from the channel into the liman landforms; and (ii) flow from the liman to the surrounding cultivated lands. Both of these unique flows possibly result from the influence of gully savannization and damming.

In summary, our study of the ecological processes of gullies demonstrates their crucial role in stabilisation and the fertility of their surrounding areas, as well as the possibility to enhance these processes through liman construction, savanna tree plantation, etc. for sustainable and profitable agricultural utilisation. The designed scheme may be adjusted to other gullied areas across the globe.

Flow of biomaterial and species invasion in gullies (natural or dammed)

(A) Flow of biomaterial in 'natural' gullies: cross-sectional flow from surrounding fields through gully slopes into the channel and longitudinal flow along the channel from the head-cut until the confluent with the Wadi. (B) Gullies as a hotbed for rare species and for species invasion routes from the wadi into the channel, and from the channel through slopes to fields. (C) Dammed gullies (limans' chain) and visual demonstration of the influence of liman chains on their surrounding areas. (D) The influence of liman on the herbaceous biomass of its' surrounding as expressed by increased vegetation coverage in areal "strips" surrounding the liman. The width of each areal strip is 2m. (E) Bio-material flow from the liman channel to all its landforms, including terraces.

Sidorchuk, A., 2006. Stages in gully evolution and self-organized criticality. Earth Surf. Processes Land. 31(11), 1329-1344.

Thresholds conditions for rill and gully initiation on road surface on the Loess Plateau

Yiyang Zhao, Yan Zhang, Meng Yang, and Jiayong Deng

College of soil and water conservation, Beijing Forestry University, Beijing, China, 100083

Road erosion is common on the hilly Loess Plateau and gullies are often formed on unpaved road surfaces under heavy rainfall, which is mainly affected by local conditions such as land use and geomorphology. However, the mechanism of road erosion has not been well understood. This paper aimed to examine the threshold condition of rill and gully initiation on unpaved roads. A small watershed on the central Loess Plateau was selected as the study area where field investigations of road erosion were conducted in 2017 and 2018. We define a road segment as a continuous road surface that flow concentration begins and ends at local maximum and minimum elevation along the road based on DSM (0.19m resolution) derived from the UAV images. Unmanned Aerial Vehicle (UAV) images and GIS were used to analyze the drainage area and runoff concentration to road segments. And runoff to each road segment was estimated by Curve Number. The results show that: (1) Under a heavy rainstorm event of 212.2 mm precipitation in 2017, 158 segments were delineated along surveyed roads of 7.91 km, of which 46 segments were eroded. 36 gullies and 85 rills occurred, with average gully depth of 53.17 cm, width of 59.03 cm, rill depth of 8.63 cm and width of 33.13 cm. After a normal rainfall of 83.8 mm in 2018, 2.09 km of road were surveyed, 33 of 51 segments were eroded. 21 gullies and 73 rills occurred, with average gully depth of 43.74 cm, width of 46.84 cm, rill depth of 9.66 cm and width of 21.12 cm. (2) Thresholds in terms of topography and runoff for rill and gully initiation on road were examined. Threshold lines for road gully initiation can be represented by the relationships between the runoff (Q, m3) and the road segment gradient (S, %), (S-0.057) Q3.642=12163.71, and the relationships between the draining area (A, m2) and the road segment gradient (S, %), (S-0.025) A1.859=8235.17, could represent the threshold conditions for rill erosion on road surface. The findings could be a useful reference for preventing road erosion and understanding the mechanism of gully erosion.

Keywords: road erosion; rill; gully; threshold condition; Loess Plateau

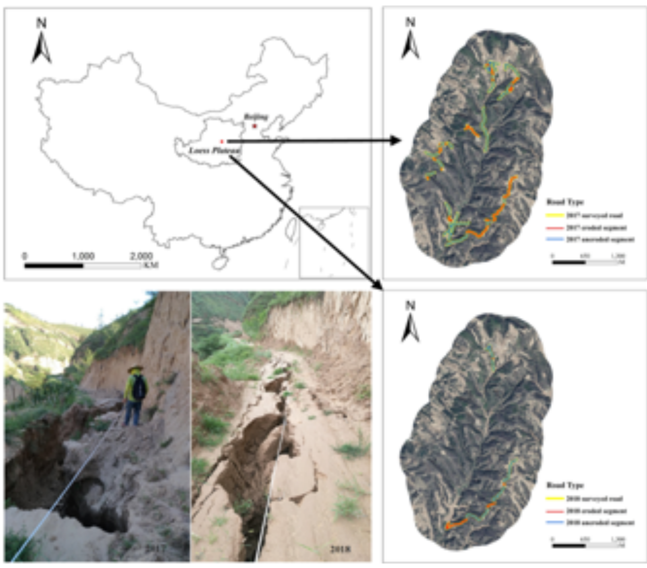


Figure 1. Location of the study watersheds and 2017/2018 road type with Google satellite images captured on May 12th, 2017 as base map.

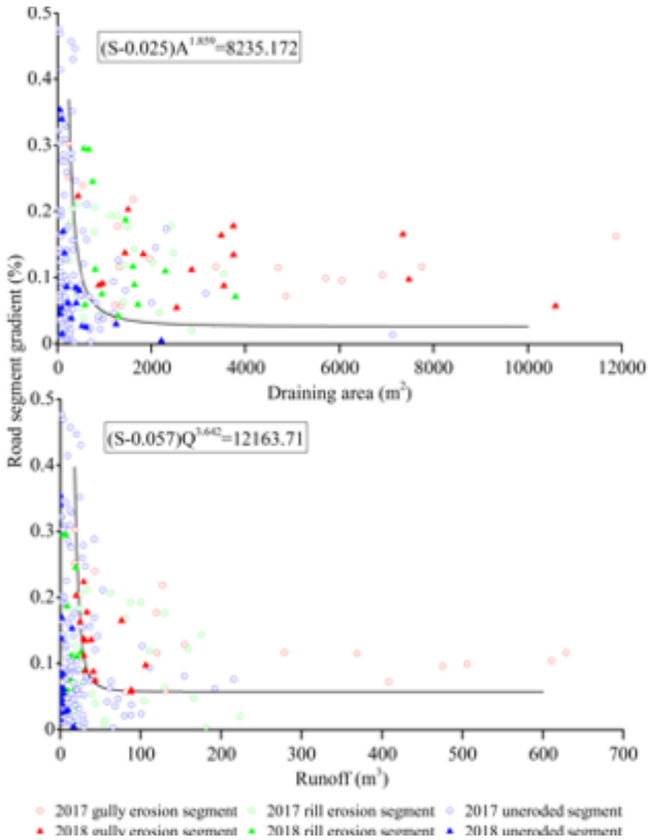


Figure 2. Topographical threshold conditions for the occurrence of gully erosion in road segments

The impact of ploughed contours on hillslope hydrology and gully erosion – a field-scale case study in the Swartland, South Africa

George Olivier[1], Jörg Helmschrot[2,3], Willem de Clercq[1]

[1] Stellenbosch University Water Institute, Private Bag X1, MATIELAND, Stellenbosch, 7602, South Africa

[2] Southern African Science Service Centre for Climate Change and Adaptive Land Use, 28 Robert Mugabe Avenue, Windhoek, Namibia

[3] Stellenbosch University, Soil Science, Private Bag X1, MATIELAND, Stellenbosch, 7602, South Africa

Research has shown that ploughed contours, man-made earthen structures, are a common agronomic measure to improve the sustainability of farming by reducing hillslope erosion and rapid surface runoff. However, little is known about the interaction between ploughed contours and gully erosion. In the Swartland region of South Africa, about 25000km of cumulative contours have been ploughed, many of these diverting water into permanent gully systems along drainage lines. A discontinuous gully system at Malansdam farm, a typical dryland farm in the Swartland region, was selected to investigate the impact of ploughed contours on hillslope hydrology and gully erosion. The gully system and ploughed contours on the adjacent fields were mapped, digitizing it in GIS from a pan-sharpened GeoEye-1 image. A Digital Surface Model (DSM), with a spatial resolution of 2.5m, was hydrologically conditioned to generate two distinct drainage patterns: 1) a natural drainage pattern to represent flow path occurrence in the absence of agricultural activities, 2) a drainage pattern enforced on the landscape due to agriculture, achieved by using a stream burning technique to force flow along ploughed contours and the gully system. Gully susceptibility for each drainage pattern was compared by making use of the Stream Power Index (SPI) and Sediment Transport Index (STI). The current state of the gully system was assessed by field survey in order to identify active processes and to verify findings from the terrain attributes analysis.

The discontinuous gully system at Malansdam had a length of 5.47km with a catchment of 1.29km2. Within this catchment, a total of 13.65km of contours have been ploughed. Gully heads were found at 71% of the ploughed contours. GIS analysis indicates that this is most likely a result of: 1) no vegetative buffer between the gully system and agricultural field; 2) an enlarged artificial catchment created by ploughed contours. Zones, where ploughed contours expire at gully heads, were highlighted by SPI and STI values to have erosive potential. Active gully heads, linearly retreating along ploughed contours were observed, verifying that ploughed contours are imposing a structural hydrological response on hillslope, intercepting water and diverting it along the contour interval into the gully network, consequently creating an artificial catchment. SPI and STI values show higher erosive potential in the upper main gully channel under structural hydrological response when compared with natural drainage. Reactivation of gully floors forming new, smaller gullies within the larger gully network, and mass wasting from gully walls being undercut by flowing water were observed, verifying that these artificial catchments are concentrating surface runoff higher up in the gully system. This study found that ploughed contours, an agronomic measure introduced to curb soil erosion, is currently accelerating gully erosion, if not in some cases causing it.

Effects of vegetation restoration on soil erodibility and its temporal variation at steep gully slopes

Guang-hui Zhanga*, Bao-jun Zhangb

(a.Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China; b. Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling, Shaanxi 712100, China)

*Corresponding author: ghzhang@bnu.edu.cn (G.-h. Zhang)

Vegetation restoration and its seasonal variation influence near soil surface characteristics, and thus likely affect soil erodibility. This study was conducted to quantify the effects of vegetation restoration on soil erodibility and its seasonal variation at steep gully slopes on the Loess Plateau. Three shrub and four grass communities were tested using erodibility indicators of K factor, aggregate stability (the mean weight diameter, MWD; the mean number of drop impact, MND), saturated hydraulic conductivity (Ks), cohesion (Coh) and penetration resistance (PR) as well as one integrated erodibility index (IEI). The results demonstrated that vegetation restoration at steep gully slopes was effective to reduce soil erodibility, and grass seemed more effective than shrub to enhance soil erosion resistance on the Loess Plateau.

Compared to the control, K factors of vegetation restored gully slopes decreased by 4%–24%, while MWD, MND, Ks, Coh and PR increased by 64%–284%, 51%–270%, 101%–417%, 10%–172%, and 63%–279%, respectively. As a result, IEI of vegetation restored gully slopes reduced by 33% to 82%. The temporal variations in soil erodibility of different plant communities were similar. K factor fluctuated considerably, but MWD, MND, Ks, Coh, and PR gradually increased over time. IEI of seven tested sites fluctuated significantly over time within the range of 41% to 86%. The changes in soil erodibility with plant communities contributed to the changes in soil organic matter content and root mass density. The corresponding seasonal variations were responsible by the temporal changes in root mass density. The results are helpful to understand the influencing mechanism of vegetation restoration on soil erosion processes at steep gully slopes in arid and semi-arid regions.

Gully Erosion and Control Practices in Northeast China

Xiaobing Liu[1], **Hao Li**[1], **Shengmin Zhang**[2], **Richard M. Cruse3**, **Xingyi Zhang**[1*]

[1]Key Laboratory of Mollisols Agroecology, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Harbin, 150081, China
[2]University of Chinese Academy of Sciences, Beijing, 100049, China
[3]Department of Agronomy, Iowa State University, Ames, 500011, IA, USA
[*]Corresponding author: zhangxy@iag.ac.cn
Presenter Email: liuxb@iga.ac.cn

ABSTRACT

Gully erosion, the most destructive and dramatic form of water erosion, is an important signature of land degradation. Worldwide, it occurs in many places with a wide range of environments. Northeast China includes Heilongjiang Province, Jilin Province, Liaoning Province, and four eastern cities in the Inner Mongolia Autonomous Region. The region is 1600 km long in the east-west axis, and 1400 km wide in the north-south axis with a total area of 124.9×104. The region has a humid continental climate; cold and arid in the winter and hot and moist in the summer. It is the grain production base or “the bread basket of China” and ecological security base of China as well where the fertile and productive Mollisols (also called Black soils) are primarily distributed in the country. Though this area has been relatively recently developed over a 100 year period since the large-scale agricultural reclamation, it went through highly intensive cultivation and rapid succession processes with the implementation of policies such as ‘March into the great grassland’ and ‘Take grain as the key link and has been characterized by a high-tension man–land relationship within short-term scales. Furthermore, coupled with the irrational farming regulations and land use, soil degradation, especially hillslope erosion and gully erosion are seriously threatening agricultural production and environment in the region. The majority of the sloping farmland has been degraded and 295 700 gullies are more than 100 m long. Among these gullies, 88.9% was developing gullies with 60.2% developed in farmland and encroaching arable land at an annual gully expansion rate of 7.39 km2. Currently, the gully area in the region is around 3648.4 km2, gully density is 1.65 km/km2 for the whole farmland area and nearly 0.5% farmland has been destroyed or abandoned due to gully erosion. Additionally, gully erosion results in the fragmentation of farmland and ultimately makes the land unsuitable for mechanization and best land management practices. The annual grain yield loss by gully erosion is around 36.2×108 kg, which is 1/10 of the total commodity grain supplied to the whole country by the region. Governmental awareness and recognition of the problems of land degradation in Northeast China started in the 1970s. As a response, massive soil water conservation activities were carried out to mitigate land degradation. During the past 50 years, researchers, farmers and ranchers in Northeast China gradually developed many practical, feasible and efficient practices in controlling and managing gully erosion. In this paper, we briefly present the general scenario of water erosion problem, and specifically introduce the changes in the number of gullies and gully density in the past fifty years in the region. We also illustrate the evidence-based practices of gully erosion control and expound how a gully erosion practice is set up at what site conditions in the region. These practices include diversion dam, various drop structures, soil check dam, masonry check dam, stone cage check dam, wicker (willow) check dam, continuous willow piles, and arbor sealing. Since the choice of an erosion-control practice involves many considerations, the discussion emphasizes the erosion-control practices without considering profitability, convenience, and sustainability. Problems and challenges are also presented.

Keywords: Land degradation; Gully erosion; Check dam; Drop structure; Overfall; Northeast China

Gully prevention and rehabilitation: a review

Amaury Frankl[1,2], Matthias Vanmaercke[3], Jan Nyssen[2], Jean Poesen[4]

[1] Research Fund Flanders (FWO), Egmontstraat 5, 1000 Brussels, Belgium

[2] Department of Geography, Ghent University, Krijgslaan 281, S8, B-9000, Ghent, Belgium

[3] Department of Geography, University of Liège, Quartier Village 4, clos Mercator 3, B-4000 Liège

[4] Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200B, 3001 Heverlee, Belgium

Drainage lines are the most dynamic places in the landscape and even minor anthropogenic (road construction) or environmental disturbances (fire) can trigger gully erosion. An increasing number of studies have, therefore, been devoted to understand processes and factors of gully erosion in various human-environmental settings, which has recently resulted in a number of review papers. Concomitantly, the number of studies on gully rehabilitation has also seen a sharp increase in recent years, but a comprehensive review on the effectiveness of gully prevention and rehabilitation methods (Fig. 1) is lacking.

Therefore, we provide a review of gully prevention and rehabilitation methods and report on their effectiveness towards gully erosion control. More specifically, we aim at presenting state-of-the-art knowledge on the following key questions that arise when aiming at restoring degraded gully systems:

- What type of measures exist to prevent and rehabilitate gullies and how effective are they?
- What is the effect of implemented measures on gully morphology and erosion dynamics?
- How are rehabilitation measures affecting catchment sediment yield?

A literature review was done by retrieving publications from the SCOPUS (https://www.scopus.com/) database. This resulted in 899 records on gully erosion that mention 'Control', 'Stabili(z)(s)ation', 'Rehabilitation', 'Reclamation' in the titles, key words or abstracts.

This review indicates that both gully prevention and gully rehabilitation methods suffer from relatively high failure rates. Vegetation barriers applied where ephemeral gullying is recurrent or flow diversions upslope of permanent gullies often do not have the envisaged effect. Gully rehabilitation measures consist of channel filling and reshaping, applying in-channel check dams and channel revegetation. These measures, also, suffer from high failure rates. In the case of check dams, breaching rates of about one-third are common only a few years after construction. If not breached, their effect on sediment storage can be considerable, and cause a sediment yield reduction of 20-50% (partial data). We argue that vegetation plays a key role in controlling gully erosion and is, by far, the best and most effective long term strategy for gully rehabilitation. Conditions of vegetation establishment, survival and trapping efficiency as bioengineering works, are therefore, discussed. We conclude that, although an increasing number of studies are devoted to gully prevention and rehabilitation, relatively few studies report on negative results related to gully erosion control, or investigate the impact of prevention and rehabilitation measures from multi-year studies. Improving knowledge on successes and failures of gully stabilization is key. Applying gully prevention and rehabilitation measures is costly and with global environmental projections, we may need more interventions to control erosion.

Figure 1: Examples of gully prevention and rehabilitation measures discussed. A: fascine (willow) (N France), B: woodchips barrier (W Belgium), C: in-channel check dams (bypassed) (N Ethiopia), D: revegetation (NW Ethiopia).

Understanding Demographics of Current Reef Trust II Participants Enables a Targeted Approach to Gully Remediation

Brad Wedlock[1], Rebecca Watson[2], Belinda Wedlock[3],

[1]Mary River Catchment Coordinating Committee, Gympie, QLD, Australia

In the Mary River Catchment, South East Queensland, 35 graziers are engaged in the Reef Trust II Program and for many, their properties have multiple gully sites. Nineteen graziers are second or third generation while the remainder are new to the industry. The purpose of this study was to establish what the contribution was in terms of sediment delivery and gully catchment area managed under different grazing demographics. The results have presented some challenging scenarios and offer questions in terms of how can the catchment group effectively reach out over the long term to maximise sediment savings and improve grazing land management to a wide demographic.

The study grouped the 35 individuals into five demographics representing grazing income contribution to their overall income. Gully catchment area for each group was also considered as was the sediment contribution per year. The individuals were grouped into those new and those experienced in the grazing industry. Results show despite engaging 28 graziers who enthusiastically take on the challenge of managing their gullies, the fact is that 73% of the sediment lost comes from commercial grazing lands under the management of a smaller group of aging experienced commercial graziers.

Questions are then raised as to firstly what contribution these 28 non-commercial graziers offer to the program and secondly how best to engage the commercial grazing community into the future beyond the current custodians. As individuals, the larger group offers innovation, youth and they actively seek knowledge to better their grazing practices. Their sites can become nurseries for new ideas which may be upscaled for larger projects at minimal cost. The answer to the second question is less certain. The catchment group understands a long term strategy is required to achieve active participation of these land managers into the future regardless of their experience in the industry.

Mitigation of Soil Erosion and Management of Gullied Lands through Bamboo Based Bioengineering Technology in Central India

S.Kala[*1], A.K.Singh[1], S.K.Dubey[2], B.K.Rao[3] and R.K.Singh[1]

[1] ICAR- Indian Institute of Soil & Water Conservation,
Research Centre, Kota, Rajasthan, India.
[2] ICAR- Indian Institute of Soil & Water Conservation,
Research Centre, Agra, Uttar Pradesh, India
[3]Director, Water and Land Management Training and Research Institute,
Rajender Nagar, Hyderabad, Telegana, India
[*]Corresponding author e-mail: kalaforestry@gmail.com

ABSTRACT

This vast tract of existing gully lands in central India is possessing potential threat to nearby productive lands because of rainfall extremes, poor soil characteristics, over exploitation and Faulty landuse practices. Demand of location specific cost-effective viable technologies for rehabilitation and productive utilization of gullied lands are highly essential. The study designed to evaluate bamboo (Dendrocalaums strictus) based bioengineering technology for erosion control and protective utilization of gullied lands to assess the hydrological behaviour, plant growth and economic analysis. This project has been funded by National Bamboo Mission, India during 2008-14. One ravenous watershed of 9.8 ha area was selected at Manikpura village (26049'- 26^0 51'N, 77^0 32' 30 -77 ^{0}35' 30" E and 168 m msl) in Pinhat block, Bah Tehsil, Agra district Uttar Pradesh, India by ICAR- Indian Institute of Soil and Water Conservation (IISWC), Research Centre, Agra(Uttar Pradesh), India. This ravine watershed is a part of Uttangan river which is tributaries of Yamuna river system. This experimental site is typically falls under core part of Yamuna ravine with medium and deep gullies having 2-8 m in depth. Bamboo plantation with three treatments has imposed in 2009-10. Three treatments impacts were studied to check the effectiveness on hydrological behaviour, growth of bamboo and soil fertility improvement.

Among three treatments, the growth performance of bamboo plants showed maximum average culm height and culm collar diameter of 11.76 m and 42.11 mm. The average crown size and number of culms per clump were recorded to be 7.27 m and 29.60 numbers respectively at Manikpura village watershed. Technology of bamboo planting (D.strictus) with staggered contour trenching practice proved as a viable alternative on ravines for gully beds stabilization, control soil erosion through good soil binding effect and quick growing vegetative cover. Hydrological results revealed that runoff was reduced from 9.6 % to 1.8 % and soil loss from 4.2 to 0.6 t/ha/yr at end assessment period. The economic analysis suggested a cash outflow of Rs. 48,000 ha-1 is possible from 7th year onwards to the stakeholders. This technology also influenced on soil pH and soil nutrient status considerably by imposition of trenches, basins and vegetative growth of bamboo in the gully beds. Therefore, rehabilitation of gullied lands can be possible and it can be achieved through use of bamboo based bioengineering measures. Further, bamboo farming and material processing are well suited to this region due to twin concerns of livelihood enhancement and environmental protection - the key components for developing these resource poor lands.

Keywords: Bamboo, Clumps, Gully beds, Soil erosion, Run-off, Vegetative cover, rehabilitation, Livelihood improvement, Resource conservation.

Figure 1 Overview of experimental site showing gully stabilization status through Bamboo based bioengineering measures at Manikpura village in Agra District (Uttar Pradesh) India

The effect of gully rehabilitation on carbon and nutrient export during a high-flow event at Crocodile Gap Rehabilitation site – Normanby catchment, Australia

Alexandra Garzon-Garcia[1,2], Joanne Burton[1,2], Andrew Brooks[3,4], John Spencer[3], Nic Doriean[3,4,5]

[1]Landscape Sciences – Department of Environment and Science, Brisbane, Australia
[2]Australian Rivers Institute – Griffith University, Brisbane, Australia
[3]Centre for Coastal Management – Griffith University, Gold Coast, Australia
[4]School of Environment and Science, Griffith University;
[5]Environmental Futures Research Institute – Griffith University, Gold Coast, Australia

The dominant source of sediment to the Great Barrier Reef from grazed rangeland catchments is subsurface erosion (i.e. gullies and channel banks). Recent work has demonstrated that particulate nutrients associated with sediments eroded from the Burdekin River catchment are available to freshwater and marine phytoplankton and generate a significant proportion of dissolved inorganic nitrogen (DIN) in marine plumes. We used two lines of evidence to examine the source of the sediment and bioavailable particulate nitrogen (BPN) in the Bowen River catchment, a sub-catchment of the Burdekin River.

The Dynamic SedNet catchment scale water quality model currently used in the Paddock to Reef Program was adapted to model BPN pools in the Bowen catchment over a 28 year period. The addition of these pools gives the total DIN generation from eroded sediment. The results showed that gullies and channel banks were the dominant source of sediment (62% and 33% respectively). However hillslope soils were the dominant source of BPN (~87%), followed by gullies (~12%) and channel banks (~1%). In addition, the spatial sources of sediment within the Bowen catchment were not the same as spatial sources of BPN, indicating that sediments generated from different sources are of different quality.

Sediment tracing was conducted using samples from tributary junctions in one high flow event in February 2016 and the Cyclone Debbie event in March/April of 2017. A combination of radionuclides, stable isotopes and bioavailable nitrogen data was used to trace the source of sediments and BPN during these events. Preliminary analysis of the tracing data indicates that virtually all of the sediment and the BPN in the two events studied, came from subsurface soils (i.e. gullies and channel banks).

The preliminary results indicate that gullies can be significant sources of BPN (and therefore PN and DIN) in this catchment. This implies that both DIN and PN reductions through gully restoration should be monitored, modelled and incorporated into accounting and target tracking. They show that sources of BPN are not identical to sources of sediment and therefore including management for BPN would provide additional water quality benefits. Sources and ultimately loads of BPN and DIN generated from eroded sediment will be a function of both sediment quantity and quality. Finally, the discrepancy between the modelling and tracing results for BPN is similar to discrepancies found when comparing sediment modelling and tracing studies in the last decade and highlights the need for further field measurement of BPN's and model improvement.

Survival and growth analysis of multipurpose trees, shrubs and grasses used to rehabilitate badlands and gullies in the sub-humid tropics

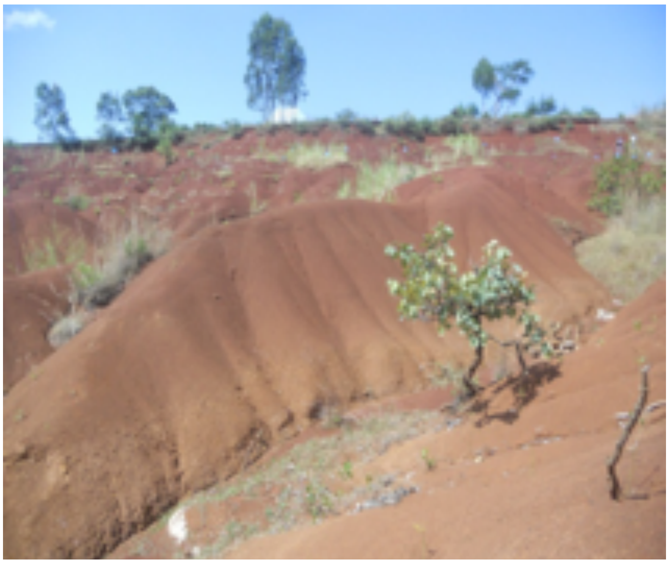
Ayalew Talema[1,2], Jean Poesen[2], Bart Muys[2], Roc Padro[3], Hirko Dibaba[1] and Jan Diels[2]

Jimma University, College of Agriculture and Veterinary Medicine, P.O.Box 307, Jimma, Ethiopia. Email: ayalew.talema@ju.edu.et, ayalewtalema@yahoo.com
KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200 E, box 2411, 3001 Leuven, Belgium.
University of Barcelona, Department of Economic History, Institutions, Politics and Global Economy, Diagonal Avenue 696, Barcelona, Spain.

ABSTRACT

Vegetation plays a vital role for sustainable rehabilitation of degraded lands such as badlands with active gully erosion. However, the establishment of plant species on badlands remains a long-lasting challenge in most regions, including the sub-humid tropics. To address this challenge, 18 multipurpose plant species (6 trees, 3 shrubs and 9 grasses) which were pre-selected from the regional species pool in Southwest Ethiopia were planted in a badland and monitored from July 2011 to June, 2014. The experiment had a split-plot design with farmyard manure (FYM) application as main plot and plant species as sub-plot factors repeated in three blocks.

The study revealed that grasses were the most successful to survive and rehabilitate the gully within the monitoring period, compared to trees and shrubs. The survival rate of the four most successful grass species, Chrysopogon zizanioides, Pennisetum macrourum, Pennisetum polystachion and Pennisetum purpureum ranged from 61 to 90% with FYM application and from 20 to 85% without FYM, while most of the well-known indigenous and exotic trees and shrubs failed to survive. For the grass Pennisetum purpureum, shoot height, shoot and root biomass were enhanced by 300%, 342% and 578% respectively due to FYM application, with a remarkably higher response to FYM compared to all the other studied species. The overall results demonstrate that badlands can be effectively restored by using early successional species such as locally adapted and selected grasses before the plantation of trees and shrubs.



The badland at Bulbul, Gilgel Gibe watershed, Southwest Ethiopia in June 2011(left) before the experiment, June 2018 (Right) after the experiment.

Reef Aid

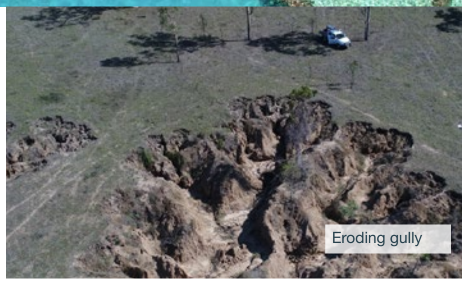
Improving water quality on the Great Barrier Reef by working with landholders to rebuild eroding gullies and restore vital coastal wetlands across the catchment.

The challenge

Over the past 150 years, land-use change and habitat loss has significantly increased erosion across the landscape neighbouring the Great Barrier Reef. Over 20,000 hectares across 35 catchments are affected. More than 70% of the coastal wetlands that filter water flowing out to the Reef have also been lost. Now with each large rainfall, tonnes of sediment laced with chemicals and fertilisers flow from eroding gullies onto the Reef, choking fish and coral, creating algal blooms and weakening marine ecosystems. That's why poor water quality is considered the second biggest threat to the Reef, after climate change.

The good news

Greening Australia is trialling a range of cost-effective solutions to restore eroding gullies and reduce sediment run-off. We work across the highest sediment-producing catchments, collaborating with government, landholders and research organisations to change management practices. At Strathalbyn Station in the Burdekin Catchment, we tested restorative earthworks to reshape and resurface eroding gullies. Remotely-sensed, 3D imagery (e.g. LiDAR) allowed us to match microtopography with prioritisation plans. Initial results show a significant improvement in water quality between treated and untreated gullies, and vegetation cover is returning to treated areas — a sign of stabilisation. Our trials continue in 2019, with our work expanding to three more properties. By 2030, we aim to stop 200,000 tonnes of sediment from reaching the Reef each year (9% of the total reduction required under the Australian Government's Reef Plan 2050).



Eroding gully

Resurfacing

Treatment and control in July 2018

Following January 2019 rains

Photo credit: D.Telfer (photos taken as part of the Innovative Gully Remediation Project, a collaborative project supported by the Queensland Government's Reef Water Quality Program and Greening Australia's Reef Aid Program)

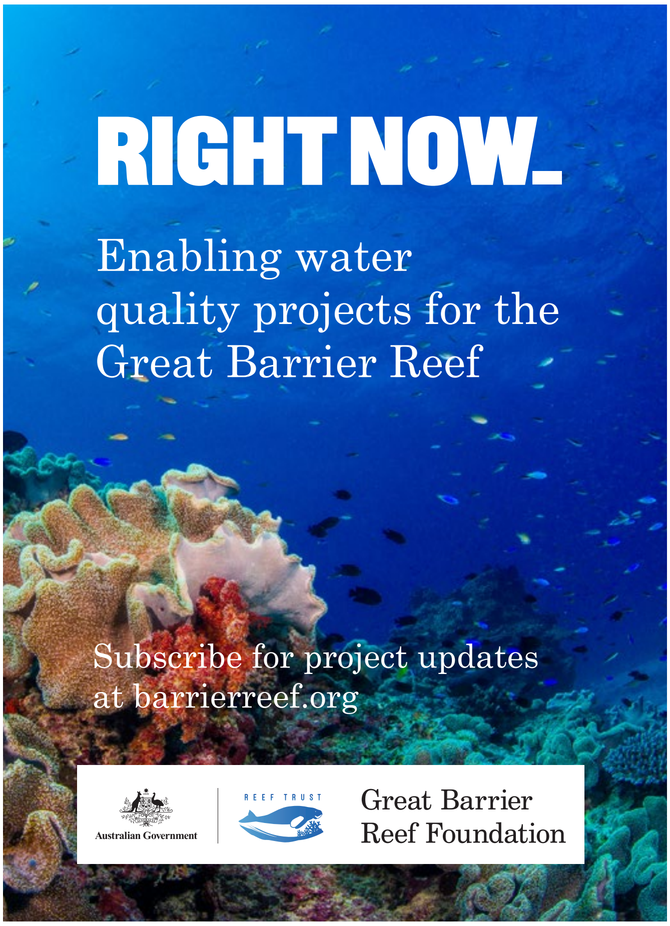
DR LYNISE WEARNE REEF AID PROGRAM LEADER
lwearne@greeningaustralia.org.au

Learn more: reefaid.org.au

Greening Australia

Tropical Water Quality Hub
National Environmental Science Programme
Reef & Rainforest RESEARCH CENTRE
The Tropical Water Quality Hub, funded by the Australian Government's National Environmental Science Program, provides innovative research for practical solutions to maintain and improve tropical water quality from catchment to reef

Fitzroy Basin Association
Accessing the best available science and techniques to help landholders tackle gullies big and small.
Contact us today.
Funded by the Australian Government and delivered through Reef Trust.
Australian Government
REEF TRUST
fba
FITZROY BASIN ASSOCIATION
Visit www.fba.org.au to find out how we can help.



RIGHT NOW_
Enabling water quality projects for the Great Barrier Reef
Subscribe for project updates at barrierreef.org
Australian Government
REEF TRUST
Great Barrier Reef Foundation

Catchment Solutions
WATER QUALITY MANAGEMENT
ENVIRONMENTAL CONSULTANCY
SERVICE PROVIDERS

7. Abstracts – Posters

Presented in alphabetical order

The effectiveness of gully remediation on runoff and sediment loss: a review

Rebecca Bartley[1], Jean Poesen[2] and Scott Wilkinson[3]
[1] CSIRO Land and Water, Brisbane
[2] Department Earth and Environmental Sciences, KU Leuven, Belgium
[3] CSIRO Land and Water, Canberra

Gully erosion often represents a large component of the sediment yield from catchments, particularly in areas with highly variable rainfall, low vegetation cover and dispersive soils. An understanding of the cost-effectiveness of erosion control measures for gully erosion is needed to support decisions about remediation prioritisation, particularly in areas where gully erosion threatens downstream ecosystems. Estimating cost-effectiveness is, however, challenging due to the lack of data available on the effectiveness of remediation implementation. This is because the measurements needed can be costly, time consuming and require several decades of data to adequately identify trends and thus remediation response.

This paper presents a global review of studies of rehabilitation and remediation within gullied landscapes. Approximately 30 studies were included in the review from 10 different countries. The remediation techniques ranged from bioremediation structures, to check dams and geomembranes. The review focused on studies that had measured changes in runoff, erosion, or sediment yield (via reduced erosion or increased deposition) following remediation. Modelling studies were not included, and the associated cost of the remediation was not assessed, as it was generally not available.

The review determined that when the remediation structures remained in-tact, reductions in runoff, erosion rate and sediment yield ranged from ~20-90% following remediation. However, the time scales required for this change can be considerable, ranging between 3 and 80 years (median ~30 years) depending on the environmental conditions (e.g. climate) and treatment method used. In almost all of the successful studies, a combination of engineering approaches (e.g. check dams) and vegetation (both grass and trees) were required. In many cases, the engineering structures eventually failed, and it was the new vegetation that provided the long-term stabilization of the site. The main challenges for gully remediation include (i) designing remediation to accommodate large rainfall/runoff events, (ii) maintaining structures and vegetation over the long term (> 5 years), (iii) technical support to design suitable remediation systems, and (iv) measurement data to quantify the effectiveness of remediation on vegetation, runoff and water quality, (v) balancing expectations of gully remediation with the commercial requirements of agricultural landscapes.

Coordinated USDA–NRCS and ARS Ephemeral Gully Erosion Conservation Planning Technology

Ronald Bingner[1], Eddy Langendoen[1], Martin Locke[1], Robert Wells[1], Glenn Wilson[1] Dennis Flanagan[2] Craig Derickson[3], Michael Kucera[3], Britt Weiser[3] Dean Krehbiel[4], Thomas Roth[4], Jarred Kneisel[5] Donald Carrington[6], Darren Manthei[6] Dwaine Gelnar[7], Nate Goodrich[7] Jodie Reisner[8], Shaun Vickers[9], Isaac Wolford[10]

[1]USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi, USA

[2]USDA-ARS National Soil Erosion Laboratory, West Lafayette, Indiana, USA

[3]USDA-NRCS, Lincoln, Nebraska, US,

[4]USDA-NRCS, Salina, Kansas, USA

[5]USDA-NRCS, Hutchinson, Kansas, USA

[6]USDA-NRCS, Des Moines, Iowa, USA

[7]USDA-NRCS, Columbia, Missouri, USA

[8]USDA-NRCS, Ft. Worth, Texas, USA

[9]USDA-NRCS, Washington, District of Columbia, USA

[10]USDA-NRCS, Morgantown, West Virginia, USA

The United States Department of Agriculture (USDA) – Natural Resources Conservation Service (NRCS) and the Agricultural Research Service (ARS) have been involved in erosion prediction technology and implementation of erosion conservation practices for many decades. NRCS efforts to implement conservation compliance on highly erodible land (HEL) has exposed the need for better technology and tools to address ephemeral gully erosion. However, the NRCS need for ephemeral gully erosion technology and tools goes well beyond just HEL compliance. NRCS needs information and science on how to quantify ephemeral erosion and how to assist landowners in developing plans for ephemeral gully erosion, especially associated with effective non-structural practice treatments. The need is even more timely and pressing now than ever before, due in part from concerns with HEL compliance.

There is a need to develop and evaluate practical field tools available to NRCS that can be used to plan and account for the benefits and effects of ephemeral gully erosion conservation practices as part of field, state, or national assessments. Currently, subjective observations are often used to satisfy quality criteria in lieu of scientifically defensible and quantitative methods. These include non-scientific methods to account for and treat ephemeral gully erosion, such as applying a simple multiplier factor to sheet and rill erosion predicted by USDA–ARS RUSLE2 or WEPP technology.

ARS has been involved in ephemeral gully erosion research for many decades, leading to incorporation of ephemeral gully erosion science components within RUSLE2, WEPP and AnnAGNPS technology. Recent initiatives between NRCS and ARS have led to coordinated activities that are intended to provide direction for the continued development of ephemeral gully technology and eventual inclusion into NRCS tools and models as part of the conservation planning process. At targeted locations, NRCS field office staff will collaborate with ARS in collecting supplemental ephemeral gully data sets for use in assessing tool application and development. This will include individual gully characterizations of their location, size and corresponding management practices using simple handheld phones with GIS capabilities. Information on drainage area and soils impacting the gullies will be developed from existing databases to provide for a multi-scale approach by integrating multiple ephemeral gullies within fields as part of a watershed system in order to evaluate the impact of conservation practices with USDA modeling technology. Information from this effort will be utilized to identify the databases and tools needed to assist in coordinated USDA–NRCS/ARS agency assessments and development of effective ephemeral gully erosion conservation planning technology.

One down, 200 to go: The effectiveness of large-scale alluvial gully rehabilitation in addressing Great Barrier Reef Water Quality

Andrew Brooks[1, 2], John Spencer[1], Nic Doriean[1], 2, Robin Thwaites[1], Tim Pietsch[1], James Daley[1], Will Higham[3], Mike Goddard[4], Damon Telfer[5] Lynise Wearne[6] and Sunny Bezahdnia[6]

[1]Griffith Centre for Coastal Management, Griffith University, Australia, 2 School of Environment and Science, Griffith University; 3Sugar Research Australia, Greenvale, Qld. Australia. 4Cape York Natural Resource Management Group, Atherton, Australia, 5Fruition Environmental, Townsville, Australia, 6Greening Australia, Brisbane, Australia

The Great Barrier Reef World Heritage Area (GBRWHA) is an international asset that is under threat from a range of stressors, both at a global scale through ocean warming and acidification, and regionally through impaired water quality and crown of thorns starfish outbreaks, which are linked to water quality. Building on extensive research over the last decade that has identified the key sources of sediment and nutrient pollution, the Australian and Queensland Governments have both initiated major programmes focused on rehabilitating gully and streambank erosion, which represent the source of at least 80 percent of the pollutants delivered to the Reef lagoon. These programmes represent the first steps in the journey to turn around more than 100 years of landscape degradation and associated declining water quality.

Results from the first major alluvial gully rehabilitation trials in the Normanby and Burdekin catchments, implemented through these programmes, are demonstrating the magnitude of sediment and nutrient reductions that can be achieved over relatively short periods of time. Initial results are suggesting that reductions of 80-90% of the pre-treatment baseline fine sediment yields are achievable within one to two years of treatment. While the magnitude of these water quality improvements is extremely encouraging, the areas treated thus far are only a small fraction of the total area of gully erosion that will need to be treated to achieve the Reef 2050 water quality targets.

In the Normanby catchment, which has an interim reduction target of 23,000 t/yr of fine sediment (< 20 µm) by 2022, several hectares of active gully have been treated over the last three years. To date this has achieved a total reduction of 103 t/yr at the river mouth (assuming a 45% sediment delivery ratio). This represents around 0.45% of the 2022 target. At Strathalbyn Station in the Burdekin catchment, a more extensive rehabilitation strategy has been implemented, with around 13 ha of highly active alluvial gullies treated in 2017 and 2018, and a further 6.5 ha to be treated in 2019. When completed, these treatments will achieve fine sediment reductions of around 4,800 t/year at the river mouth based on the results demonstrated thus far. Whilst impressive, these results only represent around 0.54% of the 890,000 t/year fine sediment water quality improvement target for the whole Burdekin catchment.

The results from these two studies, whilst extremely encouraging, underscore the considerable task ahead (and investment required) to achieve real long-term improvements in GBR water quality. Based on these results, around 200 sites of a similar magnitude to these two project sites will need to be implemented in each catchment over the next three years to achieve the first phase of the Reef 2050 water quality targets.

Sources of bioavailable particulate nutrients in a grazed rangeland, Bowen River Catchment, Australia

Joanne Burton[1,2], Alexandra Garzon-Garcia[1,2], Jon Olley[2], Rob Ellis[1], Maria Askildsen[1], Rob DeHayr[1], Phil Moody[1]

[1]Landscape Sciences, Department of Environment and Science, Brisbane, Australia.

[2]Australian Rivers Institute, Griffith University, Brisbane, Australia.

The dominant source of sediment to the Great Barrier Reef from grazed rangeland catchments is subsurface erosion (i.e. gullies and channel banks). Recent work has demonstrated that particulate nutrients associated with sediments eroded from the Burdekin River catchment are available to freshwater and marine phytoplankton and generate a significant proportion of dissolved inorganic nitrogen (DIN) in marine plumes. We used two lines of evidence to examine the source of the sediment and bioavailable particulate nitrogen (BPN) in the Bowen River catchment, a sub-catchment of the Burdekin River.

The Dynamic SedNet catchment scale water quality model currently used in the Paddock to Reef Program was adapted to model BPN pools in the Bowen catchment over a 28 year period. The addition of these pools gives the total DIN generation from eroded sediment. The results showed that gullies and channel banks were the dominant source of sediment (62% and 33% respectively). However hillslope soils were the dominant source of BPN (~87%), followed by gullies (~12%) and channel banks (~1%). In addition, the spatial sources of sediment within the Bowen catchment were not the same as spatial sources of BPN, indicating that sediments generated from different sources are of different quality.

Sediment tracing was conducted using samples from tributary junctions in one high flow event in February 2016 and the Cyclone Debbie event in March/April of 2017. A combination of radionuclides, stable isotopes and bioavailable nitrogen data was used to trace the source of sediments and BPN during these events. Preliminary analysis of the tracing data indicates that virtually all of the sediment and the BPN in the two events studied, came from subsurface soils (i.e. gullies and channel banks).

The preliminary results indicate that gullies can be significant sources of BPN (and therefore PN and DIN) in this catchment. This implies that both DIN and PN reductions through gully restoration should be monitored, modelled and incorporated into accounting and target tracking. They show that sources of BPN are not identical to sources of sediment and therefore including management for BPN would provide additional water quality benefits. Sources and ultimately loads of BPN and DIN generated from eroded sediment will be a function of both sediment quantity and quality. Finally, the discrepancy between the modelling and tracing results for BPN is similar to discrepancies found when comparing sediment modelling and tracing studies in the last decade and highlights the need for further field measurement of BPN’s and model improvement.

Spatial distribution of Benggang in tropical and subtropical regions of south China

Yujie Wei, Chongfa Cai

Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River) of the Ministry of Agriculture, College of Resources and Environment, Huazhong Agricultural University, Wuhan, 430070, China

Soil erosion, predominately promoted by gravity and developed in the form of collapsing gully, is locally defined as Benggang in red soil regions of south China. The concentrated distribution of gullies generates severe land degradation and environment deterioration in these areas. Due to the complex driving forces of Benggang erosion, the mechanisms for this regional erosion are still unclear. The spatial distribution of Benggang and its environmental factors (rainfall, lithology, elevation and geomorphology) crossed from Hubei (subtropics) to Guangdong (tropic) provinces were investigated by field investigation and ArcGIS analysis. The key driving factors that influencing the concentration of Benggang were investigated by redundancy analysis. Lithology and weathering crust dominated the formation and distribution of Benggang erosion, and more than 40% of Benggang was distributed in granite areas, especially in biotite granite areas where Benggang formed in a relatively larger scales.

The concentration of Benggang kept in line with the distribution of annual rainfall ranged in 1400 ~1600 mm, and the quantity of Benggang in large scales generally increased with the average annual rainfall. These regions concentrated by Benggang generally possessed an altitude ranged from 150 to 500 m. Besides, the density and scale of Benggang increased from north (Hubei) to south (Guangzhou) was in accordance with the increasing relative altitude. Collectively, the abundant heat and water resources in subtropical and tropical regions accelerates the weathering procedure and the formation of thick weathering crust, which, in turn, facilitates the appropriate conditions for gravity erosion. The stage of geomorphic factors including altitude and slope aspect were closely related to the development of Benggang. The underlying surface conditions altered by human activities also influence the progress of Benggang development, but it was less significant than the geomorphological factors.

Performance of a low-cost bioengineering approach for the rehabilitation of permanent gullies

Carlos Castillo[1], Juan Luna[2], Rafael Pérez[1]

[1]University of Córdoba, Department of Rural Engineering

[1]University of Córdoba, Department of Computer Architecture

Gully erosion is a major environmental issue across the world, and, therefore, calls for urgent remediation actions. These measures should be not only effective but also technically and economically feasible. The aim of this work was to design, implement and evaluate the performance of a series of inexpensive BE interventions (combining small check dams with native woody barriers) in commercial farms during a period of 2 years.

The study area is the Galapagares stream basin (80 km2), 20-km far from Córdoba city (southern Spain). In 3 gullies, variations of the BE approach were implemented (Table 1). The vegetation barriers were established from cuttings taken from existing parents in the area for Tamarix and from an own-made plant nursery for Nerium oleander.

The assessment of the performance of these biocontrol measures was carried out by studying: a) erosion/deposition dynamics: using conventional erosion pins (wooden sticks) and obtaining DEMs of Differences produced by several 3-D UAV and ground surveys using photo-reconstruction techniques; b) vegetation dynamics: we analysed the survival and growth rates and stem density of each of these woody barriers.

During the first year of study, significant erosion and deposition processes took place after a 300 mm of rainfall period. At the Menadillo 1 gully, the two most upstream check dams were completely silted up, with the sedimentation decreasing in the downstream direction. Although the initial plant survival rate was ~80% after the winter season, it decreased to 30% at the end of the summer, despite having been watered in two occasions. For the Rubio gully, a number of well-established hedges from existing plants were produced after the first year, with a stem cover close to 100% (up to 1m high from the ground). In these barriers, up to 30-cm high sedimentation wedges were deposited behind the denser barriers. For Menadillo 2 (only during the second year), the survival rate was 95% due to the increase in cuttings size and planting depth. Due to an abnormally dry hydrologic period during the second year of the study (less than 100 mm rainfall in autumn and winter, typically the wettest seasons), very little erosion has taken place.

This on-going experiment has shown that this BE approach represents a cost-efficient alternative to conventional rehabilitation schemes by using mainly local materials and allowing a direct installation by the farmers. If the vegetation barriers are properly established and maintained during the early periods of growth especially in dry years, high survival rates can be achieved and in 2 years erosion-effective hedges can be achieved. From these experiences, a practical illustrated manual for the installation of biocontrol barriers will be published and made available to farmers.

Gully	Years of study	Catchment area (ha)	Number of barriers	Check dams	Woody barrier	Age
Menadillo 1	2	2.2	12	Willow-screen	Tamarix spp.	New
Menadillo 2	1	3.5	16	Straw bale + Pallets	Tramarix spp. + Nerium oleander	New
Rubio	2	40.0	1. 120	2. --	3. Tamarix spp.	4. Pre-existing 5. (> 2 years-old)

Lidar gully mapping in the Great Barrier Reef catchments

John Gallant[1]

[1]CSIRO Land and Water, Canberra Australia

CSIRO on behalf of the Commonwealth Department of Environment and Energy is collecting high density lidar in priority management areas of the Great Barrier Reef catchments. The lidar products will form a new erosion base line from which to monitor state and change of gully and streambank erosion over time, support identification of highly erosive areas within the management units, and provide updated data to guide site selection, monitoring and evaluation for on-ground investments.

The lidar data is being acquired at a minimum of 16 pulses per square metre, using a swath overlap of more than 50% so that every point on the ground is acquired from at least two different angles. This provides a good basis for mapping gullies and streambanks and for calculating areas and volumes of material eroded from gullies. The classified points are used to produce a bare-ground digital elevation model at 0.5 m resolution. The acquisition includes airborne imagery at 15 cm resolution and ground survey control.

The initial lidar acquisition in 2018 over 5000 km^2 in the upper Herbert, lower Burdekin, Fitzroy and Mary catchments, targeting streambank erosion in the Mary and gully erosion in the others. In 2019 another 1000 km^2 is being collected, primarily in the Normanby catchment and focussed on gully erosion. Further acquisitions are expected in 2020 through 2022. The data will be made available through Queensland DES and the Commonwealth DoEE.

The 2018 acquisitions have delivered high quality data meeting all specifications. The classification of points has some inaccuracies around abrupt edges of gullies where some ground points at the top of precipitous banks are classified as vegetation, at a distance of up to about 0.5 m from the bank. The effects on the DEM are minor and a re-analysis of the point cloud data could be used if accurate delineation of the gully extent is needed.

The effect of gully rehabilitation on carbon and nutrient export during a high-flow event at Crocodile Gap Rehabilitation site – Normanby catchment, Australia

Alexandra Garzon-Garcia[1,2], Joanne Burton[1,2], Andrew Brooks[3,4], John Spencer[3], Nic Doriean[3,4,5]

[1]Landscape Sciences – Department of Environment and Science, Brisbane, Australia

[2]Australian Rivers Institute – Griffith University, Brisbane, Australia

[3]Centre for Coastal Management – Griffith University, Gold Coast, Australia

[4]School of Environment and Science, Griffith University;

[5]Environmental Futures Research Institute – Griffith University, Gold Coast, Australia

This poster presents results of carbon and nutrient export for a control site and two rehabilitated alluvial gullies at the Crocodile Gap Rehabilitation site located in the Laura River subcatchment, Normanby River catchment, Australia.

Gully rehabilitation treatments included: control (4.18 ha), treatment 1 (13.5 ha) – regrading of whole complex, gypsum addition, geofabric cover on gully head, coarse sandstone surface cover at gully head, shale capping in rest of gully, rock check dams and gully catchment contour dams; and treatment 2 (10.4 ha) – regrading of gully head, gypsum addition, geofabric cover on gully head, shale capping around head and coarse basalt chute at head. Multiple water samples (control, n = 22; treatment 1, n = 9; treatment 2, n =6) were taken by automatic samplers installed at gully outlets during a high-flow event on the 23rd of January 2018. Samples were analysed in the laboratory for total suspended solids (TSS), particle size distribution, total and dissolved organic carbon (C), nitrogen (N), and phosphorus (P) fractions. Concentrations were normalised by gully catchment area to directly compare physico-chemical parameters between gully treatments.

Normalised concentrations of TSS for all particle sizes and all analysed carbon, nitrogen, and phosphorus fractions were significantly lower in the outlet of the treated gullies relative to the control, with significantly lower values for most parameters in the more extensively treated gully (treatment 1). The particulate fractions of C, N and P were dominant for all treatments, though this trend was stronger for the control, followed by treatment 2.

The dominant form of dissolved N and P fractions was organic for all treatments. The quality of the sediment was significantly different ($p<0.05$) between treatments. Treatment 1 had significantly higher particulate organic carbon (POC) and particulate N (PN) sediment percent content, followed by treatment 2. POC:PN ratios tended to be higher in treatment 1. The variability in sediment POC, PN and POC:PN ratios was also higher in treatment 1. The higher proportion of fine sediment from this treatment only partly explains the variability in PN content ($R2 = 0.32$). TSS concentration was a better explanatory variable, as it correlated well with POC and PN ($R2 = 0.71$ and $R2=0.6$, respectively). This indicates that the source of fine sediment significantly varied during the event for treatment 1, but not for the other gullies.

These preliminary findings indicate gully rehabilitation has the potential to significantly reduce sediment/nutrient export from these gully systems to other catchments eventually draining into the coastal waters of the Great Barrier Reef. These improvements can be detected in sediment chemical characteristics, not only in the reduced quantity of sediment. There are significant improvements in the water quality from the rehabilitated gullies, with larger improvements in the more extensively treated gully.

Study on soil and water conservation benefit in different vegetation types of karst area in Danjiangkou Reservoir Area in China

Jianbin Guo[1], Mengling Zhou[1], Liu Hong[1], Jinxing Zhou[1]

[1] College of Soil and Water Conservation, Beijing Forestry University, Beijing 10083

ABSTRACT

Middle Line South-to-North Water Diversion Project is a major strategic infrastructure in China, aiming to alleviate water shortages and optimize water resources allocation in northern China. Danjiangkou Reservoir, which is located in the middle and upper reaches of the Yangtze River in southern China (E 110° 30'-111° 43', N 32° 14'-33° 19'), is an important water source location for the Middle Line South-to-North Water Diversion Project.

PURPOSE

The purpose of this study is to explore the response of runoff and sediment yield to precipitation and different vegetation types, as well as the runoff and sediment reduction performances in different vegetation types.

METHODS

From June to October in 2018, The performance of runoff and sediment yield were continuously monitored in the standard runoff plots which were composed of five different vegetation cover types (arbor forest land, sparse forest land, grassland, shrub grassland, and farmland).Correlation analysis was used to evaluate the correlation between runoff and sediment yield and perception, and t-test analysis was used to evaluate different performances in surface sediment yields under different vegetation cover types.

RESULTS

(1) The short-duration and high-intensity rainfall in this area is prone to inducing the cause of runoff and soil erosion, while the long-term and low-intensity rainfall are the opposite of former. The largest amount of erosion occurred in June-August, which indicate the key period for preventing soil erosion. (2) The response of runoff and sediment yield to precipitation characteristics of different vegetation cover types was generally consistent: the runoff and sediment yield were linearly positively correlated with precipitation, maximum precipitation density per 10 min, maximum precipitation density per 30min, maximum precipitation density per 60min, and there exist a significant correlation between runoff and sediment yield and precipitation, while no significant correlation in precipitation duration and average precipitation density. In addition, there was a significant linear positive correlation between sediment yield and production flow. (3) The runoff reduction performances in different vegetation types: farmland > arbor forest land > shrub grassland > sparse forest land > grassland. The sediment reduction performances: arbor forest land > grassland > shrub grassland > sparse forest land > farmland.

CONCLUSION

This study offers constructive suggestions for the ecological restoration in the karst area of the Danjiangkou reservoir area, and provides scientific basis for the revegetation improvement of the soil and water conservation benefit as well as water conservation capacity of the reservoir area.

Gully erosion and post-mining landscapes: modelling patterns and trends in an undisturbed catchment

Greg Hancock[1], **John Lowry**[2], **Michael Saynor**[2]

[1]School of Environmental and Life Sciences, The University of Newcastle, Callaghan, Australia

[2]Revegetation and Landform Program, Environmental Research Institute of the Supervising Scientist, Darwin, Northern Territory 0801, Australia

Gullying is a recognised and significant landscape degradation process for both natural and disturbed systems. Of particular relevance here are post-mining landscapes. It is vital that we understand gully initiation and development, as it is well-recognized that catchment disturbance can result in the development of gullies that can be very difficult to rehabilitate. Here we describe a decadal long data set of gully position and movement in a catchment undisturbed by European activity in the Northern Territory, Australia. The catchment is of high interest as it provides insights into the long-term potential evolution of the ERA Ranger mine. We find that gullying occurs throughout the catchment and that a slope-area threshold does not exist. Monitoring suggests that gully initiation thresholds are low as a result of an enhanced fire regime. Computer based landscape evolution models (LEMs) has been calibrated and tested at the site. We show that these LEMs provide a good match with both gully size and location and can be used to both qualitatively and quantitatively assess gully initiation and development. Results are presented of the modelling of gully initiation and evolution on both natural landscapes as well as proposed post-mining landforms. We demonstrate that LEMs are good tools for the assessment of soil erosion and gully development on post-mining landforms.

Developing a Cost-Effective and Prioritised Approach to Gully Remediation in the Bowen, Bogie and Broken Catchments

Matthew Miles[1], Lisa Hutchinson[2], Andrew Brooks[1]

[1]NQ Dry Tropics, Bowen, Australia
[2]Centre for Coastal Management – Griffith University, Gold Coast, Australia

The Landholders Driving Change project is a Queensland Government Major Integrated Project in the Bowen, Broken and Bogie (BBB) Catchments. The project aims to trial a range of actions to measure their effectiveness in delivering sustainable management and water quality outcomes with the objective of transferring the successful actions to other regions.

The objective of the landscape remediation delivery area is to trial a variety of gully rehabilitation techniques and approaches with the intent of identifying a range of cost effective, practical and replicable landscape remediation approaches that can be implemented in both the BBB and other regions. The landscape remediation work provides a platform for designing, implementing and monitoring across a variety of soil and land types at various scales. It also supports landholders to validate solutions for smaller scale erosion features. The project uses the best available science and technology, with the focus being on hillslope and alluvial gullies of various scales.

A Characterisation and Prioritisation report is being developed by Griffith University in parallel to the on ground remediation works and will be used as a tool to assist with site selection for future remediation works. The characterisation component uses Multi-Dimensional Hillshade analysis to analyse LiDAR DEM data to identify the extent and location of alluvial and hillslope erosion features. Reconstructing the pre-gully incision surface allows the calculation of the gully growth rates which informs the prioritisation of the individual gullies.

The first of the large scale gully remediation works took place on a large alluvial gully system on the property Mt Wickham west of Collinsville. The gully formations included a large alluvial amphitheatre with significant tunnelling of highly dispersive sodic soils. The approach at this site explored a range of cost effective measures to remediate the erosion processes at the site.

A significant percentage of the LDC budget is committed to monitoring and evaluation; a component of which is for water quality monitoring through the installation of comprehensive instrumentation. These monitoring instruments measure sediment and nutrient runoff from the remediation site and controls. The analysis of the data from these stations will measure the fine sediment and particulate nutrient reductions achieved through the works. This information along with the cost of the various remediation methods being trialled will contribute to a Cost Effectiveness Framework being developed under the project. The framework will allow the consistent comparison of the various gully remediation methods to establish the most cost-effective methods for gully remediation. This information can be used to inform gully remediation methods beyond the life of the project.

The Characterisation and Prioritisation study along with Cost Effectiveness Framework will inform the development of strategic guidance for gully remediation beyond the life of the project.

Gully Networks Detection by integration of Machine Learning and Geographic Object-Based Image Analysis.

Hejar Shahabi[6], Ben Jarihani[7], David Chittleborough[2,3]

[1]Department of Remote Sensing and GIS, University of Tabriz, Iran

[2]Sustainability Research Centre, University of the Sunshine Coast, Sunshine Coast, Queensland 4556

[3]School of Physical Sciences, University of Adelaide, Adelaide 5005

Gully erosion is the dominant source of sediment and particulate nutrients to the Great Barrier Reef (GBR) World Heritage Area. Our ability to accurately quantify sediment loads contributed by catchments, identify erosion hotspots, and prioritize and target management interventions, is currently constrained by a lack of information at a fine scale about the location and density and extent of gully systems. Bowen catchment, a tributary of Burdekin Catchment, associated with a high density of gully networks and is identified as one of the main sources of sediment load to GBR.

This project will more accurately identify and map gully systems across Bowen Catchment, using multi-source and multi-scale remote sensing and ground-based data. An advanced approach is employed by integrating Artificial Neural Network (ANN) with Geographic Object-Based Image Analysis (GEOBIA). We used Sentinel 2A and Planet satellites optical images and ALOS PALSAR topographic data as well as gully networks inventory map. First, spectral index and topographic conditioning factors such as NDVI, elevation, slope, aspect, topographic wetness index (TWI), slope length (SL), curvature, plan curvature and profile curvature were generated from datasets. Next through segmentation process in GEOBIA, multispectral images will be segmented in set of meaningful objects that relatively represent corresponding features in the real world. Then 70% of available gully networks map were used to train ANN algorithm, subsequently the trained algorithms were tested on conditioning factors to detect gully networks. Moreover, the conventional pixel-based ANN method, applied to evaluate the performance of the integrated method. Segmentation errors and ANN result were evaluated with the rest (30%) of gully networks of inventory map.

Results showed that, the integrated model presented a great performance and accuracy in gully networks detection than conventional ANN method. GEOBIA also requires less computational power than classic ANN method due to data generalisation therefore can be used for processing larger area. In addition, improving segmentation methods, reduced the spatial error of objects, which led to improved accuracy in gully networks detection.

Developing a multiple-parameter index of hydrological connectivity to identify erosion hotspots in the Upper Burdekin catchment

Tully Booth[1], Ben Jarihani[2], Jamie Shulmeister[1], Jack Koci[2]

[1]School of Earth and Environmental Sciences, University of Queensland Australia
[2]Sustainability Research Centre, University of the Sunshine Coast Australia

High loads of sediments and nutrients derived from soil erosion in agricultural catchments has detrimental impacts on the health of the Great Barrier Reef (GBR). Effective management of soil erosion across the vast GBR catchments requires the spatially explicit identification of erosion hotspots and assessment of their relative connectivity to streams and rivers. The concept of connectivity is applied increasingly in hydrological and geomorphological research to describe the coupling of landforms (e.g., hillslopes to channels) and the associated linkages and transfers of water and sediment. A key limitation of current connectivity indices is that they do not fully incorporate the full range of erosion drivers.

This study seeks to identify erosion hot-spots in the Upper Burdekin catchment, north-east Queensland, and map their relative hydrological connectivity to the catchment outlet. To achieve this aim, we will first modify an existing single-parameter Index of Connectivity (Borselli et al. 2008) into a Multiple-Parameter Index of Connectivity (MPIC). The MPIC will include parameters such as topography, rainfall erosivity, soil erodibility and vegetation cover. The MPIC will be calculated at the end of dry and wet seasons (October and April) of particularly dry (2005) and wet (2011) years, to examine the performance of the index under different hydrological conditions. This will allow areas of high connectivity to be identified, and therefore those susceptible to erosion. Validation of the MPIC will be two stages; MPIC results will first be compared to a similar index SCIMAP (a diffuse pollution risk model), and then to measured sediment loads at each time period. This study will contribute to improved approaches of spatially explicit identification of erosion hotspots and knowledge of the critical drivers of erosion and sediment transport, while also assisting effective and efficient catchment land management.

Rehabilitation outcomes using check dams and livestock exclusion in hillslope gullies, northeast Australia

Scott Wilkinson[1], Jack Koci[2], Aaron Hawdon[3], Anne Henderson[3], Rebecca Bartley[4], Brett Baker[3]

[1]CSIRO, Canberra, Australia
[2]University of Sunshine Coast, Sippy Downs, Australia
[3]CSIRO, Townsville, Australia
[4]CSIRO, Brisbane, Australia

Gullies in hillslope drainage lines are widespread in semi-arid catchments draining to the Great Barrier Reef. These landscapes have been grazed since the 1850s. In areas of granite-derived soils in the Burdekin River basin the gullies are typically 10–20 m2 cross section area, with linear densities at landscape scale of up to 5 km km-2. Open forest tree cover generally remains intact but ground cover is degraded and dominated by an invasive exotic Indian Couch (Bothriochloa pertusa). Prior work indicates that wall erosion is the largest contributor to sediment yield from gullies in these areas (Wilkinson et al., 2018). While rehabilitating gullied landscapes is a high priority for public investment in GBR catchments, the effectiveness of specific gully rehabilitation approaches remains uncertain. Even for widely-applied approaches such as check dams and grazing exclusion (e.g., Heede, 1979), variations in the characteristics of the hydrology and vegetation mean that local evaluation is required to establish typical responses.

This study sought to evaluate the impact of livestock exclusion and small timber and wire check dams, on vegetation, erosion and sediment yields in two gullies. Monitoring of vegetation, erosion and deposition occurred annually over 8 years in the treated gullies and was compared with untreated control gullies. Sediment deposits upstream of check dams had similar proportions of silt and clay as the parent soil, in contrast with untreated control gully floors which had very little sand and clay. Vegetation cover and biomass on the treated gully floors increased over time relative to grazed untreated gullies particularly during wetter than average years (>600 mm y-1), but declined during runs of dry years.

Vegetation cover on gully floors and catchments remained well below levels measured inside long-term grazing exclosures, suggesting that the revegetation response will take much longer than a decade. Fine sediment yields from treated gullies were much lower than those from control gullies for several years.

Preliminary results from this study suggest that small check dams and grazing exclusion can trap substantial amounts of fine sediment. However, the long-term effect of this approach on gully vegetation and sediment yield in this degraded landscape and variable climate remains unclear, and further work should also consider the cost-effectiveness of these activities.

REFERENCES:

Heede BH. 1979. Deteriorated watersheds can be restored: A case study. Environmental Management, 3: 271-281.

Wilkinson SN, Kinsey-Henderson AE, Hawdon AA, Hairsine PB, Bartley R, Baker B. 2018. Grazing impacts on gully dynamics indicate approaches for gully erosion control in northeast Australia. Earth Surface Processes and Landforms, 43: 1711-1725.

Quantifying successive development of interrill-rill-ephemeral gully erosion on hillslope

Gang Liu

State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Northwest A&F University, Yangling, China

Understanding slope erosion processes is of primary importance to the development of physically based erosion prediction models. However, the quantitative information about the successive development of interrill-rill-ephemeral gully (EG) erosion on hillslope is still rare. The purposes of this study was to quantitatively distinguish the spatial and temporal distribution of sediment yield from interrill, rill and EG during simulated rainstorms. In this study, rare earth elements (REEs) was used as tracers to monitor the slope erosion processes. Ten kinds of REEs mixed with cultivated soils were applied into a metal flume (5 m long, 1 m wide, 0.7 m deep) in ten layers with a slope gradient of 20°. The results indicated that the REE tracer methods could effectively monitor the spatial and temporal development of different erosion stage. According to the changing contribution rate, five stages of slope erosion, including interrill erosion, rill development, rill stable, EG development and EG stable, could be identified. The contribution rate of interrill stage was larger than 20%. The contribution rate of rill erosion was increasing during rill development stage, then it kept stable in rill stable stage. EG also went through the development and stable stages. Meanwhile, there was an overlap between rill stable stage and EG development stage. When contribution rate of EG surpassed that of rill, it was defined as EG stable stage. Meanwhile, the development of channel width always had higher increasing rate than channel depth. They also have a similar increasing rate of channel depth. Concentrate flow is the main reason caused channel development and the strong fluctuations in soil losses could be attributed to the discontinuous and abrupt collapsing of rill and gully banks and growth of rills and gullies.

Is it worth it? Where and when should we be investing in gully remediation

Tony Weber, Rohan Lucas, Jason Carter (Alluvium), Jim Binney (Natural Capital Economics), Glenn Dale (Verterra)

Recent assessments completed as part of the development of investment planning for the Great Barrier Reef Foundation have identified a significant range in cost effectiveness for gully remediation. This appears to be strongly linked to the length and/or area of gullying identified and the predicted mass load of sediment exported (a function of soil chemistry and local hydrology), but this does not consider the scale of gullying at particular locations, or the scale of a gully remediation program. In this paper, we examine how the scale of gullying , or gully remediation program, can impact on both the likely sediment exports per unit length and the likely costs of remediation. The hypothesis is that due to costs of mobilisation of relevant resources (machinery, raw materials, labour), larger scale gully programs may be more cost-effective to repair, especially if utilising proven large scale rehabilitation techniques commonly employed in mining rehabilitation.

We also examine the non-cost risks of implementation, such as land holder engagement, operation and maintenance, uncertainty in efficacy, and consistency and complexity of design and construction. The results are used to indicate the optimal scales of gullying, or gully remediation program, where investment can be most cost-effective and provide the lowest overall risk to investment.

Influence of infiltration at different pedological horizons on the process of triggering gully erosion in the Mont-Amba area (Kinshasa, DR.Congo)

Fils Makanzu Imwangana[1,2], Alex Kazadi[1], Médard Ntombi[1,2], Jules Aloni Komanda[1]

[1] Université de Kinshasa, Faculté des Sciences, Département des Géosciences, Unité de Recherche et de Formation en Gestion des Risques Naturels (URF-GRN), Kinshasa, RD.Congo, B.P.190 Kinshasa XI, filsmakanzu@yahoo.fr, +243821024563

[2] Centre de Recherches Géologiques et Minières, Laboratoire de Géomorphologie et Télédétection, Kinshasa, RD.Congo

The study of soils is one of the essential elements of the understanding of a territory for its development. Its occupation, use for agriculture (crops and livestock) and various other uses depend on it. Its degradation complicates and renders the development of the territory costly. Indeed, such is the problem posed by the gully erosion to the urbanization of the town of Kinshasa. We want to explain the generalized production of runoff from the beginning of the rainy season and even the appearance of gullies in its hinterland while, theoretically, the predominance of infiltration was expected. Indeed, the superficial horizons of the fine sandy soils of Kinshasa, which are dried during the long dry season, should have first been imbibed, saturated with water before organizing a concentrated flow. We conducted a study of infiltration capacities of the gully profiles at Mont-Amba area in Kinshasa. In practice, it is a matter of experimentally testing in situ, using a ring infiltrometer (7.8 cm in diameter or a 48 cm2 section) at the different horizons of the profile (A1, Bw1, Bw2). This is conducted to determine the roles of the incriminated factors: the porosity (A, B), the humus layer (A1) and possibly at what level the triggering of the gully erosion originated.

Our observations have shown that nearly 70% of surface horizons pose the infiltration problem from the A1 horizon, which stores a high water content that varies inversely with depth. This development seems to be contrary to the porosity especially considering that nearly 90% of these soils have a sandy texture (diameter: 250 to 500 m) assuming a good infiltration. The triggering of rainfall erosion is indeed complex and occurs differently in each profile. We believe that there is a surface air space during the dry season that would prevent rainwater from spreading rapidly in depth before seeing the moistening front progress in the profile. Also, an increase in microporosity with depth due to packing and clogging of fine elements leached from the surface reducing permeability from a certain depth. The overlying horizons that are more permeable than the lower horizons becoming saturated with water become more fluid, take off in contact with the microporous zones. Thus, there are two causes of the triggering of rainfall erosion in the anthropogenic environment of Mont-Amba. The first is due to the resistance to infiltration by the dry state of the A1 horizon, the glazing and in the presence of a thin layer of humus. The second is due to the fact that this crust developed by these sandy soils was generating, as long as it is not well moistened the hortonian flux even during low intensity rains.

Keywords: Kinshasa, sandy soil, porosity of soil, hortonian flux, anthropogenic environment, gully erosion.

Two examples from southern Spain of gullied areas affected by land use changes: implications in gully network.

David Carruana[1], Estela Nadal-Romero[2], Juan F. Martínez-Murillo[1,3]

[1]Departamento de Geografía, Universidad de Málaga, Málaga, Spain
[2]Instituto Pirenaico de Ecología, IPE-CSIC, Zaragoza, Spain
[3]Instituto de Geomorfología y Suelos, Universidad de Málaga, Málaga, Spain

Gully erosion is mainly controlled by climatic conditions, topography, and land uses. This last factor, by means of changes in vegetation cover and human activity, may either enhance or reduce those geomorphic processes leading to gully formation. The aim of the study is a preliminary assessment of temporal changes in gully networks from two-contrasted Mediterranean mountain environments: one in sub-humid climatic conditions, and other in semiarid ones. To do this, two study gullied areas were selected from South of Spain: i) one, located in high mountain conditions in Sierra de las Nieves (ca. 1600 m.a.s.l.), with mean annual rainfall and temperature of <10ºC and >800 mm y-1, respectively, red marls as bedrock, and sparse vegetation cover (25%); and ii) other, located in Alpujarras (700 m.a.s.l.), with mean annual rainfall and temperature of 15ºC and 350 mm y-1, respectively, white marls as bedrock, and sparse vegetation cover (25%). In both of them, the gully network and gullied areas as well as land uses were mapped and quantify in order to compare their changes from 1956 to 2018. In the sub-humid areas, the land uses remained similar in this period although the vegetation cover increased due to the disappearance of grazing activity. In the semiarid gullied area, the land use change was more remarkable due to afforestation, which mainly affected the north-facing slopes. Land use changes may affect the regolith surface exposed as well as runoff source areas among other geomorphic changes that need to be addressed.

Particle Size and Quick Undrained Triaxial Analysis of Soil Samples from Major Gullies Sites in Edo State

Augustine Osayande (austinelande@yahoo.com)

PhD in Environmental Resource Planning
Department of Geography and Environmental Management,
University of Abuja, Nigeria
Ishaku Ibrahim Yari Mallo ishakumallo@yahoo.com (Professor)
Department of Geography and Environmental Management,
University of Abuja, Nigeria

ABSTRACT

The issue of gully erosion is of major concern in Nigeria. The study was carried out in Edo state, Southern Nigeria. Edo State was chosen as the study area due to the fact that the magnitude of gully erosion has resulted in loss of lives and properties, destruction of arable lands and wastage of large areas of usable land. In the study particle test and quick undrained triaxial analysis of soil sample from the major gullies sites were determined. The analysis of soil samples collected from Edo South are more sand, this also explain why the areas are susceptible to gully erosion. This can also be attributed to the high volume of soil that is wash away in the area. The compressive strength of these soil samples collected from the area are in the ranges of 163Kn/m at Ambrose Ali University in Edo Central to 232 Kn/m at Igueben also Edo Central. The bulk density in the area ranges from 1.70Mg/m3 at Ambrose Ali University Ekpoma in Edo Central to 2.66Mg/m3 at Oka in Edo South and the moisture content ranges from 26.7% at Oka in Edo South to 32.0% at Ambrose Ali University Ekpoma in Edo Central

Key words: Gully, Erosion, Particle, Undrained, Triaxial

Dynamics and Characteristics of Ravine: A Study of Semi-Arid India

Padmini Pani

Centre for the Study of Regional Development
Jawaharlal Nehru University
New Delhi

Ravine is a severely eroded landform comprises of complex deep trench of gullies. The formation of ravine is a complex biophysical process. The Chambal ravine in semi-arid India is the largest gully eroded land forms in India. Around 48000-km^2 area along the river Yamuna, Chambal and its tributaries in semi-arid India are affected by the gully and developed a very rugged ravine landform. The nature of Chambal ravine is diverse and challenging to quantify and characterise due to its vastness and ruggedness. This uneven complex topography is not accessible uniformly.

The objective of this study is to understand the extent, characteristics and dynamics of the ravine. To fulfill these objectives the longitudinal field survey for 20 years, using CARTOSAT DEM (2.5 m resolution) along with other geospatial data the ravine has been delineated and classified. The LDM, GPS & clinometer have been used for quantifications of few sample gullies. The complex nature of ravine trenches is diverse.The depth of the ravine varies from 1.5 meters to more than 40 meters, the bed width ranges from few meters to 20 meters, the slope of the head scarp is gentle to very steep, and slope of sub scarps is from 45 degrees to sometimes vertical. The longitudinal and cross profile of CARTO DEM of the different sections of the ravine is proved to be useful and helped to validate the field observations.

As per these physical characteristics, the ravine has been classified as deep ravine, medium and shallow ravine.
The study revealed that the long narrow ravines are initially formed along the natural drainage line and further progressive transformations under increasing soil erosion, ravines are bifurcated into many branches and develop the bulbous pattern with rounded heads and sloping sides which are further enlarges if there are no further control of ravine. Sometime four stages of ravine development processes are recorded in this area, specifically i. hole stage, ii. piping stage, iii. Collapsing stage, iv. Recession stage. In many sites these stages complete the cycle within few years of time and developed a full-fledged gully and gradually gully mounds are started receding and due the repetition of the same cycle the landform started lowering down. The head ward extension of gullies is common here through gully lengthening process. The initiation of gullies is also very active though spring sapping in some places due to the presence of limestone and sandstone along the river Chambal.

Keywords: Semi-arid india, Chambal ravine, Geomorphology of ravine, Ravine erosion, Geospatial technology, CARTOSAT DEM

Reef Credits Gully Methods

Timothy Pietsch[1], Andrew Brooks[1,2], Jenny Sinclair3, Mike Berwick[3], James Schultz[3], John Spencer[1], Robin Thwaites[1], James Daley[1]

[1]Griffith Centre for Coastal Management, Griffith University, Australia,

[2] School of Environment and Science, Griffith University, Gold Coast, Australia

[3]GreenCollar, Sydney

Given the dominance of gully erosion as a source of sediment to the Great Barrier Reef (GBR), significant improvements to GBR water quality cannot be achieved without major investments in gully rehabilitation. As outlined elsewhere in this conference, a new model known as Reef Credits provides an incentive-based market mechanism to fund long term water quality outcomes, in this case via gully rehabilitation. Given that there are currently no robust models to predict sediment reductions resulting from gully rehabilitation works, the method proposed to underpin this strategy requires that the water quality improvements are monitored across a 25 year crediting period (albeit not continuously) and maintained permanently.

Reef Credits represent a quantifiable amount of sediment or nutrient abatement, measured at the end of gully, at the 'end of system' by applying a catchment sediment budget model. The gully method takes account of cumulative avoided sediment production across the 25 year crediting period. To quantify this the project proponent is required to firstly establish the baseline erosion rate (averaged over the last 20 plus years) of a gully and demonstrate that the gully is likely to continue on this trajectory over the next 25 years (in absence of any intervention).

This not only requires establishing the gully growth trajectory, but involves surveying the sediments that will be encountered on that trajectory to demonstrate their comparability with those eroded thus far. Given there are unlikely to be any sites where someone has been monitoring gully sediment yields for 20 plus years, establishing a baseline will typically involve reconstruction of a gully growth rate via historical airphoto analysis. In some instances repeat LiDAR surveys spanning a decade or so may exist, and this may be sufficient to demonstrate a baseline yield, particularly if complemented by an airphoto time series. Regardless of the type and length of available data, the timeseries requires adjustment for rainfall, to account for any bias in the rainfall history. It is also expected that at least one contemporary LiDAR survey is used to determine the present gully volume.

Where it is not possible to establish a robust baseline erosion rate, a control site may be used, providing it is a comparable gully, to measure deviation between the treatment and control site, and hence the sediment abatement. The cumulative deviation (in the 20µm sediment fraction) from the erosion trajectory after treatment against the baseline project yield, and/or the control, represents the quantity of Reef Credits generated. Proponents are required to monitor the sediment yield using a combination of methods; including ongoing monitoring of gully volumetric change and through direct water quality monitoring (see Dorian et al, and Spencer et al., this conference), at regular intervals over the crediting period.

Impacts of land use/cover change on soil erosion in Chaobai River Basin

Feng Jingjin[1], Jiang Qun'ou[1*], Shi Mingchang[1]

[1]School of Soil and Water Conservation, Beijing Forestry University, Beijing, China

ABSTRACT

Regional soil erosion changes are closely related with land use/cover changes, however, the impacts of land use/cover on the soil erosion changes is various in different regions. Therefore, it is significant to explore the impacts of land use/cover on the soil erosion changes to offer the references for the land use planning and water and soil conservation.

METHODS

This study selects Chaobai River Basin in Beijing as the case area, and apply the RUSLE model and soil erosion intensity index to estimate the tempo-spatial distribution of soil erosion and soil erosion intensity index of the Chaobai River Basin in Beijing based on the 30-year average annual rainfall data, soil attribute data, high-resolution DEM data, remote sensing data and land use data. On the above basis, the changes of soil erosion under different land use/cover conditions in different periods are finally explored.

RESULTS

The results showed that the soil erosion changes, which are caused by the conversion of cropland to forestland and the cropland to grassland under the same coverage grade condition, had a decreasing trend, and their mean value decreased by 362.32 t/(km^2·a) and 259.54 t/(km^2·a) from 1990 to 2015. As for the soil erosion changes that are caused by the conversion of forestland to grassland showed an increasing trend with 230.94 t/(km^2·a). However, the soil erosion intensity index of forestland and grassland in the Chaobai River Basin in Beijing is overall greater than that of cropland, and reached the maximum value in 2005, which were 201.57 and 190.10, respectively. This is mainly because of the degradation of forestland and grassland. Although the conversion from the cropland to forestland and grassland reduces the soil erosion, the soil erosion in forestland and grassland are still serious and cannot be ignored.

CONCLUSIONS

Those conclusions can provide a certain technical reference for realizing the optimal allocation of land resources in Beijing mountainous areas and effectively controlling soil erosion.

Gully head modelling in Mediterranean badland areas

Dino Torri[1], Jean Poesen[2], Mauro Rossi[1], Sofie de De Geeter[2], Cati Cremer[2]

[1]Insituto di Ricerca per la Protezione Idrogeologica (IRPI), Consiglio Nazionale delle Ricerche (CNR), Perugia, Italy

[2]Department of Earth and Environmental Sciences, KU Leuven, Heverlee, Belgium

The prediction of the location of gully heads in various environments is an important step towards predicting slope and catchment dynamics and to properly estimate soil erosion rates. So far, data collection and modelling of topographic thresholds for gully head prediction has mainly focused on forested areas, rangelands, pastures and cropland. However, such data for badlands are very scarce, even if such environments are most interesting to study gully processes, resulting from the complex interaction between soil degradation and erosion, and soil building processes. In this study we extend the database on topographical thresholds for gully head formation through data collection in badland areas and to improve the prediction of gully head development in a given landscape. For this purpose, we selected different badland sites in the Mediterranean that are characterized by different badland morphologies that developed in differed geo-environmental conditions.

The analysis of the conditions under which gully heads developed allowed to refine a recently reported gully head threshold equation, and to illustrate how to use the updated model. This model shows that the resistance to gully head formation depends on slope gradient and drainage area at gully heads, land use in the gully catchment at the moment of gully development (expressed numerically by parameters derived from the Runoff Curve Number method), surface rock fragment cover, presence of joints, pipes, and factors/processes affecting soil detachment rate. This study improves our understanding of environmental conditions that control the development of gully heads in various badland types through a combination of field data collection of gully heads and modelling.

Gully rejuvenation by debris flows in forested catchments of southeast Australia: landscape change linked to drought, wildfire and ENSO

Petter Nyman[1], Ian D. Rutherfurd[2], Patrick N.J. Lane[1], and Gary J. Sheridan[1]

[1]School of Ecosystem and Forest Sciences, University of Melbourne, Parkville, Victoria 3010, Australia
[2]School of Geography, University of Melbourne, Parkville, Victoria 3010, Australia

Post-orogenic mountains of southeast Australia are relatively stable because of dense forest cover and slopes that are not very steep. Background erosion rates from forested catchments in this region are low. This means that catchments provide a reliable source of potable water that can delivered to consumers with minimal treatment cost. Between 2003 and 2013, however, drought, large wildfires, and record-breaking rainfall contributed to major gullying caused by debris flows in SE Australia that appear to be unprecedented in spatial extent and density in historical records.

Amongst other infrastructure damage, water supply catchments throughout the region have been severely impacted by these events due to the high turbidity caused by clay inputs to reservoirs. Here we use a debris flow inventory from this period of dry and wet extremes to examine the processes and climatic controls underlying the region-wide debris flow response. Results reveal shallow landslides and surface runoff as two distinct initiation mechanisms, linked to different geologic settings and contrasting hydroclimatic conditions. Landslide-generated debris flows occurred in sandy soils, independent of past fires, and were tightly controlled by extreme rainfall causing saturation and mass failure during La Niña.

In contrast, runoff-generated debris flows occurred in clay-rich soils from short and intense rainstorms after wildfires in dry conditions, often associated with El Niño. Thus, it appears that both ends of the wet and dry climate extremes produce the same general geomorphic response, debris flows, but in different areas and by different initiation processes. Debris flow activity is therefore at a maximum when amplitude and frequency of climate oscillations are large. Debris flows in SE Australia mean that periods of gully erosion in forests are likely to become more frequent and widespread as wildfire activity and rainfall intensity are predicted to increase.

Gully Mapping and Erosion Volume Calculation: A 3D approach using Cartosat-1 Stereo Images

Farha Sattar[1], Rober James Wasson[2], Muhammad Nawaz[3]

[1]Charles Darwin University, Darwin, Australia
[2]Australian National University, ty, Australia
[3] National University of Singapore, Singapore

Gully erosion is a major contributor of high load of sediment volumes in Australian river catchments. Gully erosion volume calculation requires careful selection of data and methods which are appropriate at the required level and scale. Gully identification and mapping methods have been under discussion for many years to find improved techniques for gully mapping as well as to study gully morphology and underlying erosion processes. This paper describes a method to process Cartosat-1 stereo images at 2.5 m resolution and presents the necessary steps involved in generating a three dimensional (3D) digital surface model (DSM).

A user friendly and efficient 3D gully identification and mapping method is presented to store morphometric parameters of gullies and to calculate erosion volume. An example is provided from the Daly River catchment in the Northern Territory.

Method Development for Measuring and Monitoring Gully Formation Using Drones

Mike Saynor, John Lowry, Tim Whiteside, Dave Loewensteiner, Andrew Esparon, Renee Bartolo

Supervising Scientist Branch, Department of the Environment and Energy Darwin Australia

The Ranger uranium mine in the Northern Territory is approaching closure and is legislated to be rehabilitated by January 2026. The rehabilitation of the mine site is subject to several Environmental Requirements relating to the final landform including:

- Erosion characteristics of the rehabilitated landform, as far as can reasonably be achieved, do not vary significantly from comparable landforms in surrounding undisturbed areas, and
- Mine tailings are physically isolated from the environment for at least 10,000 years.

Tailings from the Ranger mine are being placed in the two mined pits and covered to physically isolate them from the environment. Development of gullies on the rehabilitated mine site could provide increased sediment to the downstream environment and potentially expose tailings.

The Supervising Scientist Branch (SSB) are utilising a range of drones and sensors to produce digital elevation data at spatial accuracies suitable for measuring gully formation and development. The recent acquisition of a LiDAR (Light Detection and Ranging) system is intended to increase the accuracy of assessment of gully detection and development.

This paper is focussed on determining the most appropriate data collection techniques for both optical and LiDAR drone sensors in mapping and measuring gullies. The test site was an area of the South Alligator River Valley (within Kakadu National Park) adjacent to a containment facility, where there is known gully formation. The sensors used were a Quanergy M8 (LiDAR which is part of the NextCore system), Zen Muse X5S (20 MP on board a DJI M200), and DJI Phantom Pro 4. Ground techniques including DSLR photo survey and LiBackpack D50 (Simultaneous Localisation And Mapping (SLAM) ground LiDAR) were also undertaken to provide a comparison as well as ground truth. The drone-based sensors were tested for the following parameters: flight pattern; height; speed; flight spacing; accuracy; flight duration; and areal coverage.

The main outcome of this project is method development to use LiDAR for monitoring and assessing gully formation and development in the constructed Ranger rehabilitated landform. This methodology will continue to be refined to enable the monitoring of gully development following the rehabilitation of the Ranger mine.

Effect of Gully on Regional Soil Erosion

Mingchang Shi [1], **Jingjin Feng**[2], **Chunyang Chen**[3],**Haoyu shi**[4]

[1,2,3] Beijing Forestry University, Beijing, China

[4] University of California, Santa Barbara, California, USA

Mountainous areas in China account for 69% of the country's land area, with complex topography and well-developed gullies. Gullies have a significant impact on regional soil erosion. The regional scale soil erosion has the characteristics of large area and complex principle. Based on GIS and RS technology, this study constructed a spatial model of soil erosion E=R*K*S*H*C. The regional soil erosion model factors include rainfall, soil, slope, runoff path, and surface cover. The soil erosion model was used to estimate the soil erosion modulus of the Chaobai River Basin in Beijing in 2017. Finally, the soil erosion spatial model estimation results are compared with the RUSLE estimation results. The results show that the erosion gully has a significant effect on the spatial distribution of soil erosion intensity in the region, as follows.

(1) Estimate the regional soil erosion by using the 5km^2 watershed as the reference, and calculate the gully density of the basin. The estimation of regional soil erosion is more realistic using this parameter. The runoff path factor is processed by the DEM data. The ratio of the length of the channel line in the catchment area to the area of the catchment area is used as the gully density.

(2) In a specific geographical environment, the density of gully has a significant correlation with the impact of regional soil erosion. When the soil erosion intensity reaches 2500t/(km^2·a) in the northern soil mountainous area, the gully density is around 3.

(3) The runoff of rainfall converged on the slope, and the runoff converged into the gully step by step, which aggravated the soil erosion. On the soil erosion distribution map, the soil erosion is more obvious around the gully, which had the remarkable distribution characteristics of the gully erosion influence.

(4) In the study, the regional distribution characteristics of soil erosion in the Chaobai River Valley of Beijing in 2017 were described more consistently. The estimation of the spatial model of soil erosion maintains the flaky and linear distribution characteristics of the runoff path factor. The trend of erosion development along the runoff path is obvious, which is more in line with the fact that the erosion in mountain areas occurs mostly on the slopes on both sides of river networks. It also fits better into this abstraction, which is made up of a set of irregular small watersheds or a set of larger slopes.

Which soils have the most gullies in the GBR catchments, Australia?

Mark Silburn[1], Tessa Chamberlain[1], Peter Zund[2], Shawn Darr[1]

[1] Department of Natural Resources, Mines and Energy, Toowoomba, Australia

[2] Department of Environment and Science, Brisbane, Australia

ABSTRACT

Gully erosion is a major source of sediment in streams in Great Barrier Reef (GBR) catchments, Queensland, Australia. This study attempts to identify the landscapes, soil types and sub-soil properties that are more prone to gully development in the GBR catchments.

Gully density mapping (Darr and Pringle 2017) measures the number of 100 m^2 cells with gullies present per km^2, based on satellite imagery. This was compared to broad scale geomorphic mapping (Story et al 1967; Speck et al 1968; Forster and Barton 1995; Shields 2002), to identify the landscapes on which gullies are more common. In the eastern portion of the Fitzroy Basin, the highest average gully presence (over 10%) occurs on hills with woodlands and bluegrass vegetation, undulating rises and plains with softwood scrub, and undulating rises and plains with woodlands (Figure 1). Together, these three landscape units cover 22% of the study area, highlighting potential hotspots of gullying in this region. Development of a consistent geomorphic framework across the GBR catchments would allow this analysis to be carried out more widely, to help target gully research in key landscapes.

Soil site data was obtained from the Queensland Soil and Land Information (SALI) database, which contains soil descriptions (and sometimes soil chemistry) for some 2,200 soil sites beside gullies (within 20m). Counts of gully sites for each order of the Australian Soil Classification (Isbell 2016) were compared with the areal extent of each soil order.

This analysis indicated that Kurosols have marginally the most gullies per unit area of soil, followed by Calcarosols, Sodosols, Chromosols, Dermosols and Vertosols. Kandosols, Rudosols, Tenosols, Hydrosols, Ferrosols and Podosols have about seven-times less gullies per unit of soil area and Vertosols have about half the gullies than the group with the greater frequency of gullies. Sodosols have the largest areal extent in GBR catchments (36%) followed by Chromosols (17%), Vertosols (14%), Dermosols (15%), Kandosols (6%) and Rudosols (4%).

Subsoil electrical conductivity (EC) and exchangeable sodium percentage (ESP) data for 19 soil profiles at research gullies in the Burdekin, Bowen and Fitzroy catchments indicate that all gullies had dispersive sub-soil, mostly without, and sometime with, mechanical energy. ESP alone is a poor predictor – you need EC and ESP. The laboratory R1 dispersion ratio (silt+clay/ total dispersed silt+clay) was also high in most subsoils (>0.8). The field (10 minute) modified Emerson's dispersion method generally did not indicate strong dispersion and does not seem as useful as EC-ESP and R1. This analysis will be extended to the chemistry of soils in SALI beside gullies. Continuation of these forms of analysis will assist in confirming landscapes at high risk for gully erosion and efforts to predict occurrence of gullies, a process that has proven difficult previously.

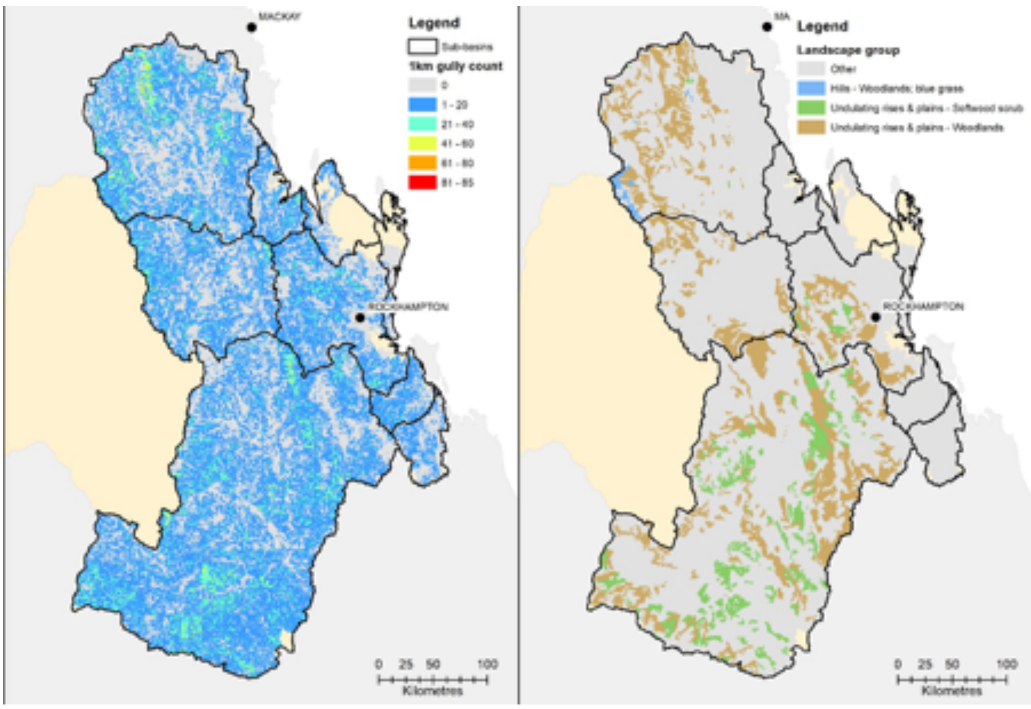


Figure 1. Gully density mapping, and the three landscape units with highest average gully density; eastern Fitzroy NRM region

A comparison of remote sensing techniques for measuring gully sediment yields and rehabilitation effectiveness

John Spencer[1], Andrew Brooks[1,2], James Daley[1], Nic Doriean[1,2,3] Tim Pietsch[1], Robin Thwaites[1]

[1]Centre for Coastal Management – Griffith University, Gold Coast, Australia
[2] School of Environment and Science, Griffith University, Gold Coast, Australia
[3]Environmental Futures Research Institute – Griffith University, Gold Coast, Australia

Recent advances in our understanding of the causes of declining water quality in the catchments draining to the Great Barrier Reef World Heritage Area (GBRWHA) have highlighted gully erosion as a key sediment source. Both the Australian and Queensland Governments now have major programmes focused on gully rehabilitation. With this focus, there is an increasing need to be able to quantify the water quality improvements associated with gully rehabilitation efforts, particularly as it appears likely that resource allocation will at least partly shift towards a model that funds quantifiable water quality outcomes through a Reef Credits market-based approach. Under such an approach, water quality improvements must be measurable, and hence the monitoring methods employed must be both scientifically rigorous, but also cost-effective. At present there is no standardized approach employed in monitoring gully rehabilitation success, but the success of an outcome-based funding model depends on the development of rigorous approaches with known margins of error and signal-to-noise ratios.

In this paper we outline and compare a range of spatial gully monitoring methods applied at Strathalbyn Station in the lower Burdekin River, Queensland Australia, and discuss the advantages and drawbacks of the various techniques as applied to large complex alluvial gully systems.

These gully systems are tens of hectares in area, with highly complex topography where it is very difficult to fully capture all of the topographic variability due to highly crenulated gullying, tunnelling and bank overhangs. We compare various LiDAR methods, including standard resolution airborne LiDAR (typically 10-20 pts m^{-2}), terrestrial LiDAR (> 1000 pts m^{-2}) and high-resolution airborne LiDAR (up to 300 pts m^{-2}), along with remotely-controlled UAV (drone) structure-from-motion (SfM) photogrammetrically-derived digital terrain models (DTMs).

We present data on the point density distribution, minimum resolution and costs per unit area of the different techniques. No one technique is applicable for all purposes for which data is required for project planning, design and monitoring. Rather, the appropriate method needs to be matched to the scale of the gully, or gullies, their spatial relationship in the landscape, and the intended purpose. Vegetation cover is a major limitation for the application of UAV derived SfM DTMs, particularly considering that a primary focus of gully rehabilitation strategies is to maximise vegetation cover within the gully and its catchment. All of these methods are intended to be a component of a comprehensive monitoring approach that includes direct water quality monitoring strategies as outlined in other presentations at this conference.

Gully to stream channel transition zones and how to identify them

Justin Stout, Tim Pietsch, Andrew Brooks, Robin Thwaites, John Spencer, Graeme Curwin, James Daley
Griffith Centre for Coastal Management, Griffith University, Gold Coast, Australia

Gullies are common features across many landscapes and are recognized as both a driver of landscape evolution and a product of anthropogenic disturbances. In catchments with anthropogenic disturbance gully formation often results in excess sediment delivery to rivers, ultimately degrading the receiving water bodies. Catchment erosion models such as Dynamic SedNet are used to determine how management practices and/or rehabilitations will reduce the yield of excess sediment. To improve model parameterization, catchment models need to distinguish between gully erosion and streambank erosion. However, the transition point from gully to low order channels is difficult to identify, both in the field and through remote sensing methods. Differing drivers of streambank erosion and gully erosion can result in widely variable yields of sediment, and if streambanks and gullies are treated the same grossly over/under estimate the predicted sediment yield. What is needed is a standardized method (both conceptual and empirical) to identify where gully erosion processes begin to transition to open channel flow processes.

Here we present an analysis to systematically identify the transition zone that accounts for similarities and differences in gully and streambank erosion processes and the resulting geomorphic forms. We treat the transition point from gully to stream channel as a fuzzy transition zone. Using a conceptual model developed from the literature and our experience we developed and parameterized a set of fuzzy inference rules to identify probable transition zones. Transition zones were mapped using 1 m LiDAR and aerial imagery and then field validated using the conceptual model and field observations. As a result, we show that fuzzy logic and conceptual models are useful in identifying possible transition zones, but true objectivity is elusive. However, using multiple lines of evidence and a fuzzy logic approach identification of the transition zone is reproducible both in the field and via remotely sensed methods.

Quantitative Analysis of Characteristics for Farmland Gullies in Northeast Black Soil Region of China

Jie Tang[1], Gang Liu1[*], Yun Xie1 Yongqiu Wu[1], Jianwei Li[2], Bo Shen[2],Lingqin Meng[2], Yan Gao[2]

[1]State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing, China
[2]Songliao Water Resources Commission, Ministry of Water resources, Changchun Jilin, China

ABSTRACT
Gully erosion, dominated by topography and human planting, has destructed the farmland after more than 100 years cultivation in northeastern China. To understand gully's characteristics for gully survey by using remote sensing images, 123 farmland gullies were investigated on site in three geomorphic areas of hill, tableland and rolling hill with cross section measurements. The ratio of the distance between the gully head and the gully catchment outlet to the catchment channel length (DR) was defined to classify the forward gullies and obstructed gullies.

The results showed that: (1) the characteristics of the farmland gullies were obvious different in three geomorphic areas. The mean ratios of gully length to gully volume were 0.42, 1.86 and 1.92 for hill, tableland and rolling hill areas, and the mean ratios of gully length to gully width were 7.47, 72.85 and 172.96 correspondingly, which revealed wider, shorter, and larger gullies in the hill regions, narrower, longer, and smaller gullies in the rolling hill regions, and in between for tableland. (2) The average widths of forward gully in three geomorphic areas were 6.75m, 1.93m and 1.52m, and 48.51m, 107.57m and 252.08m in lengths. The obstructed gullies had similar widths of 7.08m, 2.82m and 1.39m, and similar lengths of 42.63m, 96.37m and 191.88m respectively, to forward gullies. However, the later had a potential headcut retreat.

(3)The gully volumes had good relationships with gully lengths which could be identified by remote sensing images. The R2 of linear regressions of gully volumes to gully lengths were 0.98, 0.52 and 0.90 in three regions for forward gullies, and 0.81, 0.69 and 0.97 respectively for obstructed gullies. Gully erosion rate could be quantitatively estimated by using derived regressions after two consecutive times of remote sensing gully survey, which provide quick, efficiency, and precision gully survey results in regional scale.

Key words: gully erosion; remote sensing; classification; models.

What is Where? Material Mapping Methods for Queensland Alluvial Gullies

Robin Thwaites[1], Peter Zund[2], Andrew Brooks[1]

[1]Centre for Coastal Management, Griffith University, Gold Coast, Australia

[2]Science and Technology Division, Queensland Government Department of Environment and Science, Brisbane, Australia

Investigations into alluvial gully erosion in Great Barrier Reef (GBR) catchments requires new tools to describe, classify, and map their soil and sediments ('soil-materials'), in detail. Customary soil mapping methods are inadequate to characterize and communicate the variation in soil materials for these complex gully systems. The approach assigns greater significance to sub-solum materials and geomorphic processes, for characterisation and analysis than does traditional soil mapping.

A multi-purpose approach is described to underpin consistent gully classification and to aid rehabilitation designs. The approach employed uses a range of data, including:

- fine-scale, high resolution spatial data for soil material interpretation, location, and occurrence, in 3-dimensional gully space;
- technical soil science data at broad to fine spatial scales for environmental correlation and knowledge base;
- soil material observational and analytical data at fine scale in 3-dimensional gully space for site assessment and works planning and design;
- local and regional data and information for conceptual model construction, knowledge transfer, monitoring and management, prediction and prevention, and environmental correlation.

We present examples from two field sites in GBR catchments; Strathalbyn in the lower Burdekin and Crocodile Station in Cape York, Australia.

An initial task is a desktop-based identification of soil material pattern, using aerial and satellite imagery, and high-resolution LiDAR DEMs, combined with extant geological and soil mapping data. This, and initial field reconnaissance and observations provided the basis for an initial conceptual site model. Conventional soil mapping techniques were used for the broader scale surface soil associations (Soil Profile Classes) and to classify profiles according to the Australian Soil Classification standards. Field description and sampling was carried out by:

- augering and coring up to a maximum of 1.8 m using vehicle-mounted hydraulic push-tube corer, around and beyond the gully system;
- observations of exposures within gullies
- sampling of identified layers (minimum 3 samples) in gully walls, at selected, representative sample points, for the whole depth of the section;
- collection of samples for laboratory analysis;
- soil-materials layer description of sections using specifically designed field data-sheets for data base entry.

All sample points were geolocated using GPS or identified on DEMs derived from either drone photogrammetry, terrestrial LiDAR or aerial LiDAR.

Maps and tabular descriptions of Soil Material Systems (terrain units) and Soil Material Units (soil-material layers) are then produced from the field and analytical data in GIS on the 1 m LiDAR DEM base for a 3-dimensional presentation in GIS. Three-dimensional fence diagrams of Soil Material Units have been produced to aid their estimation of areas and volumes, in conjunction with the maps on the DEM base in GIS.

The soil-material approach used here, while still in development, is proving to be effective and efficient for both research outcomes as well as resource management communication and planning purposes.

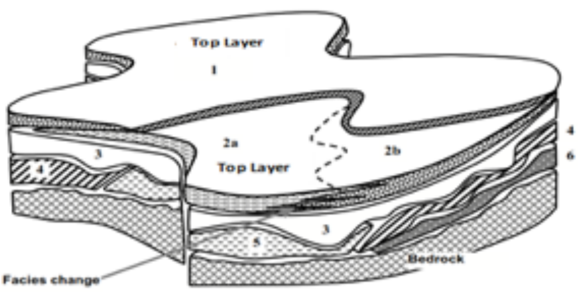


Figure 1. Schematic representation of soil materials as layers (layers may be pedological horizons or sedimentological strata). A Soil Material Unit can comprise more than one layer. The top layer usually can be referred to as the topsoil, if the topsoil has not been eroded. In that case it is possible that the top layer is layer 2.

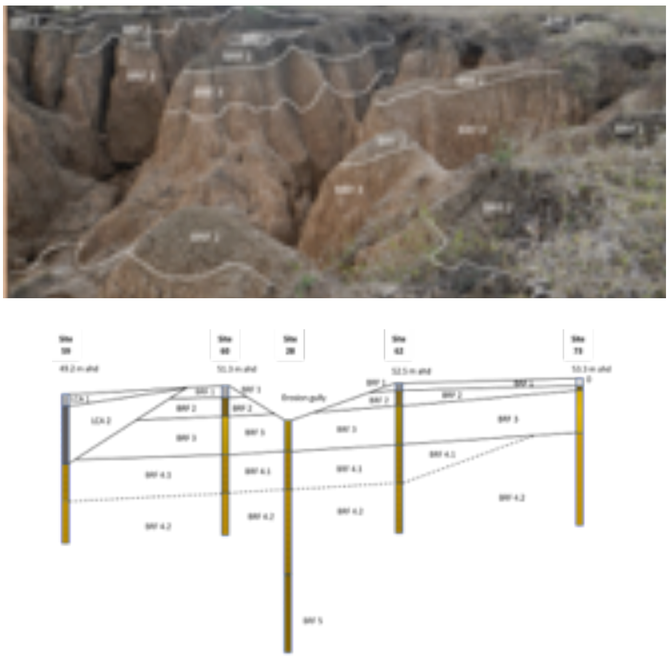


Figure 2. a) Soil-geomorphic layers (as Soil Material Units – SMUs) identified in Gully 7 at Strathalbyn Station; b) Soil Material Units (SMUs), grouped by Soil Material System (i.e. LCA and BRF), correlated by elevation above AHD from both gully exposure and soil core observations.

Does the topographic threshold concept explain the initiation points of sunken lanes in the European loess belt?

Sofie De Geeter[1], Jean Poesen[2], Matthias Vanmaercke[1]

[1]University of Liège, Department of Geography, Clos Mercator 3, 4000 Liège, Belgium

[2]KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Heverlee, Belgium

Sunken lanes (or road gullies) are a common geomorphic feature in loess regions, such as the European loess belt. These landforms are usually incrementally created by various erosion processes (by water, mass movements and traffic). They are important for ecology and biodiversity (e.g. by creating micro-climates), for geomorphology and hydrology (e.g. by functioning as a sediment source and by enhancing the runoff and sediment connectivity of the landscape), and for recreation (e.g. scenic walking and cycling routes). Several studies focused on these aspects of sunken lanes. Nonetheless, little is known about their origin and evolution. The formation of sunken lanes is typically only understood in qualitative terms, while no studies have provided a quantitative analysis of their initiation. To address this research gap and to improve our understanding of this process, we investigated to what extent sunken lanes (i.e. 'road gullies') can be treated and described as a gully erosion process. More specifically, we explored whether their position in the landscape and characteristics are controlled by a topographic slope-area (SA) threshold for gully initiation (i.e. S = kA-b, with S the local soil surface slope, A the catchment area draining to the gully head, k a coefficient reflecting the gully erosion resistance of the loessic material and b an exponent).

Based on field surveys and LIDAR data analyses, we determined the S and A-values for 132 sunken lane heads in the Belgian loess belt and collected data on several other characteristics (initiation and sedimentation point, width, depth and length of each sunken lane). Our results showed a very large scatter on the SA-values. Moreover, the morphological characteristics of sunken lanes (e.g. width, length) showed no clear relation with their corresponding SA-values. However, it was possible to identify a weak SA-threshold relation with a low b-exponent (-0.016) and a low k-coefficient (0.022) (Figure 1a). This indicates that the formation of sunken lanes is not in line with the topographic threshold conditions that govern the initiation of natural gullies in various types of environments (Figure 1b). The low k-coefficient points to the fact that there is a very low resistance to gully head development in loess. Also other results indicated that sunken lanes behave very differently from natural (ephemeral or permanent) gullies. This supports the conclusion that not only concentrated flow detachment and transport, but also human activities (mainly traffic erosion) play a major role in the initiation of sunken lanes.

Prevention and Mitigation of Urban Gullies in D.R. Congo: Lessons learned from Failures and Successes

Matthias Vanmaercke[1], Fils Makanzu Imwangana[2,3], Serge Cogels[4], Olivier Dewitte[5], Theodore Trefon[5], Charles Bielders[6], Jean Poesen[7], Robert Wazi Nandefo[8], Willy Mbalanda Lawunda[9], Guy Ilombe Mawe[1,5], Christian Mushayuma[1,5], Eric Lutete Landu[1,6], Christian Kitenge wa Kitenge [4]

[1] Université de Liège, Départment de Géographie, Géographie physique et du Quaternaire ; [2] Université de Kinshasa, Département des Géosciences, Unité de Recherches et de Formation en Gestion des Risques Naturels (URF-GRN) ; [3] Centre de Recherches Géologiques et Minières, Laboratoire de Géomorphologie et Télédétection, Kinshasa, RD.Congo ; [4] Université Libre de Bruxelles, Centre d'Anthropologie Culturelle, Brussels, Belgium; [5] Royal Museum for Central Africa, Department of Earth Sciences; [6] Université catholique de Louvain, Earth and Life Institute – Environmental Sciences ; [7] KU Leuven, Department of Earth and Environmental Sciences; [8] Université Officielle de Bukavu, Département de Géologie ; [9] Université de Kinshasa, Département de Sociologie

Intense rainfall, inappropriate city infrastructure and lack of urban planning lead to the formation of large gullies in many cities in the Democratic Republic of Congo (DRC), but also many other tropical urban areas. Such urban gullies are clearly an understudied and underestimated geohazard. They are often formed in a matter of hours due to the concentration of rainfall runoff and, once formed, continue to expand during subsequent years. Given their nature and location in densely populated areas, they often claim casualties, cause large damage to houses and infrastructure and impede the development of many (peri-) urban areas. These problems directly affect the livelihood of perhaps more than a million of mainly poor people in DRC and may strongly aggravate as a result of rapid urban growth and climate change. Several initiatives already exist to stabilize existing gullies, but an estimated 50% of these measures fail. Furthermore, prevention receives very little attention.

The ARES-PRD project "PREMITURG" (2018-2023) aims to contribute to the prevention and mitigation of urban gullies by strengthening the research and decision-making capacity of Congolese universities and other stakeholders in disaster risk reduction. For this, we aim to (i) study the factors controlling this erosion process; (ii) identify the most effective/efficient prevention and mitigation measures (iii) study the societal and governance context of urban gullies as well as its influence on the prevention and mitigation of urban gullies; and (iv) valorize and appropriate the obtained research results. This will mainly be done by the training of 3 MSc and 3 PhD students of DRC. Their research will focus on urban gullies and prevention and mitigation initiatives in Kinshasa, Bukavu and Kikwit. In Kinshasa, also the societal context of urban gullies will be investigated. Apart from the training of these students, the project will support local MSc studies and provide a range of prediction tools, field manuals, trainings, seminars and workshops to assist decision makers and other stakeholders in addressing this issue.

The central philosophy behind this project is that a lot can be learned from already existing initiatives aiming to prevent or mitigate urban gullies. These initiatives are taken by a wide range of actors and stakeholders, but often on an isolated basis. We aim to integrate and study these existing efforts. This will not only allow us to learn from their successes and failures, but will also increase interactions and synergies between the various actors and stakeholders involved with this problem. The insights obtained through this project will also be of great value to other tropical countries where urban gullies are a growing problem.

Combined Multi-Resolution Mapping of Gully and Channel Extent and Future Risk from Digital Elevation Models

Simon Walker[1,2], Scott Wilkinson[2], Albert Van Dijk[1], Peter Hairsine[1]

[1]Fenner School, Australian National University, Canberra, Australia
[2]CSIRO Land and Water, Canberra, Australia

While channel erosion is recognised as a major, often-dominant, source of river sediment, channel geometry and its change remain impractical to measure for anything but small experimental watersheds. Remediation efforts in landscapes affected by channel erosion focus on mitigating current erosion, preventing future erosion, or both. Designing remediation strategies requires information on the extent and location of current incised channel features, as well as a method to determine locations where incision may occur in the future. We present a multi-resolution algorithm to concurrently map both existing incised landform elements as well as areas at risk of future incision.

We focussed on developing a transferrable method capable of operating across diverse landscapes. A multi-resolution approach was taken to facilitate mapping of landform elements, and areas at risk of future incision, across multiple scales.

The algorithm was tested in three contrasting environments in eastern Australia with promising results. Sensitivity analysis indicates the method is reasonably versatile across landscapes, but that outputs become more sensitive as the average slope of the landscape increases. A comparison between cleared and uncleared hillsides suggested that areas indicated at risk of incision are plausible, and that cleared areas were more susceptible to channel incision.

The only required input to the algorithm is a digital elevation model, as such all mapping outputs assume topography alone provides sufficient information to identify areas of interest. It is expected that incorporating additional ancillary variables important to the erosion process, such as soil type and vegetation cover, would improve mapping results.

Modelling interrill and rill erosion processes on steep hillslopes

Zhanli Wang[1], **Qingwei Zhang**[1]

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling, Shaanxi 712100, China

Interrill and rill erosion processes on steep slopes are important soil erosion processes and the main sediment sources on hillslope of the Loess Plateau of China. Revealing interrill and rill erosion erosion processes on steep hillslope and developing corresponding erosion equations can help to understand the mechanisms and characteristics of soil erosion on steep hillslope and to provide a scientific and technologic supports for controlling soil loss of hillslope on the Loess Plateau of China.

The observation experiment of splash erosion ring under simulated rainfall, simulated rainfall experiment with multi-plot-based observation, simulated rainfall experiment plus steady inflow with multi-plot-based observation, flume experiment and flume experiment with hopper feeding soil were used for experimental modeling of interrill and rill erosion processes on loess hillslope.

The results showed: (1) Collected splash erosion amount decreases with increase of splash distance, and 91-97% of splash erosion amount distribute in the splash distance of 0-0.3 m under the condition of 0 o; (2) Both sheet flow and rill flow are in the laminar flow and the supercritical flow on hillslope under experimental conditions. Stream power and shear stress are the best hydrodynamic parameters for describing sheet erosion and rill erosion processes respectively; (3) Stream power is the most closely hydrodynamic parameter to detachment capacity and sediment transport capacity of rill flow; (4) The process-based simulation equation of rill erosion is the quaternary power-logarithm combination equation of the response of rill erosion rate to detachment capacity of rill flow, sediment transport capacity of rill flow and influx of sediment onto rill.

Extent of gully erosion in Poland

Rafal Wawer, Eugeniusz Nowocien

[1]Department of Soil Science Erosion Control and Land Protection, The Institute fo Soil Science and Plant Cultivaton – State Research Institute. Pulawy, Poland
Rafal.wawer@iung.pulawy.pl

A country-wide mapping of the occurrence of gullies was performed in early 1990' by the Institute of Soil Science and Plant Cultivation, aimed at identifying areas with highest priority in erosion control measures.

The map of gully occurrence was derived manually from the topographical maps 1:25.000 for the whole country. Experts delineated gully borders adding areas directly affected by it. Digitisation of the map into a vector gadaset was later performed in ArcGIS. The administrative division of Poland, starting from the lowest communes, then county's and highest – voivodships, were given a degree (5 degrees) of gully erosion thread, that induced a degree of action urgency, indicating the urgency for erosion control measures.

The results indicate that overall 19,2% of arable land and 5,4% of forests undergo gully erosion, while as much as 7,8% and 2,0% of the areas are threatened with erosion intensity form average do very strong (degree from 3 to 5). The highest density of gullies are observed on loess Naleczow Plateau reaching 13km per square kilometre.

The map was used and is still being used by the administration for decision making on spatial management in land development plans. The, spectacular till 1990', events of gully erosion in Poland became much lesser problem due agriculture slow down in late 1990' and early 2000' and are now kept in control thanks to new agricultural practices and land afforestations and land protection measures paid by the state.

Laboratory and field simulated gully erosion using a physically-based numerical model

Yafei Jia[1], Robert R. Wells[2], Henrique G. Momm[3], Sean J. Bennett[4] and Ronald L. Bingner[2]

[1] National Center for Computational Hydroscience and Engineering, University of Mississippi, University, MS, USA.

[2] National Sedimentation Laboratory, USDA-Agricultural Research Service, Oxford, MS, USA.

[3] Dept. of Geosciences, Middle Tennessee State University, Murfreesboro, TN, USA.

[4] Dept. of Geography, University at Buffalo, Buffalo, NY, USA.

Gully erosion is detrimental to agricultural lands and threatens agricultural productivity. Following several decades of study, there are still more questions than answers. Erosion by sheet runoff and concentrated flow are very complex problems that are commonly related to soil properties, hydrology, human activity, landscape characteristics, climate and their interactions. Landscape evolution theory involves a coupled understanding of rainfall, runoff and erosion processes that requires a combined campaign of field observations, physical experiments and numerical simulations. Here, a physically-based numerical model, CCHE2D, is applied to simulate landscape evolution processes due to raindrop impact and overland flow. CCHE2D solves a set of full hydrodynamic equations for depth-integrated flows. The numerical model simulates a thin layer of runoff that flows over complex terrains and mixed regimes of sheet and concentrated flow. The sediment transport model includes rain splash erosion and soil surface erosion.

Two soil erosion simulations are presented in this study: an experimental landscape and an agricultural field. Experiments in the laboratory created overland flow and soil erosion using simulated rainfall, in which the evolving topographic surface was captured by close-range photogrammetry and sediment-laden runoff was recorded at multiple time periods at the flume outlet. In the agricultural field, terrain data were collected by aerial photogrammetry using an unmanned aerial system (UAS) following planting and approximately one month later. Climate during the period was collected using NexRad radar. Simulated geomorphological and sediment budget changes over time results were compared to experimental measurements and field observations. Integration of high-resolution spatial and temporal topographic measurements with physically-based numerical models supports the development of dynamic landscape evolution models needed for accurate prediction and quantification of gully initiation, evolution and impact on total soil loss.

Predictive modelling to understand areas at risk of gully erosion in basins draining to the Great Barrier Reef

Elisabeth Bui[1*], Scott Wilkinson[1], Linda Gregory[1], Rebecca Bartley[2]

[1] CSIRO Land and Water, GPO Box 1666, Canberra ACT 2601, Australia
[2] CSIRO Land and Water, GPO Box 2583, Brisbane, QLD 4001, Australia

Gully erosion, a major source of sediment in many river basins globally, impacts negatively on the water quality of the Great Barrier Reef lagoon. The very large Burdekin and Fitzroy River basins, covering 240,000 km^2 in semi-arid tropical climate, are thought to be the main sources of suspended sediments to the Great Barrier Reef lagoon. Understanding the environmental controls on gully erosion is useful to help define management responses and to predict local areas at risk future incision.

A decade of investment in the National Collaborative Research Infrastructure Strategy has produced detailed topographic, soil, and vegetation cover data for Australia and this is now a relatively data-rich environment. Gullied areas in the Burdekin and Fitzroy basins have been mapped from photogrammetric data at 1-km and, in some sub-catchments, at 100-m grid resolution. We used these new datasets in random forest modelling to identify the environmental factors associated with gully frequency in the Burdekin-Fitzroy basins. We investigate whether data resolution leads to different conclusions about the relative importance of predictors.

We find that over 1 km^2 grid cells, gamma-radiometric potassium dose, slope, soil classes, and silt content in 0-30 cm depth interval are the best predictors of gully frequency. Soils on sedimentary lithologies and felsic igneous rocks, with strong contrast in texture between the A- and B-horizons are those most prone to gullying, especially when their protective vegetation cover is low. Areas where gully frequency is lower than predicted tend to have higher vegetation ground cover. These factors have practical implications for land management since livestock grazing is the most extensive land use in the region. Over 100-m grid cells, topographic variables are the best predictors of gully presence. Gullying is more likely to be present at elevations of 200-400m and where slope% is ~2-3%; other forms of erosion tend to occur at ~200 m. Gullying is more likely to be present where the topographic wetness index is between 11 and 13.

A gully erosion control program to improve Great Barrier Reef water quality: Prioritisation and findings

Scott Wilkinson[1], Peter Hairsine[2], Aaron Hawdon[3], Jenet Austin[1]

[1]CSIRO, Canberra, Australia
[2]The Australian National University, Canberra, Australia
[3]CSIRO, Townsville, Australia

Gully erosion is the largest source of fine sediment and associated nutrients in the river basins draining to the Great Barrier Reef (GBR) lagoon, yet it occupies less than 1% of the land area. The first gully erosion control program aimed at water quality improvements was funded by the Australian Government's Reef Trust, running from 2015 until 2018. The program aimed to control and prevent gully erosion and targeted 8 priority catchments predicted to make the highest contributions from gully erosion to GBR fine sediment yields. It incorporated technical advice and aimed to demonstrate cost-effective erosion control. A technical guide was developed, including a calculator for project managers to assess the cost-effectiveness of planned works at each site. A protocol to monitor the success of implementation at each site was also defined including works intactness, and vegetation outcomes relative to control sites.

Gully erosion control was undertaken on 210 gullies and 88 properties in the priority catchments (Wilkinson et al., 2019). These activities are expected to reduce fine sediment export to the GBR lagoon by 5,400 t/yr, and bioavailable nitrogen and phosphorus loads by a conservatively estimated 1,600 kg/yr and 720 kg/yr, respectively. However, these load reductions are small relative to the targets which have been set. The works involved $2.8M of direct on-ground costs, with the load reductions averaging $510 per t/y reduction in fine sediment. Including all aspects of delivery such as site identification, communication and monitoring, the cost was approximately $1,500 per t/y.

The program demonstrated that cost-effective water quality improvement through gully erosion control is tractable and can be implemented at a larger scale. The sediment savings from the program were 10 times those which would have been achieved without spatial targeting of active gullies, at river basin and site scales. However, a large proportion of the total sediment savings were derived from a small proportion of sites, indicating the potential to improve cost-effectiveness beyond that achieved in this pilot program. Significant development occurred in the local capacity to deliver gully erosion control.

Refinements suggested for future investments are: (i) for natural resource management projects that require time for planning of construction and vegetation growth, the minimum project duration is five years, (ii) it is recommended that future gully erosion control programs concentrate their efforts at a smaller number of sites where large and cost-effective sediment savings can be quantified, (iii) further development and trialing of gully revegetation techniques is required for highly degraded sites where natural regeneration approaches are insufficient, (iv) site contracts should include a provision for site maintenance, (v) increased proportion of funding for monitoring should be considered for similar programs in the future.

Wilkinson SN, Hairsine PB, Hawdon AA, Austin J. 2019. Technical findings and outcomes from the Reef Trust Gully Erosion Control Programme. Press) CSIRO (In press). pp: 50.

Experiment on influence of vegetation coverage and rainfall intensity on the artificial slope soil loss

Xiaodong Ji[1], **Xiao Li**[1]

[1]School of Soil and Water Conservation, Beijing Forestry University, Beijing, China

ABSTRACT

Shrubs and herbaceous vegetation play an irreplaceable role in ecological construction. With their unique morphological structure intercepting rainfall and reducing the erosion of raindrops on the surface, its role in controlling soil erosion has attracted more and more attention. Vegetation coverage and rainfall intensity are the key factors affecting soil erosion. In this study, the Qingshui River Basin in the upper reaches of the Yongding River was used as the research area, and the Vitex negundo L. and Carex spp. were used as research object respectively. Based on the indoor simulated rainfall experiments, 4 vegetation coverage degrees of 0, 25%, 50%, 75% and 5 rainfall intensity changes of 30, 45, 60, 75, 90 mm/h were set. The runoff and sediment yield of the slope were measured during the rainfall process, and the effects of vegetation coverage and rainfall intensity on runoff and sediment yield were systemically analysed.

The results showed that: (1) Under the same vegetation coverage, the surface runoff, subsurface flow and soil moisture change of each treatment group showed an increase with time, then stabilized, and the rate of sediment production increased first and then decreased. Under different vegetation coverage, the runoff and sediment yield of each treatment group decreased with the increase of coverage.

At the same time, the effect of runoff accumulated and sand reduction by pure grass and shrub-grass were significantly better than that of pure irrigation. In the experimental group with good runoff accumulated effect, the amount of subsurface flow and the increase of soil moisture were large. (2) Under the same rainfall intensity, the surface runoff, subsurface flow and soil moisture change of each treatment group increased with time, then stabilized. The sediment yield increased first and then decreased. Under different rainfall intensities, the runoff and sediment yield of each treatment group increased with the increase of rainfall intensity.

Based on the above results, the vegetation has a good effect of soil and water conservation. The research results will help to quantitatively evaluate the effects of vegetation on runoff accumulated and erosion reduction, and lay a foundation for the future study of the relationship between vegetation measurements and soil erosion and the selection of reasonable slope vegetation allocation.

Impact of soil type and physicochemical properties on gully development within land consolidation terrace slopes in the Dry-hot valley region, China

Dan Yang[1,2], **Donghong Xiong**[2]

[1] School of Land and Resource, China West Normal University, Nanchong, PR China

[2] Key Laboratory of Mountain Hazards and Earth Surface Processes, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, China

Gully erosion on land consolidation terrace slopes (LCTSs) is well developed in Jinsha Dry-hot valley region, and has caused serious soil losses. According to field investigations, the soil erosion modulus caused by gully erosion on LCTSs can be up to 8000 t/km2/a due to insufficient soil compaction, steep and long slopes, and lack of protective measures, which can lead to continuous increases of sediment in Jinsha River and its tributaries. Moreover, the development of gully on LCTSs can severely destroy terrace land systems and hamper ecological and economic benefits within the study area. Field investigations and previous studies reveal that soil type and physicochemical properties were important factors influencing gully development on LCTSs.

The influence mechanism of soil type and physical-chemical properties on gully erosion on LCTSs was addressed with a series of field investigations and artificial rainfall tests conducted in Jinsha Dry-hot valley region in March to May 2016. In this study, the focus was on the influence of three major soil types (including dry-red soil, entisol and vertisols) on the gully development processes on LCTSs and the main physicochemical properties that would change the evolution pattern of gully erosion in the study region.

Results show that: 1) There was a similar time-changing trend for shear stress and resistance coefficient which increased first and then tended to be relatively stable for the remainder of testing. However, the shear stress and resistance coefficient were significantly greater for dry-red soil than those for vertisols on LCTSs. 2) The dynamic ratio of eroding force to resistance might be the decisive dynamic condition for gully development on LCTSs, and the critical dynamic ratio for rill development on LCTSs was between 0.065 and 0.103; 3) Width and density of gullies were mainly controlled by non-capillary porosity and soil dispersion rate had a strong effect on lacerate-degree of gullies than other soil properties, while soil physicochemical properties only had a very slight effect on depth and cross-sectional area for gullies on LCTSs. Moreover, it can be found that the impact manner and degree of soil properties on different morphological characteristics of gullies on LCTSs were very different, and different soil properties also had differential contribution in the development processes of gullies on LCTSs.

Effects of DEM resolution on soil erosion modelling

Xihua Yang[1], Linxin Shan[2], Qinggaozi Zhu[3]

[1]NSW Office of Environment and Heritage, Parramatta, Australia
[2]College of Urban and Environmental Science, Northwest University, Xi'an, China
[3]School of Life Sciences, University of Technology, Sydney, Australia

The slope length and steepness or LS is a crucial factor in soil erosion modelling. Accurate estimation of LS relies on the accuracy of the input Digital Elevation Models (DEM) and the spatial resolutions. The increasing capacity of Geographic Information Science (GIS) and emerging high-resolution DEM data sources such as Light Detection and Ranging (LiDAR) DEM products make it possible to model LS in great detail, but in the meantime also raise the scale and resolution issues in spatial modelling and analysis. Yet, few studies discussed the effects of DEM resolutions on LS estimation and soil erosion modelling.

This case study aimed to assess and compare LS values computed using various DEM sources including LiDAR and the Shuttle Radar Topography Mission (SRTM) at resolutions ranging from 1 m to 90 m on a recently burnt landscape, Warrumbungle National Park (WNP) in NSW, Australia. The LS was calculated using an overall flow path-based slope-length accumulation algorithm based on the revised universal soil loss equation (RUSLE). As a result, six LS raster layers for WNP have been calculated from DEMs at resolutions of 1 m, 5 m, 10 m, 25 m, 30 m and 90 m. Comparisons show that the average value of the LS factor increases as the DEM resolution becomes coarser.

The LS values calculated from the 5 m and 10 m DEMs are closer to the measured LS (LS_reference) values, which are more suitable for the study area compared to the coarser DEMs (greater than 25 m). 12 soil plots were established across WNP and field measurements on slopes, slope-length and sediment were used for comparison and assessment of the LS values (Figure 1) and the impacts on hillslope erosion.

Large portion (>50%) of LS values are less than 5 among the LS values calculated by DEMs at all different resolutions, but the percentage decreases as the DEM resolution decreases. The LS value calculated from the 10 m DEM is the closest to the measured values, therefore we recommend using the 10 m DEM for calculating LS and soil erosion for WNP or studies at similar scale and landscape. Findings from this study are of assistance to soil erosion and geospatial modelling communities for choosing and using DEM of appropriate resolution for their spatial modelling and analyses.

Using rare earth elements to monitor ephemeral gully erosion processes

Qiong Zhang and Gang Liu

State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Northwest A&F University, Yangling, China

Ephemeral gully erosion is widespread on the Loess Plateau of China. However, information concerning ephemeral gully erosion processes is still not fully understood and needs further research. The purpose of this study was to quantitatively monitor ephemeral gully erosion processes using REE oxides as tracers under simulated rainstorms. Ten different rare earth element oxide powders (Eu_2O_3, Yb_2O_3, Tb_4O_7, Sm_2O_3, Ho_2O_3, CeO_2, La_2O_3, Nd_2O_3, Dy_2O_3 and Tm_2O_3) were mixed with cultivated loess soil and applied as tracers to form the ephemeral gully in this study. The spatial distribution of REE oxides was showed in Figure 1. Simulated rainfall was applied to a soil plot (5 m long, 1 m wide and 0.5 m deep) under three conditions (intensity of 60 mm h-1 with 20°, 90 mm h-1 with 20°and 90 mm h-1 with 15°). The results indicate that REE tracer method can be applied to monitor ephemeral gully erosion processes quantitatively.

Compared with the measured erosion amount, the error of the tracing erosion amount was less than 15%. Erosion rate increased sharply and tended to stabilize with fluctuation till the termination of rainfall under all conditions. However, erosion rate of each tracer area showed different changing trends. Erosion rate of incision was larger than widening during the ephemeral gully erosion process. Meanwhile, erosion rate of both incision and widening were increased in changing speed. According to the changing contribution rate of incision and widening, the processes of ephemeral gully erosion can be divided into three stages. The contribution rate of incision larger than 80% at the first stage, then it decreased to about 60% at the next stage, finally it increased to 70-80% at the last stage. The contribution rate of widening was opposite to that of incision.

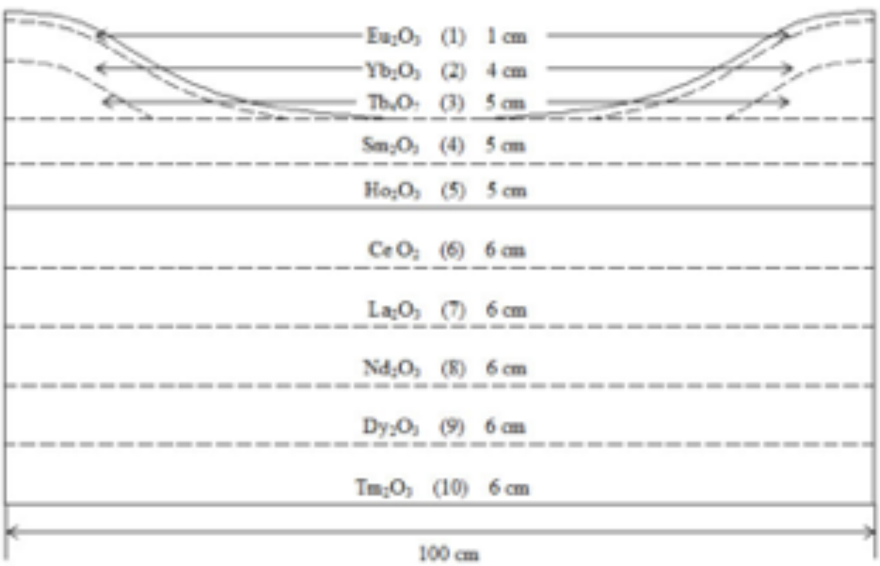


Figure 1 Schematic representation of REE oxides distribution (Eu2O3 is REE oxide powder, (1) is area number, 1 cm is area depth.)

Identifying sediment transport capacity of raindrop-impacted overland flow within transport-limited system of interrill erosion processes on loess hillslopes of China

Qingwei Zhang[1], Zhanli Wang[1]

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling, Shaanxi 712100, China

Interrill erosion processes typically involve such scientific issues as detachment-limited and transport-limited erosion behaviour. An accurate estimation of the sediment transport capacity (Tc) by raindrop-impacted overland flow is critical for interrill erosion modelling and for evaluating sediment budgets under erosion-limiting conditions.

Simulated rainfall experiments with rainfall intensities from 0.8 to 2.5 mm min-1 over a three-area soil pan with slope gradients from 12.7% to 46.6% were conducted to identify the transport-limited cases and determine Tc by raindrop-impacted overland flow within the transport-limited systems of interrill erosion processes. Results indicated that Tc increased as a power function of rainfall intensity and slope gradient (R2=0.84, NSE=0.75), and Tc was more sensitive to rainfall intensity than to slope gradient.

In terms of R2 and NSE, stream power was the key hydraulic parameter that influenced Tc among flow velocity (R2=0.64, NSE=0.39), shear stress (R2=0.53, NSE=0.23), stream power (R2=0.76, NSE=0.52) and unit stream power (R2=0.49, NSE=0.16). The addition of rainfall physical parameters in response equations of Tc in addition to hydraulic parameter, could improve an accuracy of Tc modelling. Stream power combined with rainfall kinetic energy can best describe the Tc of raindrop-impacted overland flow within the transport-limited system of interrill erosion processes by a power-exponent function (R2=0.90, NSE=0.72). Rainfall kinetic energy can reduce the Darcy-Weisbach resistance coefficient of raindrop-impacted overland flow and thus benefit sediment transporting.

This study provides another method for directly identifying the Tc of raindrop-impacted overland flows in interrill erosion processes on steep loess slopes, and points out that rainfall impacts should be particularly considered when studying Tc by raindrop-impacted overland flow.

Assessment of gully erosion susceptibility in Zoige wetland of China

Xuexia Zhang[1,2], **Jianbin Guo**[1,2], **QunoJiang**[1,2], **Yi Cui**[1], **and Changqing Guo**[1]

[1] School of Soil and Water Conservation, BeijingForestryUniversity, Beijing, P. R. China

[2] Key Laboratory of State Forestry Administration on Soil and Water Conservation, BeijingForestryUniversity, Beijing, P. R. China

This paper presents three GIS-aided procedures for the evaluation of gullying susceptibility on a statistical basis. Field surveys and image interpretation allowed gully identification, in order to investigate the role of instability factors in controlling the spatial distribution of gullies. Zoige wetland is an important water conservation area of Eastern margin of Qinghai-Tibet Plateau. In recent years, the wetland has been degraded and desertified, which has seriously affected the ecological balance of the upper reaches of the Yangtze and Yellow Rivers. Relevant studies have shown that gully erosion is a key factor in the degradation and desertification of Zoige wetland. The ditches of Zoige wetland are mainly located in the areas where swamps and swampy meadows are concentrated. There are 219 ditches with a total length of 459.47 km.

In this paper, random forest decision tree, maximum entropy evaluation and bivariate multivariate algorithm are used to evaluate gully erosion in the Zoige wetland. Combining with topography, soil vegetation and human activities, the gully erosion susceptibility of the study area is evaluated.

The validation of the gully data interpreted by Google Earth shows that the evaluation results of the three algorithms are very good. Among them, maximum entropy evaluation is the best one. The best results were obtained with bivariate multivariate algorithm, followed by random forest decision tree. The evaluation results can provide a basis for wetland ecological restoration.

Discrimination of soil losses from ridge and furrow in longitudinal ridge-tillage under upslope inflow and rainfall simulation

Lei Wang[1], Fenli Zheng[1,2*], Xun-chang (John) Zhang[3], Glenn V. Wilson[4], Chao Qin[1,5], Chao He[1], Gang Liu[1,2], Jiaqiong Zhang[1,2]

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling, PR China

[2] Institute of Soil and Water Conservation, CAS & MWR, Yangling, PR China

[3] USDA-ARS Grazinglands Research Laboratory, El Reno, USA

[4] USDA-ARS National Sedimentation Laboratory, Oxford, USA

[5] State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, PR China

Longitudinal ridge-tillage greatly enhances hillslope soil erosion due to increased flow concentration in furrows and sediment delivery from ridge sideslopes. Currently, contributions of upslope inflow and rainfall to soil loss and identification of sediment sources in a ridge-furrow system are still unclear. A set of experiments on 10-m long, 2-m wide field runoff plots at a 5° slope gradient were conducted in the Chinese Mollisol region to quantify upslope inflow and rainfall effects on hillslope erosion and to discriminate sediment contributions from ridges and furrows in a longitudinal ridge-tillage system. The experimental treatments included five upslope inflow rates alone (10, 20, 30, 40 and 50 L min-1), two rainfall intensities alone (50 and 100 mm h-1) and the five inflow rates combined with these two rainfall intensities. A stereoscopic photogrammetry method was used to measure micro-topographic changes before and after each run.

The results showed that, compared with inflow-only treatments, soil losses increased by 1.4-5.2 times and 2.5-14.0 times under treatments of five upslope inflow rates combined with both 50 and 100 mm h-1 rainfall intensities, respectively. Rainfall caused more soil loss in the longitudinal ridge-tillage system than upslope inflow alone. When inflow rate was almost the same as the rainfall intensity, the contributions of the positive interactions of inflow and rainfall to soil loss was 43.9% and 45.3%, respectively. The contributions of the synergistic effects increased with the increase of rainfall intensities. Moreover, in the five upslope inflow-only treatments, soil erosion mainly occurred in the bottom of furrows and ridge toe slopes; while for the inflow combined with rainfall treatments, ridge sideslope erosion dominated as soil loss from ridge areas accounted for 58.5%-67.5% and 53.0%-61.8% for the 50 and 100 mm h-1 rainfall intensities, respectively. Therefore, ridge sideslope erosion may be the main sediment source in the longitudinal ridge-tillage system. Soil conservation measures need to be developed for protecting ridge sideslopes.

The optimum soil dispersibility measure

Peter Zund

Science and Technology Division, Queensland Government Department of Environment and Science, Brisbane, Australia

Understanding how dispersible your soils are is essential to understanding the erosion processes of your gullies. The levels of dispersibility also directly relate to how the gullies may best be rehabilitated. There is a range of ways for both inferring and measuring soil dispersibility, however which should you choose? This paper presents an assessment of the various methods and recommendations for preferable use.

At two alluvial gully research sites (Strathalbyn Station, Lower Burdekin Basin and Crocodile Station, Cape York) in Queensland, Australia we have extensively measured soil dispersibility and analysed related soil attributes. Soil samples were collected from gully walls and soil cores and soil dispersibility measured using: i) a quick field observation method, ii) the Emersion test, iii) the Loveday and Pyke dispersion index and iv) a laboratory based dispersion ratio method. Soil particle size, pH, salinity and sodicity were also analysed on samples. The four dispersion and two soil slaking methods were compared. The preferred dispersion method identified was then correlated with individual soil attributes.

It was found that the 2-hour field method is correlated with the 2-4 day Emerson test and thus the field method provides an efficient alternative to the full Emerson test. However, by only doing the field method, fewer conclusions can be made about soil behaviour. The method giving the most consistent results was the laboratory-based dispersion ratio. Soil samples for this method are consistently prepared (dried at 40o and sieved to 2mm) allowing more consistent comparisons to be made. This method must be performed along with gravimetric and hydrometer-based particle size analyse, which are also essential to assess your soils' properties. While the laboratory dispersion method is more costly, it provides greater consistent results and greater efficiency. Otherwise, carefully performed field tests can be conducted if cost is an issue.

Often soil dispersibility is also inferred from soil properties such as sodicity, salinity, magnesium, potassium and pH. These soil properties were also correlated with the laboratory dispersion ratio and only sodicity (exchangeable sodium percentage) had a reasonable relationship. Hence if your project does not have data on a direct dispersion method then you could infer soil dispersibility from ESP.

8. Attendees

Name	Organisation	Country
Ayehu, NigussieHaregeweyn	International Platform for Dryland Research and Education, Tottori University	Japan
Barker, Margret	Department of Natural Resources, Mines and Energy	Australia
Bartley, Rebecca	CSIRO	Australia
Behzadnia, Sunny	Greening Australia	Australia
Bernatek-Jakiel, Anita	Jagiellonian University	Poland
Bingner, Ronald	USDA-ARS National Sedimentation Laboratory	USA
Brooks, Andrew	Griffith University	Australia
Bryan, Rachel	Fitzroy Basin Association	Australia
Burrows, Damien	James Cook University	Australia
Campo-Bescos, Miguel	Public University of Navarre	Spain
Carmody, Julie	Reef and Rainforest Research Centre	Australia
Casalí, Javier	Public University of Navarre	Spain
Castillo, Carlos	University of Cordoba	Spain
Castine, Sarah	Great Barrier Reef Foundation	Australia
Conway, Susan	CNRS laboratories, University of Nantes	France
Corral-Pazos-de Provens, Eva	University of Huelva	Spain
Cupples, Neil	North Queensland Dry Tropics	Australia
Curtin, James	Ergon Energy	Australia
Curwen, Graeme	Griffith University	Australia
Dale, Glenn	Tree Crop Technologies Pty Ltd, Verterra	Australia
Daley, James	Griffith University	Australia
Darr, Shawn	Department of Natural Resources, Mines and Energy	Australia
Davenport, Craig	Fitzroy Basin Association	Australia
Day, John	The Burnett Murray Regional Group	Australia
Dong, Yifan	Institute of International Rivers and Eco-Security, Yunan University	China
Doriean, Nicholas	Griffith University	Australia
Faggotter (Burton), Joanne	Department Environment and Science	Australia
Franklin, John	Soil and Water	Australia
Fry, Scott	North Queensland Dry Tropics NRM	Australia
Gallant, John	CSIRO	Australia
Garzon-Garcia, Alexandra	Department Environment and Science	Australia
Gerhardt, Karin	Great Barrier Reef Foundation	Australia
Ghahramani, Afshin	University of Southern Queensland	Australia
Guo, Jianbin	Beijing Forestry University	China
Hancock, Greg	The University of Newcastle	Australia
Hawdon, Aaron	CSIRO	Australia
Hayward, Jodie	CSIRO	Australia
Hunt, Rob	North Queensland Dry Tropics	Australia
Imwangana, Fils Makanzu	University of Kinshasa	DR Congo
Jarihani, Ben	University of the Sunshine Coast	Australia
Jeston, Phillip	Catchment Solutions Pty Ltd	Australia
Ji, Xiaodong	School of Soil and Water Conservation, Beijing Forestry University	China
Jiang, Qunou	Beijing Forestry University	China
Karlson, Benjamin	Department of the Environment and Energy	Australia
Kerr, Rod	North Queensland Dry Tropics	Australia
Kinsey-Henderson, Anne	CSIRO	Australia

Koci, Jack	University of the Sunshine Coast	Australia
Kroon, Frederieke	Australian Institute of Marine Science	Australia
Kyle, Tasia	CSIRO	Australia
Legass, Ayalew	Jimma University	Ethiopia
Li, Hao	The Northeast Institute of Geography and Agroecology, CAS	China
Gang, Liu	Northwest A&F University	China
June, Liu	Shaanxi Normal University	China
Liu, Xiaobing	The Northeast Institute of Geography and Agroecology, CAS	China
Locke, Martin	United States of Department Agriculture	USA
Lowry, John	Department of the Environment and Energy	Australia
Lucas, Rohan	Alluvium Consulting	Australia
Momm, Henrique	Geosciences, Middle Tennessee State University	USA
Mor-Mussery, Amir	Faculty of Agriculture	Israel
Morris, Sheriden	Reef and Rainforest Research Centre	Australia
Morrison, David	Department of Natural Resources, Mines and Energy	Australia
Mould, Richard	Australian Concrete Mats	Australia
Neilly, Adam	Neilly Group Engineering	Australia
Nichols, Mary	USDA-ARS Southwest Watershed Research Center	USA
Olivier, George	Stellenbosch University / Coventry University	South Africa
Osumgborogwu, Ikenna	Durham University	West Africa
Pani, Padmini	Jawaharlal Nehru University	India
Parkner, Thomas	University of Tsukuba	Japan
Pietsch, Timothy	Griffith University	Australia
Poole, Chris	North Queensland Dry Tropics	Australia
Rehbein, Tracey	CSIRO	Australia
Roberts, Melanie	Australian Rivers Institute, Griffith University	Australia
Romero, Estela Nadal	Instituto Pirenaico de Ecología	Spain
Roots, Kevin	Department of Natural Resources Mines and Energy	Australia
Rossi, Mauro	CNR, Research Institute for Hydrogeological Protection	Italy
Roth, Christian	CSIRO	Australia
Rutherfurd, Ian	School of Geography, University of Melbourne	Australia
Samadharmam, Kala	Indian Council of Agricultural Research	Inida
Saynor, Mike	Supervising Scientist, ERISS	Australia
Shi, Haoyu	Beijing Forestry University	China
Shi, Mingchang	Beijing Forestry University	China
Silburn, Mark	Department of Natural Resources Mine and Energy	Australia
Sinclair, Jennifer	Greencollar	Australia
Skeat, Sam	North Queensland Dry Tropics	Australia
Spencer, John	Griffith University	Australia
Stout, Justin	Griffith University	Australia
Su, Zhengan	Institute of Mountain Hazards & Environment, CAS	China
Su, Xuemeng	Shaanxi Normal University	China
Sugars, Mark	Department Natural Resources, Mines and Energy	Australia
Taguas, Encarnacion	University of Cordoba	Spain
Tang, Jie	Faculty of Geographic Sciences, BNU	China
Telfer, Damon	Fruition Environmental Pty Ltd	Australia
Thomson, Belinda	NRM Regions QLD	Australia
Thwaites, Robin	Griffith University	Australia

Tomlinson, Rodger	Griffith University	Australia
Twycross, Brett	Neilly Group Engineering	Australia
Vallejo Orti, Miguel	Namibia University of Science and Technology	South Africa
Vanmaercke, Matthias	University of Liège	Belgium
Walker, Elis	North Queensland Dry Tropics	Australia
Walker, Simon	Australian National University	Australia
Wang, Lei	Northwest A&F University	China
Wang, Zhanli	Northwest A&F University	China
Warnick, Amy	CSIRO	Australia
Watson, Rebecca	Mary River Catchment Coordinating Committee	Australia
Wearne, Lynise	Greening Australia	Australia
Weber, Tony	Alluvium Consulting	Australia
Wedlock, Belinda	Mary River Catchment Coordinating Committee	Australia
Wedlock, Brad	Mary River Catchment Coordinating Committee	Australia
Weldesemaet, Yitbarek	Environmental Society of Ethiopia	Ethiopia
Wells, Robert	National Sedimentation Laboratory, USDA-Agricultural Research Service	USA
Welsh, Michael	Department of the Environment and Energy	Australia
Wilkinson, Peter	Verterra Ecological Engineering	Australia
Wilkinson, Scott	CSIRO	Australia
Wilson, Glenn	USDA-ARS, National Sedimentation Laboratory, Oxford	USA
Xiong, Donghong	Institute of Mountain Hazards & Environment, CAS	China
Yang, Dan	College of Land and Resources, China West Normal University	China
Yang, Xihua	NSW Office of Environment and Heritage	Australia
Yuan, Mutian	College of Soil and Water Conservation, Beijing Forestry University	China
Zhang, Qiong	Northwest A&F University	China
Zhang, Guang-hui	Beijing Normal University	China
Zhang, Hanlu	University of Queensland	Australia
Zhang, Qingwei	Northwest A&F University	China
Zhang, Xingyi	The Northeast Institute of Geography and Agroecology, CAS	China
Zhang, Xuexia	Beijing Forestry University	China
Zhang, Yan	Beijing Forestry University	China
Zhao, Yiyang	College of soil and water conservation, Beijing Forestry University	China
Zheng, Fenli	Northwest A&F University	China
Zund, Peter	Queensland Government, Department of Environment and Science	Australia

www.csiro.au/8ISGE