Prioritisation of neighbourhood catchments: Recommendations, gaps and future research

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1. Introduction

To improve targeting of future investments the Fitzroy Basin Water Quality Improvement Plan (WQIP) integrates a prioritization process to assess where in the landscape investments will result in the most efficient outcome. Four different prioritisation scenarios were employed to identify priority Neighborhood Catchments (NC).

1. The total load from the whole of the NC;
2. The intensity of sediment generation and export per hectare, and;
3. The degree of investment necessary to achieve Ecologically Relevant Targets.
4. The areas which present cost effective options.

The data used to prioritise in these scenarios included the Source Catchments Modelling for identification of where and how much sediment, nutrient and herbicide was being exported to the reef from the different erosion processes and industries. Ground cover data was used to estimate the cover for the past seven years and adjusted in the landscape relative to rainfall. Paddock to Reef management practice survey data was used to estimate the effectiveness of investments following the rationale that higher level management practices would be required to support infrastructure investments. Economic cost data was used to estimate three cost components; the opportunity cost, the infrastructure and maintenance cost, and extension costs. Finally, because of the time pressure to achieve outcomes, the sediment delivery ratio (what is generated on the paddock cf. what is exported to the reef) was taken into consideration. The NC that ranked highly across all of these parameters were then selected as priority NCs for future investment.

Each of these data layers are highly complex in themselves. A number of caveats and areas for future research should be understood to interpret the recommendations and improve the process in the future. Although there are limitations, the process does identify key areas where improvements and focused outcomes can be achieved. Within each of these NC the different geography, biophysical characteristics, and prevalent management mean that a range of investments are required.

There is also the opportunity to further customize program design to achieve improved outcomes and more efficient results. This report first provides a number of recommendations regarding the key NC that have been selected. Following this, a number of gaps and areas for future research are described.

2. Recommendations

The development of the prioritisation report of the Water Quality improvement Plan has identified a number of neighbourhood catchments for sediment and nutrient reductions. The purpose of this document is to provide specific recommendations for consideration in planning and implementation. These include a range of focus areas from program design, implementation, monitoring and recording. This report is derived from the findings in Star et al. 2015 and is required in consideration with the other components in the Water Quality Improvement Plan.

2.1. Recommendations for program design

2.1.1. Tailoring investments to specific situations

It is recommended that only neighbourhood catchments that are considered *very high* and *high or large projects that meet the relevant criteria* to be considered eligible for developing projects and on-ground funding. Where on-ground funds are allocated, extension to the landholder to support the remediation and infrastructure is critical, not only at time of implementation but also in managing the site with improved practices from that point forward. This could potentially lead to a smaller number of higher value projects, and a likely need for a higher degree of monitoring and impact evaluation, consistent with the increasing need for investors to have high confidence that outcomes are being achieved.

It must also be noted in the recent feedback from landholders highlighted that incentives were seen as the most importance factor to change (Coutts 2013), highlighting the importance of such a mechanism to engage and progress change. Given the low returns in agriculture currently this will be critical over time.

2.1.2. Integrating interventions

The prioritisation approach has been based on the mechanism of a mix of incentives and extension to cost the reductions. Numerous evaluation studies conducted recently in the grains, grazing and sugarcane sectors confirm the importance of extension support in conjunction with planning and financial incentives in achieving complex NRM outcomes. Extension in this context implies professional capacity building which employs the range of extension models (Figure1), depending on the situation and need. These extension models have varying requirements for resourcing and also great variations in their effectiveness, particularly for complex issues. The models on the left are suited to easily adopted issues. Issues with track records of low adoption will generally require emphasis on the extension models toward the right side of fig x.

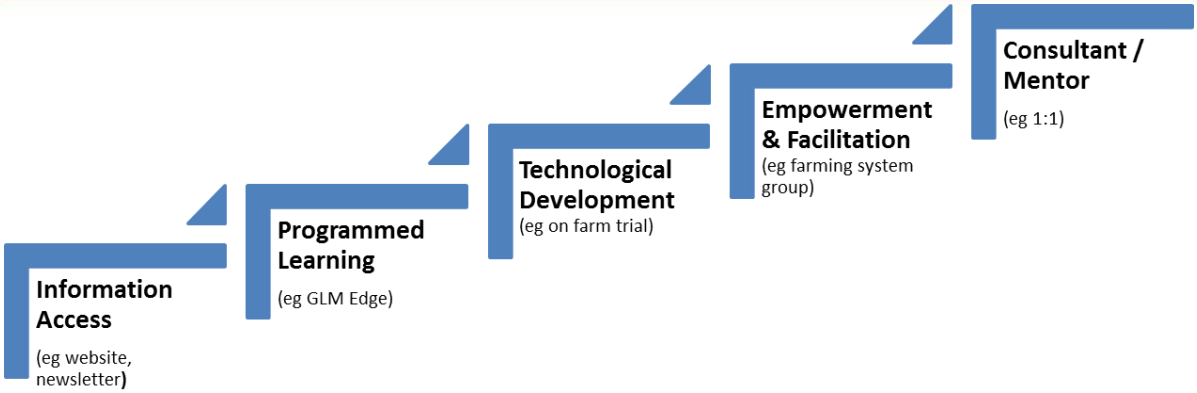

Figure 1: extension models employed in capacity building extension (after Coutts J and Roberts K, 2003).

The point is that these resources are hard to marshall together. The way this has occurred in recent times is through industry BMP programs. These industry programs are not only the most effective means of engaging with high numbers of landholders, they also integrate the range of extension models, particularly when linked with incentive programs that increase access to things like programmed learning and consultants. Maintaining investment and collaboration with industry BMP programs should be a priority for Reef Plan investments generally. In addition to integrating the extension models and providing a critical extension mass, these programs provide a planning and justification step with landholders that provides increased certainty for investors.

2.1.3. The grazing industry doesn't have a **monopoly** on sediment.

To date there has been relatively low levels of reef investment in the cropping industry in pursuit of sediment, nutrient or herbicide reduction outcomes. There is the opportunity to achieve multiple benefits from engaging with the grains industry. The existing higher degree of adoption of good soil management practices (such as reduced tillage and basic controlled traffic systems) allows potentially faster progression to achieve outcomes than with the grazing industry. The cropping industry is also based on the highest productivity soils that are predominately basalt based. These soils contain very high fractions of fine particles (<16µm), which are now considered of highest priority based on the sediment story and Ecologically Relevant Targets (ERT's) (Lewis et al. 2015).

Table 1 below has been developed from Thorburn and Wilkinson (2013) and Silburn et al (2012) to estimate the likely reductions in sediment for implementing changes for the different erosion processes. This is required to be a consideration when identifying projects within the selected neighbourhood catchments. It can be noted the difference between grains and grazing for hillslope sediment rates with contour banks alone providing a low cost option with large sediment reductions.

Table 1. Reductions in sediment based on process and industry.

Land type productivity	Hillslope(t/ha)	Gully (t/ha)	Streambank (t/ha)
Grazing Very high (C-B)	0.38	1.44	1.12
Grazing High (C-B)	1.7	1.98	1.54
Grazing Medium (C-B)	1.54	1.44	1.12
Grazing Low (C-B)	1	2.79	2.17
Grains (Conventional-zero tillage with contour banks)	2.8		

2.1.4. Alternate approaches.

With the transition from Reef Programme to Reef Trust funding there may be still be justification to directly link extension and incentives, something that has already been demonstrated to be highly effective through evaluations conducted on the GrainsBMP program. Reef Trust may also provide a means of further honing in on the most cost efficient outcomes through implementing a well thought out reverse auction process in the grains industry. Reverse auctions have previously been implemented in the sugar industry and there is the opportunity in the grains industry to run a similar process for soil conservation practices. Given the high level of inputs into production, management and on-ground awareness there is the opportunity to have large sediment reductions at low costs.

2.1.5. Collaboration with resource companies.

Another novel approach which may prove to be highly efficient is in direct partnering or collaborations with resource companies that are managing grazing lands under mining leases (as much as 4% of the catchment). These present situations where stock could easily be excluded (without any significant cost to the business) to increase ground cover, and where resource companies also have the earthmoving plant, equipment and skills to actively remediate any high priority erosion sites. If there are mining leases overlapping areas of significant gully erosion, these could potentially be highly cost effective as FBA's role could be the facilitator and enabler (and maybe not also the funder). The Fitzroy River Partnership for River Health is highly engaged with this sector and may provide insights and opportunity for this collaboration to occur.

Given the current announcement of El Niño, the ability to maintain cover at the break of season and during isolated rainfall events is critical to mitigating the formation of future gullies and streambank erosion processes (Tindal et al 2014). Therefore continued general extension and on-going Grazing Land Management (GLM) support is required across all catchments. Extension in this context implies technical extension. Sites selected in these NC for remediation and other infrastructure or extension programs, must have continued monitoring and site standards and photos kept to continue the learning and the assessment over time.

2.2. Specific Recommendations

The recommendations provided below are aimed to assist in targeting erosion process within the grazing or grains industry the catchment specified. Scenario two is biased towards gullying and streambank and this therefore would be reflected in the recommendations. These recommendations are based around the results from Scenario one and three. It is recommended that further information is sought through field officers and local extension staff to fully understand the NC geography and biophysical characteristics.

C1

Located on basalt soils with a mix of cropping and grazing lands. There is also a significant mine operating in this NC. There is scope for the following:

- For grazing, provide incentives for fencing and stock exclusion from gullies, streams and targeted capacity building extension to improve cover on large grazing properties.
- There are a number of smaller lifestyle blocks therefore extension activities that occur after hours may provide opportunity to improve management practices.
- Do not provide incentives for lifestyle blocks, only provide extension.
- Opportunistic cropping and cropping in general must be considered, particularly for hillslope erosion.
- Provide incentives for contour banks in cropping and minimum till practices. Although there are a number of cropping properties which already have contour banks, repairs, maintenance and system design improvements are also an area to provide incentives.

C11

Located in the Theresa Creek area this catchment has an extensive mix of land types and waterways. There is also a mine site which has an extensive road network. There is scope for the following:

- Specifically target gully remediation projects on large areas.
- There may be opportunities for one property to have multiple project sites.
- Ensure cover is maintained. Although currently it has relatively good cover it may lead to further gullying at the break of season.
- Consider the mix of land types through properties when selecting projects and consideration of solutions, as the response should vary based on these characteristics.
- There is a large portion of the catchment that exists on soils with high erosivity that must be considered firstly in project selection.
- Low delivery rate must be considered as there may be other projects in the catchment that will have an impact on the reef in a shorter time frame.

C23

Located in close proximity to the Comet River in a mix of fertile cropping lands and brigalow land types there are patches of basaltic and highly erosive soils. There is scope for the following:

- Focus only on streambank remediation through allowing revegetation of riparian areas on grazing properties, and increasing general ground cover.
- Focus on hillslope and gully erosion in cropping areas through shifting management to minimum tillage, and the use of contour banks and improved break crop cover management.
- Improve extension to cropping areas and projects.

C35, C38

Situated in the Arcadia Valley, this is a mix of highly fertile land types that are either used to grow forage crops or crops for feed lotting, and grazing. The area is limited by no ground-water, so often, water is an issue before cover is. There is scope for the following:

- Target progression of cropping management practices for reduction in hillslope erosion given that they are not taking the crop to a high value market. There is little private benefit to shift to A or B management practices.
- Target gullies in grazing lands. This is the main source for sediment exported, there are also highly erosive sub-soils so prevention of further gulling is required.
- Ensure cover is maintained, particularly in the El Niño period.
- Provide extension to leucaena growers regarding management of pasture at the end of the dry season.
- There is also the potential opportunity to engage with mining companies in C35 for mutually beneficial outcomes.

D3

On a mix of highly productive land types and highly erosive soils. There is scope for the following:

- Focus on grazing lands only and gully and stream bank projects only.
- There are areas of low cover that must be considered for extension to ensure that further gullying and subsurface erosion does not occur.
- Located where there are soils with fine particle size and relatively high delivery.

D9, D10

Located on the Dawson River there are a number of high quality land types and relatively low erosive soils with some small patches of high erosivity. There is scope for the following:

- Target gully erosion in the NC in the grazing industry.
- In the cropping areas focus on shifting to controlled traffic and minimum till systems with, contours where practical.
- Although general cover is high there is also a mix of erosive soil types potentially making it quite hard to manage.

- Ensure cover is maintained and a whole of system approach to management is provided through extension staff.

D12, D13

Located in the New England and Duargina/Biloela basin which exhibit basaltic soils (of fine fractions). Also close proximity to the reef, the catchment has a mix of cropping and grazing opportunities. There is scope for the following:

- Focus on gully remediation in the grazing industry.
- Ensure improvement of cover and 3P pastures.
- Shift cropping systems to A or B management practices and provide incentives to shift to controlled traffic, minimum tillage and implement contour banks. Most of the cropping in this catchment is smaller scale and the private benefits for shifting are minimal.
- Having very low cover, improved pasture species away from annuals and to 3P grasses is critical.
- Gullies and scalds in this NC are key projects to focus on.
- For cropping focus on hillslope changes such as controlled traffic and minimum tillage.
- There is mining lease in D12 where opportunities may arise for engagement

D16, D17, D26

A mix of good quality land types. There are a number of stream networks, however a small number of landholders to engage with. There is scope for the following:

- Focus on gully and streambank projects in the grazing sector.
- There is an extensive stream order network across properties to ensure outcomes practical considerations are required.
- Focus on shifting cropping practices to minimum tillage, controlled traffic and contour banks, particularly in the undulating areas.
- There is a mix of highly erosive soils so ensure that cover is maintained during the El Niño period and a mix of 3P grasses is available.
- Provide extension to leucaena growers regarding management of pasture at the end of the dry season.

D47, D50, D58, D64

These catchments exhibit large property size and low cover. These catchments fall into the Surat Basin and have areas that are a mix of cropping and grazing. There is scope for the following:

- Focus on gullying and streambank projects in these catchments.
- D50 and D58 have very low cover and extension should be coupled with on-ground investments to improve cover, particularly in El Niño years.
- There is a mix of erosive soils with D47, D58, D64 all exhibiting highly erosive soils.
- Highlighting the importance of maintaining cover and prevention of any future gullies.

- There are a number of large properties which provide effective management change in adoption of B management practices.

F2, F3

These NC have very high delivery ratio along with a low number of landholders. The NC have an extensive mix of erosive soils and a mix of land types. There is scope for the following:

- Focus only on gully and streambank projects in the grazing industry.
- Ensure that cover is maintained in the El Niño period to avoid hillslope erosion and prevent further gullies forming.
- Try to engage properties with scale to allow for management change over a large area.

F13, F16, F17, F25, F27

Due to the high rainfall intensity and close distance to the coast these catchments deliver large amounts of sediment. There is scope for the following:

- Focus on gullying and streambank projects in grazing.
- Ensure cover is maintained and that extension is provided to ensure that this happens over the El Niño cycle.
- There are a number of smaller holders where engagement may be more effective out of hours and if possible, where clusters of small scale producers are willing to work together.
- There are highly erosive soils in F16, F25, and F27 where the focus for extension is required to be on mitigating the development of further gullies.
- Streambank is the only focus in F25**.**

T10

This catchment is located in the Three Rivers sub-catchment and are at the head waters of the Connors River which is known for its fast flowing and intense rainfall events. There is scope for the following:

- Target streambank projects and ensure allowance for high flow events in the remediation approach.
- The NC also exhibits high amounts of slope in areas which is required to be considered in projects.
- This NC has a limited number of landholders and therefore the ability to engage and improvement management over a large area would provide significant sediment reductions.
- Cover is reasonable currently and it is critical to ensure that continues.

T20, T21

Located in the Three Rivers sub-catchment there is a mix of land types in these catchments. There is scope for the following:

- Target streambank and gully projects in both T20 and T21 in the grazing industry.
- Ensure adequate extension is provided as groundcover is an issue.
- In the cropping industry where possible, target hillslope erosion processes through minimum tillage, controlled traffic and contour banks.
- The scope to find large projects for management change in these catchments is high.
- Cover is low in parts of thee catchments and critical to maintain.

T31, T35

With limited landholders in these NC there is the opportunity to achieve changes at a large scale. There is a mix of high to highly erosive soils that must be considered in remediation methods. There is scope for the following:

- In the grazing industry, focus on gullies and streambank projects in both NC.
- There is opportunity for hillslope sediment reductions in the cropping industry.
- Ensure that groundcover is maintained or improved particularly at the break of season.

T39

This NC has a mix of land types grazing a cropping lands and adjacent to the Mackenzie River. There is scope for the following.

- In the grazing industry target streambank and gully project particularly those in close proximity to the major waterways
- Target hillslope erosion in cropping through the use of shifting to minimum tillage and controlled traffic practices.
- Ensure that groundcover is improved with relevant extension and support.

3. Biophysical gaps and opportunities

3.1. Grains opportunities

The opportunity for sediment and nutrient reductions has been focused intensely on the grazing and sugar areas with little consideration of broad acre cropping, due to its small footprint over the whole area of the Reef catchments. The prioritisation approach highlighted that targeting grains' areas has the opportunity to reduce sediments in a cost effective manner and increasing evidence is highlighting that basaltic clay based soils (predominately utilised for cropping) are doing more extensive damage than previously thought (Bainbridge, Wolanski *et al.* 2012).

The understanding of cropping and its contribution for both sediment and nutrient is limited. Recently, increased awareness of the role of fine sediments <4µm, and the link between soil particle size and nutrients bound to it, have been highlighted (Bainbridge, Wolanski *et al.* 2012). Nitrogen fertiliser applications increase concentrations of inorganic N in soils, so DIN exports increase with

increasing N fertiliser use. DIN exports are somewhat better related to N surplus, the difference between N applied to crops and N in crop off-take (Thorburn, Wilkinson *et al.* 2013). Past work has been unable to clearly articulate surplus nitrogen from grains cropping in the Central highlands. It has been suggested that the rates of nitrogen (N) applied in the Fitzroy are as high as <400 kg km^2 yr^{-1}. Past worked has been based on the assumption that in the Fitzroy 100kg ha yr^{-1} of N is applied, 90kg ha yr^{-1} is utilised by the crop and 10kg ha^{-1} is surplus (Thorburn and Wilkinson 2013). Recent estimates from 2013 data highlight that average rates of N applied are between 31kg and 40kg $ha^{-1,}$ with approximately 40.3kg to 52 kg ha yr^{-1} exported from the paddock as harvested grain (McCosker 2015). This indicates a net N deficit rather than N surplus and suggests that rates of N fertiliser application may not be the issue. However the inherent N existing in brigalow soils may be critical, with soil management potentially providing the most efficient approach to reductions. Further research is required to fully understand these trade-offs.

3.2. Identification of hotspots and erosion processes

The identification of current soil erosion hot spots is solely based on current scientific information accounted for in Source Catchment Modelling. Past sediment tracing studies, soil erosivity mapping and gully mapping have all occurred in the Burdekin, however not in the Fitzroy to date. Therefore there are limiting data sets to update Source Catchment Modelling. These updates are what is required to be considered for further research, and to ensure across all the reef catchments that efficient outcomes are achieved.

Furthermore, the biophysical processes of soil erosion remain poorly understood (Bainbridge, Wolanski *et al.* 2012). There are only very limited trial or study sites established (e.g., Hughes, Olley *et al.* 2009; Murphy, Dougall *et al.* 2013; Siriwardena, Finlayson *et al.* 2006) in the Fitzroy Basin that aim to increase the knowledge base about local soil erosion processes. Hence, there is a severe lack in the scientific understanding of how biophysical erosion processes work on a small and large spatial scale.

3.2.1. Erosion processes

The mapping of soil erosion using remote sensing techniques is important as it can provide empirical information rather than estimated data about erosion hot spots and erosion types. In the Burdekin, the gully mapping identified that extension of gullies occurred at different times with gully changes driven by large localised events, and with gullies rapidly changing under the factors of low groundcover, and high intensity rainfall. However, at this stage there exists a significant lack in the mapping of soil erosion in the Fitzroy Basin. Although LiDAR mapping has been completed for ten gully sites over a 40-60 year period in the Burdekin, the only mapping in the Fitzroy has been for the Isaac sub-catchment (Tindal et al, 2015).

Soil erosion mapping is a resource intensive task (labour and technical) and will require time and funding to produce a complete initial record of erosion types for the Fitzroy Basin. It should also be noted that subsequent mapping of soil erosion may be necessary to monitor any changes to the

initially recorded state of erosion in future. There is also limited understanding of the effectiveness of treatments by varied approaches to gully remediation.

Similarly, streambank erosion, particularly in the areas of basalt soils where fine sediments contribute are poorly understood. Further research regarding remediation is required. Hillslope erosion is the key driver of streambank and gully erosion processes and the importance of cover should still be a key focus across the catchment.

3.2.2. Trial Sites and monitoring

The biophysical processes of soil erosion remain poorly understood across all reef catchments (Bainbridge, Wolanski *et al.* 2012). There are only very limited trial or study sites established (e.g., Hughes, Olley *et al.* 2009; Murphy, Dougall *et al.* 2013; Siriwardena, Finlayson *et al.* 2006) in the Fitzroy Basin that aim to increase the knowledge base about local soil erosion processes. Hence, there is a severe lack in the scientific understanding of how biophysical erosion processes work on a small and large spatial scale. Important questions, such as, the role of climate (El Nino) in the formation of soil erosion, and change in sediment loads over time, have not been investigated. Furthermore, uncertainties exist in the links between erosion processes, e.g., whether scolds (bare areas) always occur in proximity of gullies or if they also occur independent of gullies.

Soil erosion is a dynamic process, thus, any spatial prioritisation approach of remediation activities should include a time component that assesses erosion change over time. Unfortunately, the data required to understand the time processes for achieving remediation is limited, and the significant heterogeneity around the catchment would result in this varying based on the characteristics of the particular process. Further monitoring of sites where funding has occurred across a number of programs is critical for future programs to not only understand the interactions of the processes, but also the time periods and characteristics of remediation.

Using the modelled sediment loads in the analysis of this study does not differentiate between suspended (>16 µm) and fine (< 15.9 µm) sediment transportation. The differentiation between both forms of sediment is important as there is evidence that particularly the clay and fine silt fractions (< 15.9 µm) dominate the suspended sediment load flow into the GBR (Bainbridge, Wolanski *et al.* 2012). Due to their sticky nature, these fine sediments pose a risk to benthic organisms, such as corals and seagrass (Bainbridge, Wolanski *et al.* 2012). Hence, by not distinguishing between course and fine sediment loads that are exported from each neighbourhood catchment to the GBR, the prioritisation process of areas for soil erosion management neglects an important biophysical process.

3.1. Management effectiveness

The direct link between management practice data and cover is complex due to time lags, isolated rainfall events and the land type inherent resilience. Currently, ground cover mapping is used extensively for assessing erosion and land condition however to ensure the correct algorithms and metrics are used, continual development and progression is required. One approach to achieve this is for it to be linked to actual monitored cover. Similarly the development of the best management

framework has been developed through time and is used to assess progress towards the reef targets. However, the direct link of management practices and weightings of importance to groundcover is not well understood.

The management effectiveness data layer has not taken into consideration the impact of grazing that has happened on national parks under the previous government, nor has it accounted for the grazing lease agreements that are potentially in place with the mining companies. These are areas where further research is required.

3.2. Economic Data and costs

This analysis involves an implicit assumption that reducing sediment emissions at the paddock level will subsequently reduce emissions at the lagoon level, leading to improvements in water quality. The temporal lags between the load entering the river and the load entering into the lagoon have been accounted for in the delivery ratio. The bioeconomic models are simplistic in assuming that each property reflects the neighbourhood catchments condition level and average stocking rates (Based on the combination of land types in the NC). Pasture utilisation rates are applied uniformly across each property. The assumptions that landholders are always profit maximising and have perfect knowledge should also be noted.

The bioeconomic modelling has not captured all biophysical factors, such as site-specific effects, while the costs may not have adequately reflected cumulative and threshold effects (Wu and Boggess 1999; Wu and Skelton-Groth 2002). Also, the potential for multiple environmental benefits has not been recognised in the budget allocation.

The cost factor accounts for initial capital infrastructure cost of the most simplistic approach and therefore only represents a cost comparison. The costs are adjusted up or down based on the load as an indication for the complexity, however only by a factor adjustment, and therefore it has not fully accounted for site specific steps. The costs do however allow comparable decisions to be made amongst NC and three main components of further research would increase the data accuracy significantly. Involvement of economics in remediation projects over the long term would ensure that the trade-offs are better accounted foe

4. Discussion and Conclusion

The results identify neighborhood catchments in the Fitzroy Basin that have a high ranking across the five parameters of loads, residual cover, effectiveness, cost and delivery ratio. The NC are spatially spread across the catchments with clear groupings identified. The recommendations highlight a number of key considerations for the FBA. First, future funding and design of programs to achieve outcomes for sediment reductions are most effective. Second, strategies to implement these programs based on the characteristics of these neighbourhood catchments. Finally, ensure the gaps in knowledge and the future considerations for research are provided.

The identification of priority areas for remediation in the Fitzroy Basin implies that funding sources and effective funding schemes (e.g., ongoing maintenance and extension) need to be revised. The current change in funding climate will require FBA to generate some novel cost effective and target approaches. Potential approaches are reverse auctions in the grains industry, targeted incentive and extension programs in the grains industry, targeted remediation programs of gullies and streambanks in collaboration with the mining industry.

Extension described in the recommendations is required to be of a strong technical background and able to offer support and develop solutions with the landholder as the project progresses. This may require up-skilling a number of existing extension officers and providing soil conservation training to existing staff. There is currently limited existing staff across FBA along with State agencies with this knowledge and this is a critical deficiency to be addressed.

A number of the selected NCs have characteristic soils of high erosive soils. Given the state of the current El Nino, groundcover needs to be taken into consideration with landholders to develop strategies that to improve or maintain ground cover. Results of past LiDAR work have identified that larger gullies may have been driven by episodic or event-based rainfall events, which were possibly exacerbated by low ground cover. Highlighting that maintaining good ground cover at the end of a drought or the break of dry season is important to avoid large sediment loss through the development of gullies erosion (Tindal *et al* 2014).

These recommendations must be considered along with the knowledge that fields officers contribute. Although some NC were validated by project staff there are a number of others that were not sighted and therefore local knowledge will be able to contribute further recommendations.

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