Slope and contour bank prevalence on broad acre cropping land in the Fitzroy Basin, Queensland, Australia.

For Paddock to Reef Management Practice Adoption Program Prioritisation

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This publication has been compiled by Paul Humphreys - Paddock to Reef Evaluation, Rural Economic Development, Department of Agriculture and Fisheries.

The Department of Agriculture and Fisheries proudly acknowledges all First Nations peoples (Aboriginal peoples and Torres Strait Islanders) and the Traditional Owners and Custodians of the country on which we live and work. We acknowledge their continuing connection to land, waters and culture and commit to ongoing reconciliation. We pay our respect to their Elders past, present and emerging.

Summary

The water quality of the Great Barrier Reef is adversely impacted by terrestrial pollutant runoff. Agricultural land uses are a significant contributor to the pollutant loads entering the Great Barrier Reef, particularly with respect to fine sediment. Broad-acre cropping has the potential to contribute large proportions of fine sediment per unit area due to the nature of cropping systems and cropping soils often containing high proportions of fine silt and clay particles. The Department of Agriculture and Fisheries, Management Practice Adoption Team are an integral part of the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program. The Team is responsible for describing “best practice” for improving water quality; and monitoring and measuring the adoption of practices across catchments draining into the Great Barrier Reef. The Team also provides data and feedback to program funders such as the Australian and Queensland Governments on project effectiveness. This feedback is crucial in ensuring that future investment in programs to improve agricultural land practices and water quality considers priority areas, cost-effectiveness, and overall Great Barrier Reef water quality benefits.

Broad-acre grain cropping is one of the agricultural commodities monitored and invested in by the Paddock to Reef Program. When cropping occurs on sloping land, the risk of erosion and soil loss increases. The construction of contour banks is one soil conservation measure that aids in reducing the risk of erosion and soil loss. The general recommendation in Queensland is that contour banks should be present on cropping land with a slope of 1% or greater. However, there is limited definitive data available on the slope of cropping land or the occurrence of contour banks on cropping land in the Fitzroy Basin in Central Queensland. An analysis was undertaken to estimate how much cropping land in the six major cropping areas of the Fitzroy basin occurs on land with a slope equal to or greater than 1%; and the proportion of the area where contour banks currently exist.

The analysis found that the Nogoa basin sub-area had the lowest proportion of cropping land on ≥1% slope without contour banks present, while the Fitzroy basin sub-area had the highest proportion. The Nogoa also has the largest total area of cropping, while the Fitzroy has the smallest total cropping area. Additional analysis found that ~90% of the cropping land on ≥1% slope without contour banks has a riverine fine sediment delivery ratio of 30% or less. This is a conceptual ratio between the volume of fine sediment entering an inland waterway verses the volume that arrives at the Great Barrier Reef lagoon. A summary of these results is shown in Table 1.

Table 1 Summary of results

Basin sub area	Cropping area (ha)	≥1% slope (ha)*	≥1% slope without contour banks (ha)*	Area >30% RSDR (ha)*
Comet	144797	63,000 - 70,000	39,000 - 41,000	0
Dawson	154721	78,000 - 83,000	48,000 - 50,000	9,000 - 10,000
Fitzroy	10106	5,000 - 6,000	4,000 - 5,000	4,000 - 5,000
Isaac	34319	15,000 - 17,000	7,000 - 8,000	1,000
Mackenzie	11939	4,000	2,000 - 3,000	2,000
Nogoa	172102	111,000 - 131,000	51,000 - 60,000	0
Sub Total	527984	277,000 - 309,000	153,000 - 165,000	16,000 - 17,000

*Rounded to the nearest 1,000 ha

These results can inform investment on the basis of area of most need, while the slope and fine sediment delivery ratio can be queried to inform or tailor investment priority setting and targeting within catchments.

Additionally, as the unit area losses from cropping land are significantly greater than other agricultural land uses in the Fitzroy basin, it is feasible that investment in soil conservation on cropping land can be equally or more cost-effective as investment in other commodities irrespective of riverine sediment delivery ratios. It also has the potential to provide additional positive benefits to industry sustainability, food security, and riverine health. Targeting cropping land that require contour banks (~54% of all the cropping land ≥1%) should be a priority for Great Barrier Reef water quality improvement. However, investment must also support and promote soil conservation knowledge and practices to ensure soil conservation measures, practices and existing contour banks and waterway structures (present on ~46% of all cropping land ≥1%) are correctly designed, fit for purpose, maintained, and functioning optimally.

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Introduction

The Australian and Queensland governments are committed to investing in improvement to the water quality and long-term sustainability of the Great Barrier Reef (GBR). Agricultural land uses in GBR catchments are identified as one on the factors contributing to the decline in water quality of the GBR. To reduce the impact of agricultural land use, the Reef 2050 Water Quality Improvement Plan 2017 – 2022 (WQIP) (Australian Government and Queensland Government, 2018) set a target of 90% of land in priority GBR catchments are managed using “best practices” for the management of soil, nutrient, and pesticides by 2025. This target applies to grazing, horticulture, bananas, sugarcane, and broad acre grains cropping land use. The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (P2R Program) provides a water quality risk framework (WQRF) that describes “best practices” (for each of the priority commodities) and evaluates and reports the progress towards the 90% adoption target. As of 2022, the 90% adoption target is under review and likely to change for program investment in the future.

The Fitzroy Basin is the largest priority region in the GBR at 155,515 km^2 with grazing (74% of the land area) and broad acre cropping (3% of the land area) dominating the land uses (Department of Environment and Science, 2019). Approximately 1.82 million tonnes of total suspended sediment are exported to the GBR from the Fitzroy basin annually, of which 1.61 million tonnes are from anthropogenic sources (Bartley et al., 2017). Despite the relatively small footprint, cropping is estimated to contribute 13% of the total end of system load (Bartley, et al, 2017). Additionally, the sediment generation per hectare from cropping in the Fitzroy is relatively high (Carroll *et al.*, 2010; Murphy *et al.*, 2013) at almost seven time greater per hectare than that generated from grazing land (Table 2). Cropping soils (particularly black vertosols in the Fitzroy) often also have a high proportion of fine silt and clay (Murphy *et al.*, 2013) , and it is these fine (<20μm) particles that are transported the furthest and known to cause negative impacts to the marine ecosystem (Bartley *et al.*, 2014)

Table 2. Cropping vs grazing total suspended sediment (TSS) contribution for the Fitzroy Basin.

TSS for the Fitzroy (million tonnes/year)	1.82	
Agricultural land use	**Cropping**	**Grazing**
Land use area (ha)	~536,000	~11,575,000
Contribution to total suspended sediment	13%	38%
TSS (million tonnes/year)	0.23	0.69
TSS (tonnes/hectare)	0.4	0.06
TSS (kilograms/hectare)	442	66

Calculated from (Bartley et al.*, 2017), and* (Queensland Department of Environment and Science, 2019b)

Multiple studies reinforce the greater rates of soil loss per hectare from cropping over grazing land. In the paired, calibrated Brigalow Catchment Study, cumulative annual soil loss over time from cropping was over 4 times greater than that measured from grazing, and over 6 times greater than uncleared land (Elledge and Thornton, 2017). Annual soil losses measured in grazing across Queensland varying from as low as 0.4 t ha^{-1} (Thornton and Elledge, 2021) to ~8 t ha^{-1} (Bartley *et al.*, 2010) and as high as ~5 t ha^{-1} to ~15 t ha^{-1} (Silburn *et al.*, 2011). In contrast, annual soil loss from cropping in Queensland has been measured at <2 t ha^{-1} (Carroll *et al.*, 1997) to over 120 t ha^{-1} (Freebairn and Wockner, 1986). Rainfall intensity, existing soil moisture, and slope all influence rates of erosion, however management can be undertaken to mitigate these risk factors. Slope can be managed with contour banks, while conservation farming practices (such as zero tillage and stubble retention) can increase cover, infiltration, and surface roughness protecting the soil surface and reducing erosion risk. Used collectively, even on slopes of between 4% - 7%, with contour banks reducing slope lengths to 35m – 61m; zero tillage and retaining attached stubble consistently provides the lowest rates of soil loss (Freebairn and Wockner, 1986). Fundamentally these practices reduce the peak runoff rate which is a critical factor when designing contour banks (Freebairn, 2004).

Because peak runoff rate can be influenced by tillage and stubble factors, contour banks designed with the assumption that contour bays and channels have minimal to no stubble may not perform as designed with a change to a high stubble cropping systems. Similarly, incorrect channel depth (due to infrequent maintenance), and a sporadic significant rain event, can cause a cascading failure of multiple contour banks down a slope leading to significant erosion and damage (Freebairn, 2004; Thomas *et al.*, 2007) seen in Figure 1 and Figure 2. This highlights the importance of considering whole of property management and cropping sequences when designing and implementing erosion control and soil conservation measures.

Figure 1. Cascading contour bank failure (Freebairn, 2004)

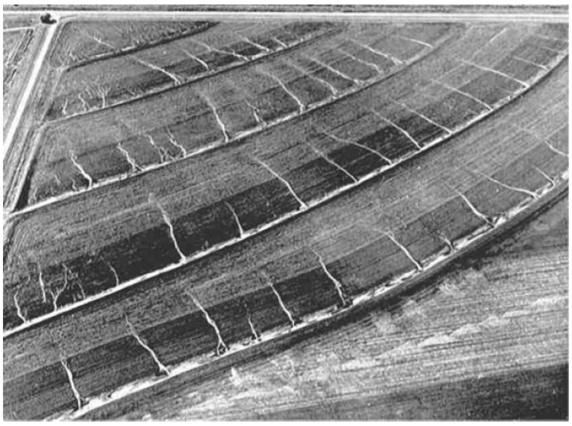

Figure 2. Cascading contour bank failure on a 6% slope, with 60m contour bank spacing (Thomas *et al.*, 2007)

To summarise soil erosion risk for cropping, risk increases as cover decreases, and soil disturbance, soil compaction, and slope increases. While risk decreases with improved infiltration, reduced compaction and increased ground cover. Most of these risk factors can be managed or reduced through the selection of equipment or practices such as reduced / zero tillage farming, controlled traffic farming (CTF) and crop stubble/fallow management that ensures greater volumes of standing stubble and crop residue more often. Slope however is more complex; because as both slope gradient and slope length increases, the erosive energy of rainfall runoff also increases (therefore also the erosion risk). While slope length is not as important as slope gradient, there is little a land manager can do to realistically reduced slope gradient (Freebairn, 2004). The construction of contour banks, however reduces the length of slope therefore contributing to an overall reduction in the erosive energy potential of rainfall runoff (the LS factor in the Universal Soil Loss Equation (Wischmeier and Smith, 1978). In Queensland, the general recommendation for cropping land is that contour banks should be constructed on slopes of ≥1% to manage erosion risk (Carey BW, Stone B, Norman PL, 2015).

In establishing that cropping land is potentially a considerable source of erosion, and of soils likely to contain a high proportion of fine sediment particles; it stands to reason that addressing erosion on cropping land has the potential to achieve beneficial GBR water quality outcomes. While almost all cropping practices beneficial to improving water quality can (at least theoretically) be adopted on all cropping land, from a water quality risk perspective, contour banks would not be expected to be implemented on cropping land if the slope is <1%. From the perspective of guiding investment, funding and resources with regards to contour banks needs to be appropriate for the scale of the need; and where the need is, spatially or geographically. To define this, an understanding of the current level of need and adoption of contour banks requires an answer to two questions:

1. "How much cropping land is ≥1% slope?", and
2. "If there is a slope ≥1%, are contour banks present?"

As there is no dataset readily available to answer either of these questions, a data collation and analysis was required. Of the approximately 536,000 ha of cropping that occurs across the Fitzroy Basin region, an analysis was undertaken focused on the ~528,000 ha of cropping in the six major cropping catchments, the Nogoa River, Isaac River, Mackenzie River, Fitzroy River, Comet River and Dawson River. This technical report is the outcome of that data collation and analysis.

Method

Our analysis used ESRI ArcGIS Pro (version 2.7.3, 2.8 and 2.93) geographic information system (GIS) and Microsoft 365 Excel.

Spatial extent of analysis

Cropping areas were identified using the Queensland Land Use Mapping Program (QLUMP) Fitzroy NRM 1999 - 2017 dataset (Queensland Department of Environment and Science, 2019b) by filtering the "Secondary_2017" field for "Cropping" land use. The total hectares of cropping area were also derived from this layer. The Drainage basin sub areas – Queensland data set (Queensland Department of Environment and Science, 2019a) was used to identify the six GBR priority basin sub-areas for cropping in the Fitzroy Basin (the Dawson, Comet, Nogoa, Mackenzie, Isaac, and Fitzroy catchments). The QLUMP cropping area was clipped to and intersected with the six priority basin sub areas (BSA) (Figure 3). The QLUMP cropping features in each BSA were then converted into a single multi-part feature.

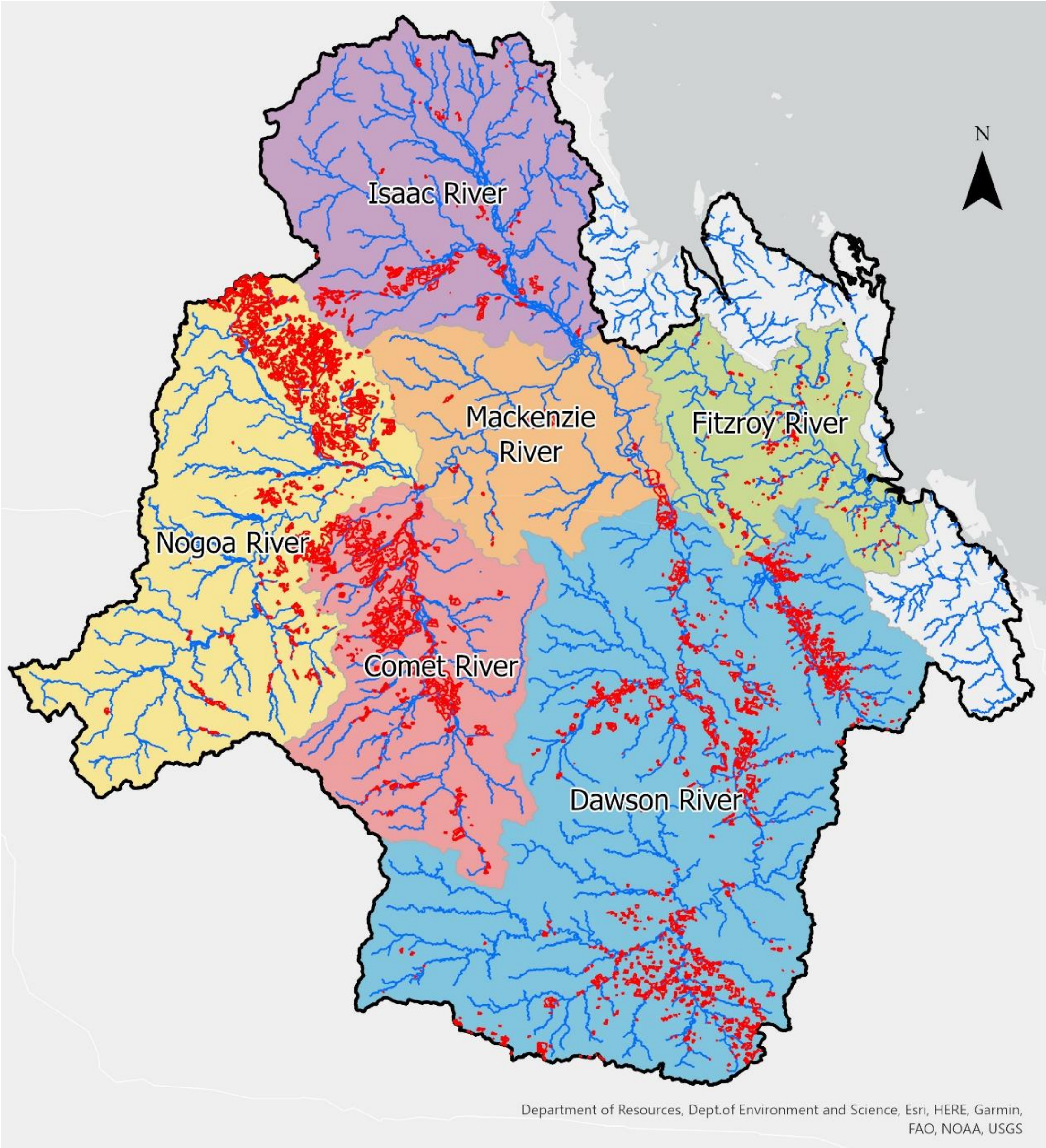

Figure 3. Fitzroy basin sub-area priority grains cropping areas
(Produced in ArcGIS Pro with data from (Queensland Department of Environment and Science, 2019a); and (Queensland Department of Environment and Science, 2019b), and (Esri, 2022)

Contour bank presence

A polyline feature layer (sourced from the Queensland Government Department of Environment and Science, Remote Sensing Centre) of contour banks in Queensland was clipped to the priority cropping BSA's. The layer was produced in 2010, so was updated by manually reviewing each QLUMP cropping area polygon using the latest available imagery. The imagery sources utilised were the Queensland Imagery Latest State Program Queensland Government SISP Restricted Basemap Service (Queensland Department of Resources, 2019); the Esri "World Imagery Basemap" (Esri, 2021); and Planet.com quarterly and monthly mosaic imagery, and daily imagery subscription service from 2021 to February 2022 (Planet Labs PBC, 2022). Line features were added where contour banks were present or removed, as necessary.

Contour banks are linear infrastructure with the distance between banks (within a paddock) varying greatly depending on the slope, initial design, and construction. The recommended contour bank spacing can vary from as little as 30 meters up to several hundred meters (Carey BW, Stone B, Norman PL, 2015). To delineate the land area where contour banks could be present, contour bank area was defined by creating a polygon buffer around each contour bank polyline. A 180m, buffer was created to capture “sets” of contour banks in any given paddock. The individual buffer polygons (for each individual contour bank) were dissolved into a single multi-part polygon feature. The merged single multi-part polygon feature was then buffered -180m to capture only the area where contour banks are present to define the contour bank area (CBA).

Land slope analysis

To identify land slope in cropping areas, two digital elevation model (DEM) layers showing the percent of land slope were utilised for comparison, the *Percent slope derived from 1" SRTM DEM-S* (Gallant and Austin, 2012b) (1 sec), and the *Median of Percent Slope over 300 m derived from 1" SRTM DEM-S* (Gallant and Austin, 2012a) (300m med). Within each BSA, random point features were generated with the total number of random points corresponding with the total number of hectares of cropping identified in each BSA (e.g., the Mackenzie BSA contains 11,939 hectares of cropping, so 11,939 random points were generated). This was repeated in each BSA with the minimum proximity for each point set at 75m. Each of the six random point layers were then merged into a single random point layer and intersected with the BSA layer to identify each point with the BSA name. A slope value from both the 1 sec and 300m med slope layers was then extracted to each point feature.

Intersection of slope and contour analysis

The random points layer containing the two slope values of the underlying landscape was queried (select by attribute) to select the random points for both the 1 sec and 300m med slope values equal to or greater than 1.0%. A value of 1 was assigned to each random point to record “≥1% slope risk” (in separate attribute table fields for each slope value). Points with a slope value less than 1% were assigned a value of 0. The random points layer was then queried (*select by location*) for points that intersect with the CBA feature. Where a point intersected with the CBA feature it was assigned a value of 1. Points not intersecting the CBA layer were assigned a value of 0. An example of the random point attribute table is shown in Table 3.

Table 3. Example of values assigned to random point query results

BSA	1 sec slope %	300m med slope %	≥1% Slope risk (1 sec)	≥1% Slope risk (300m med)	CBA
Dawson	4.6	3.1	1	1	0
Comet	1.2	0.9	1	0	1
Nogoa	2.3	1.6	1	1	1

The attribute table for the random points layer was then analysed using the ArcGIS Pro attribute table “Statistics” tool to calculate the total number of random points (P_t) and the total number of random points with a slope risk value of 1 ($SR1_t^{1\ sec}$ and $SR1_t^{300m\ med}$) for each BSA, and entered into a Microsoft Excel spreadsheet with the following functions performed for each BSA:

Slope risk area % of total cropping (SRA %) = $(SR1_t^{1\ sec} \div P_t)$ *and* $(SR1_t^{300m\ med} \div P_t)$

Target area

The “target area” was defined as area with a ≥1% slope that does not have contour banks present. To identify the “target area”, in ArcGIS Pro the random points layer was queried (*select by attribute*) for points that met the query expression result of a “slope risk” value of 1 and a “CBA” value of 0 (i.e. ≥1% slope, no contour banks present). The results of the query were summed for each BSA. To determine what proportion of all the land ≥1% slope in each BSA that does not have contour banks present, the results of the queries were entered into Microsoft Excel and the following functions performed:

Target area as % of total cropping area (1 sec) = $SR1_t^{1\ sec} \div (CA_t * SRA\%^{1\ sec})$

Target area as % of total cropping area (300m med) = $SR1_t^{300m\ med} \div (CA_t * SRA\%_t^{300m\ med})$

Because the total number of random points (P_t) in each BSA is equal to the total hectares of cropping in each BSA (CA_t), these values were used interchangeably.

Intersecting with RSDR

To provide further context to inform investment and prioritisation decisions, the random points layer was intersected with a spatial layer of the Fitzroy Basin Paddock to Reef modelling SOURCE catchments and riverine sediment delivery ratios (RSDR) layer (McCloskey *et al.*, 2021) for fine sediment delivery to the coast. In Microsoft Excel, the random points data was analysed for each BSA to group and sum the “target area” random points into ten RSDR bands ranging from 0% - 10% to 90% – 100%, to show the number of random points in each RSDR band in each BSA for both the 1 sec and 300m med slope layer.

Caveats

While the methodology developed for this analysis has provided a definitive result that has answered the two fundamental questions proposed (how much cropping land is ≥1% slope, and if ≥1% slope are contour banks present), there are several caveats that need to be considered.

Cropping area

The only large scale, spatial dataset of cropping land use available for the Fitzroy Basin is the QLUMP Land use mapping 1999 to 2017 - Fitzroy NRM, last mapped up to 2017 and published 20 June 2019. With a 4 – 5 year lag between the cropping areas identified in 2017 and this analysis occurring in 2021/22, it is likely that some areas currently with cropping occurring have been omitted. The QLUMP identifies cropping land relatively accurately, with the larger permanent cropping enterprises well represented. However, cropping in the Fitzroy Basin varies dramatically in the size of the area being cropped (between enterprises), and the occurrence or presence of cropping can be temporally sporadic. Cropping often may not be the primary land use of an enterprise, for example most of the land area is used for another purpose (e.g., grazing) with the cropping portion supplementing beef cattle production. Alternatively, the primary source of income may be off farm and cropping is more of a secondary income or hobby. Cropping can therefore often be undertaken infrequently as an opportunistic venture in a year with favourable seasonal or market conditions, then not be undertaken again at that enterprise for several years. As such, depending on when QLUMP mapping is undertaken, areas infrequently cropped may or may not be represented.

Age and resolution of imagery

Multiple imagery data sources were used to manually map the presence of any contour banks on cropping land. While some of the sources were very up to date (e.g. some Planet daily imagery was only several days old), others were dated 2017/18 (Queensland Government Imagery), or dating was unknown and therefore potentially older (Esri World Imagery Basemap). The resolution of the imagery also varies between sources from 10cm in some of the Queensland Government imagery to 3m in the Planet imagery. This variability of time and resolution means that potentially areas that do in fact have contour banks in place may not have been identified due to poor quality imagery, imagery being too old or cloud cover obscuring the image.

Slope threshold, data source and accuracy

A nominal number was required to identify sloping land at risk from erosion to be able to determine if contour banks should be present. The general recommendation for cropping land in Queensland is that contour banks should be constructed on land with a slope ≥1% to manage erosion risk (Carey BW, Stone B, Norman PL, 2015). However, small changes to the nominal threshold value (e.g., a tenth of one percent) results in notably different results. A trial analysis performed during this work (results in Table 4) show that a threshold value change of 0.1% to 1.1% results in differences of between 2% - 6% of the cropping area across the six priority SBA's. In the largest cropping BSA, (the Nogoa) a 6% variation in area (using the 300m med slope layer) equates to difference in area detected of over 10,000 ha. This is an area equivalent in size to the entire area of cropping in the Fitzroy BSA. Similarly, the accuracy margins of the slope layers may well obscure these variabilities and significantly over or underestimate the true total area of ≥1%.

Table 4 Trial analysis with 1.0% versus 1.1% slope value threshold

BSA	**Cropping Area (Ha)**	**1 sec slope layer**			**300m med slope layer**		
		≥1.0%	**≥ 1.1%**	**Diff**	**≥1.0%**	**≥1.1%**	**Diff**
Comet	144,797	44%	40%	4%	48%	42%	6%
Dawson	154,721	51%	48%	3%	53%	51%	2%
Fitzroy	10,106	54%	51%	3%	57%	54%	3%
Isaac	34,319	44%	40%	4%	48%	44%	4%
Mackenzie	11,939	30%	27%	3%	30%	26%	4%
Nogoa	172,102	64%	60%	4%	76%	70%	6%

There are also differences in the total area of ≥1% slope identified between the 1 sec and the 300m med slope layers. Similarly, the amount of difference also varies between the BSA's. Digital elevation models are not a perfect representation of the earth's surface, and indeed accuracy from the "smoothing of noise" in the DEM data can be ±50m (and as high as 110m), however elevation change due to smoothing is mostly less than 1.5 m and the overall mean difference due to smoothing less than 0.2 m (Gallant *et al.*, 2011). Averaging over larger areas can effectively eliminate the effects of noise but can also "smooth" out real topography and is therefore most apparent in the flattest and noisiest areas (Gallant *et al.*, 2011). Fitzroy Basin cropping areas are relatively large, but also topographically relatively flat (and therefore prone to noise). However, it is relatively uniform (likely less "noisy"), so it could be argued that the 300m med slope layer may be a more accurate and fit for purpose representation of cropping area slope. However, in the absence of a comparison with ground-truthing of slopes in paddock, it is problematic to assume one slope value layer is a better representation than the other. It is also not the purpose of this analysis to examine the accuracy of the slope layers.

Contour bank area buffer

Defining where the influence of contour banks commences or ceases at the top or bottom of a slope is difficult to determine remotely at a catchment scale. To manage this variability the polylines representing contour banks were buffered to create "contour bank area". A buffer distance of 180m was chosen to capture and group both single spaced (90m) and double spaced (180m) contours into "areas" of contour banks. In the absence of ground-truthing comparison, selecting the buffer distance that would be considered the "most" accurate is difficult.

Results

Slope data set variability

The proportion of land identified with a ≥1% slope varied between the two different slope layers; the results are shown in Table 5. The greatest variation occurred in the Nogoa BSA at 12% variation (64% and 76%), while the Mackenzie BSA showed no variation between the two slope layers (both 30% of the cropping land). The remaining BSA's had between 2% and 6% variation between the two slope layers. Across the entire analysis area there was a 7% variation (52% - 59%) equating to a difference of 32,854 ha.

Table 5. Comparison between 1 sec layer and 300m med layer of area ≥1% slope

		≥1% slope (1 sec)		≥1% slope (300m med)	
Basin sub-area	**Cropping Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**
Comet	144,797	44%	63,378	48%	70,131
Dawson	154,721	51%	78,344	53%	82,679
Fitzroy	10,106	54%	5,423	57%	5,788
Isaac	34,319	44%	15,026	48%	16,574
Mackenzie	11,939	30%	3,571	30%	3,527
Nogoa	172,102	64%	110,798	76%	130,695
Total	**527,984**	**52%**	**276,540**	**59%**	**309,394**

Target area analysis

The target area analysis (results shown in Table 6) found that of all cropping land ≥1% slope, the highest proportion without contour banks was in the Fitzroy 80.1% to 80.4%, an area of between 4,359 ha and 4,636 ha of the 5,423 ha to 5,788 ha of land ≥1% slope. The lowest proportion was in the Nogoa BSA (45.6% - 45.9%), which was also the largest area (between 50,876 ha and 59,541 ha) out of 110,798 ha to 130,695 ha of land ≥1% slope. The smallest area of ≥1% slope without contour banks was in the Mackenzie BSA between 2,456 ha and 2,707 ha. Across the entire analysis area between 53.3% and 55.2% of the land ≥1% slope does not have contour banks, equivalent to between 152,688 ha and 164,839 ha of the 276,540 ha to 390,394 ha of land ≥1% slope.

Table 6. Target area analysis results (≥1% slope with no contour banks)

	(1 Sec)		(300 m med)	
Basin sub-area	**Proportion (%)**	**Area (ha)**	**Proportion (%)**	**Area (ha)**
Comet	62.3%	39,470	58.5%	41,049
Dawson	61.3%	48,034	60.0%	49,619
Fitzroy	80.4%	4,359	80.1%	4,636
Isaac	48.2%	7,242	45.5%	7,538
Mackenzie	75.8%	2,707	69.6%	2,456
Nogoa	45.9%	50,876	45.6%	59,541
Total	55.2%	152,688	53.3%	164,839

Sediment delivery ratio analysis

The analysis against the riverine sediment delivery ratio (RSDR) (1 sec shown in Table 7, and 300m med in Table 8) found that the majority (89% - 90%) of the target area (≥1% slope without contour banks) across the entire analysis area has RSDR values ≤ 30%.

Table 7. Investment target areas with respect to RSDR (1 sec)

	Comet	Dawson	Fitzroy	Isaac	Mackenzie	Nogoa	Total
≤30% RSDR (ha)	39,470	37,494	41	6,544	530	50,574	134,653
% Target area	26%	25%	0%	4%	0%	33%	89%
>30% RSDR (ha)	0	10,037	4,318	693	2,177	7	17,232
% Target area	0%	7%	3%	0%	1%	0%	11%

Table 8 Investment target areas with respect to RSDR (300m med)

	Comet	Dawson	Fitzroy	Isaac	Mackenzie	Nogoa	Total
≤30% RSDR (ha)	41,049	40,130	40	6,962	527	59,176	147,884
% Target area	25%	24%	0%	4%	0%	36%	90%
>30% RSDR (ha)	0	8,942	4,596	571	1,929	10	16,048
% Target area	0%	5%	3%	0%	1%	0%	10%

Discussion

The ground-truthing of slope at sites via in-paddock surveys will always be the most accurate method to determine slope. However, this is impractical for sub-catchment and basin scale analysis. Similarly, decision makers need to collate data remotely on the current levels of adoption at a basin and sub-catchment scale to decide on how best to direct investment to support on-ground activities (for instance funding slope surveying, developing soil management plans, on-farm extension support etc). While accurately identifying slopes of <5% (and particularly defining 1% or less) with remote sensing is complex and prone to "noise" (errors) in low relief areas, the smoothed 1 second SRTM-derived DEM-S are sufficiently accurate, particularly compared to interpolated digital elevation models (Kinsey-Henderson and Wilkinson, 2013). There are also few alternatives to remotely analyse slope on the roughly 528,000 ha of cropping land across the six major cropping catchments that were analysed in the Fitzroy Basin.

With regards to the two slope layers used, the 1 sec slope layer consistently identified less area with ≥1% slope compared to the 300m median slope layer which may be due to a combination of the difference in pixel size between the layers and the fact it is a "median" value. The 1 sec slope layer is ~30m pixels while the 300m median slope is ~90m pixels, so more random points inherently fall within a single pixel and are attributed the same value. Alternatively, the 300m median slope layer across the entire analysis area had a median of 1.18% while in contrast the 1 sec slope layer had a median of 1.06%. This is closer to the target area analysis value of 1.0% so it is possible that a greater proportion of pixels have a value less than 1% slope as a result.

Target area analysis findings

This work found the presence of contour banks on cropping land in the target area overall is moderate. Between 44.8% and 46.7% (123,852 ha and 144,555 ha) of all cropping land that is ≥1% slope currently has contour banks present. However, at a BSA level this varies substantially and becomes more complex to understand with regards to informing soil conservation investment. In the Fitzroy BSA, roughly 80% of land ≥1% slope does not have contour banks, but this amounts to a relatively small area of ~4,500 ha. In contrast, the Nogoa has roughly 46% of land ≥1% slope not protected by contour banks, which accounts for roughly 51,000 ha to 60,000 ha. In order of area (rounded ha) of land ≥1% slope not protected by contour banks by basin sub area the ranking is:

- Nogoa – 51,000 ha – 60,000 ha
- Dawson – 48,000 ha – 50,000 ha
- Comet – 39,000 ha – 41,000 ha
- Isaac – 7,200 ha – 7,500 ha
- Fitzroy – 4,400 ha – 4,600 ha
- Mackenzie – 2,500 ha – 2,700 ha

These findings mean that for the first time the P2R Program has a conclusive reference point to assess the adoption of contour banks across the Fitzroy grains cropping industry, and definitive monitoring of whether adoption levels are increasing or decreasing, is now possible.

Influence of sediment delivery

Knowing where contour banks are required; how should investment be targeted to achieve the best value for money if the objective is only to improve water quality in the GBR? The P2R Program modelling estimates the end of system pollutant loads for rivers discharging into the GBR (McCloskey *et al.*, 2021). The riverine fine sediment delivery ratio (RSDR) conceptualises how eroded soil is transported through waterways to the mouth of a river and describes what proportion of the fine sediment entering an inland stream or waterway is likely to be delivered (from a given location) to the river mouth and into the GBR lagoon. Figure 4 is a representative map of the Fitzroy basin RSDR's showing the location of cropping land in each of the BSA's analysed. However, targeting investment toward areas with high delivery ratios is simplistic and will generally drive investment (and effort) towards the coast. Which in the case of grains cropping, would be directing investment and effort away from 90% of the industry and some of the highest risk situations. There are also other important reasons to target soil conservation efforts including sustainability, food security, and riverine health.

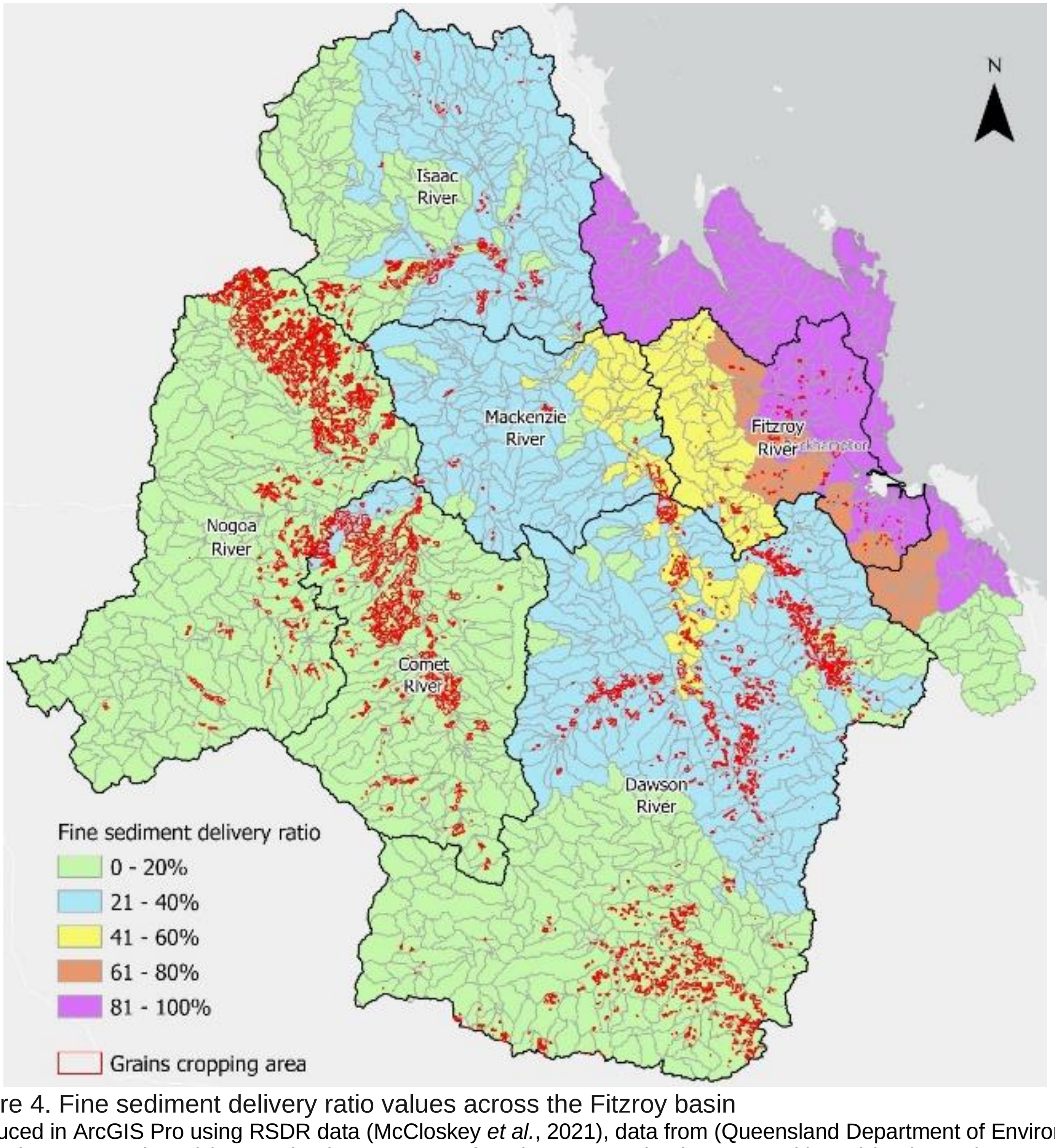

Figure 4. Fine sediment delivery ratio values across the Fitzroy basin
Produced in ArcGIS Pro using RSDR data (McCloskey *et al.*, 2021), data from (Queensland Department of Environment and Science, 2019a); and (Queensland Department of Environment and Science, 2019b), and (Esri, 2022)

Influence of other factors on water quality risk

So how else to prioritise and invest in the highest erosion risk cropping areas? The answer is further complicated by several other factors. As slope gradient increase, erosion risk increases. However, some soil types are by nature more prone to erosion than others, while larger areas of cropping have the potential to generate greater overall loads of sediment than smaller areas. Similarly, a given volume of eroded soil with a high proportion of fine particles will generate a higher volume of fine sediment pollution than soil with a lower proportion of fine particles. And finally, erosion from cropping areas that are a greater distance from a stream or waterway will generally deliver less sediment pollutants to the waterway (and therefore to the GBR) than cropping areas a short distance to a stream or waterway.

The P2R Projector (Projector) website (https://p2rprojector.net.au/) is a purpose-built decision support and prioritisation tool to assist in estimating the potential water quality improvements of farm-scale agricultural practice change projects. It is specifically designed to accommodate as accurately as possibly the multiple complexities (soil type, slope, climate, spatial location, interaction of other practices etc) to generate end of riverine system fine sediment load reductions from specific changes in practice on farms. A particular practice (or suites of practices) can be applied to sites to “simulate” the pollutant load reduction that the P2R Program modelling may calculate from the practice change. While these results will not directly represent load reductions at a farm scale, they can accurately represent the differences the P2R Program modelling will generate from practice change with respect to different practices, different catchments, and different agricultural industries.

Findings and recommendations

Analysis findings

This analysis now means for the first time in the P2R Program a conclusive spatial reference point is available to assess the adoption of contour banks across the Fitzroy grains cropping industry, and definitive monitoring of whether adoption is increasing or decreasing, is now possible. This analysis has found that over the six basin sub areas analysed across the Fitzroy Basin, the presence of contour banks is moderate (45% – 47% of all land ≥1% slope), but as low as 20% in some basin sub-areas. This suggests there is still an area between 153,000 ha – 165,000 ha of cropping land (29% - 31% of all the cropping land across the six basin sub areas) where contour banks could significantly reduce soil erosion.

However, in addition, land managers need access to soil conservation skills to ensure both existing and new contour banks and erosion control structures are correctly planned, designed, and fit for purpose, and their current farming system. Investment could expedite adoption of soil conservation measures through providing access to these technical services and knowledge to ensure soil conservation measures are appropriate for their situation.

Recommendations

All GBR water quality investment should aim to support programs and projects that have the potential to deliver the greatest reductions in fine sediment at the coast for the lowest cost. However, simply prioritising locations with high riverine sediment delivery ratios, alone is misguided. Large areas of cropping land situated on high slope gradients, where highly erosive soils with high proportions of fine particles are present, in conjunction with a short paddock to stream distance will generally have a greater risk to water quality than spatially and geographically comparable sites with contrary attributes. In extreme cases, a site with a low RSDR but a very high rate or risk of erosion (combined with poor soil conservation practices) could potentially deliver more fine sediment to the GBR than a site with a very high RSDR but a low rate or risk of erosion (with reasonable soil conservation practices undertaken).

The erosion risk from cropping land is inherently high, so there is the potential that, compared to other land uses such as grazing, greater fine sediment reductions may be possible for a similar cost, or similar reductions may be possible through an investment effort over a much smaller area. The available pool of funding though is finite, with total investment in GBR water quality programs from 2018/19 to 2022 varying between $34m - $45m and $56m - $82m annually (Commonwealth of Australia, 2021). However, this investment is shared with the grazing, cane, banana, and horticulture industries; and across nutrient and pesticide pollutant reduction programs in all GBR catchments as well as remediation of gully and streambank erosion.

Greater losses of total sediment per unit area can occur in cropping compared to grazing, so cropping program investment can potentially be more expensive for individual projects yet be comparatively cost-effective per tonne of fine sediment compared to a grazing project. Alternatively, achieving an equivalent reduction in fine sediment from grazing land may require greater practice change or over a much greater area compared to the area or magnitude of practice change required in cropping. Furthermore, measuring the cost at site and valuing the purchase as fine sediment reductions at the coast, means the RSDR becomes a dominant factor in cost-effectiveness, which may not truly reflect the overall cost effectiveness of a program, and will likely drive projects towards coastal areas and not necessarily the areas where the highest fine sediment erosion is occurring.

Because of the level of complexity in determining what actions, where and how to invest to improve reef water quality, tools such as the P2R Projector decision support tool may be utilised to inform these decisions. The P2R Projector adjusts for soil type, climate, paddock to stream fine sediment load transportation, and riverine fine sediment transportation and delivery, to inform prioritisation of on-ground action.

To achieve cost-effective practice change in cropping for GBR water quality improvement, investment needs to support programs that not only provide extension services to promote practice change, but broader soil conservation knowledge, awareness, and services to identify the highest erosion risk cropping land. This should include assisting land managers in identifying slope, soil types and their erosion risk as well as the appropriate practices, management and farming systems for their soils and situation. Programs must also then, where required provide the technical skills, services, and support to ensure the most effective practices are appropriately applied, and erosion control structures are appropriately designed, constructed, and maintain for both current and new farming systems.

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