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Development of a Riparian Condition Assessment Protocol for Northern Gulf Rivers using Remote Sensing and Ground Survey

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Final Report

Project No – GRU38

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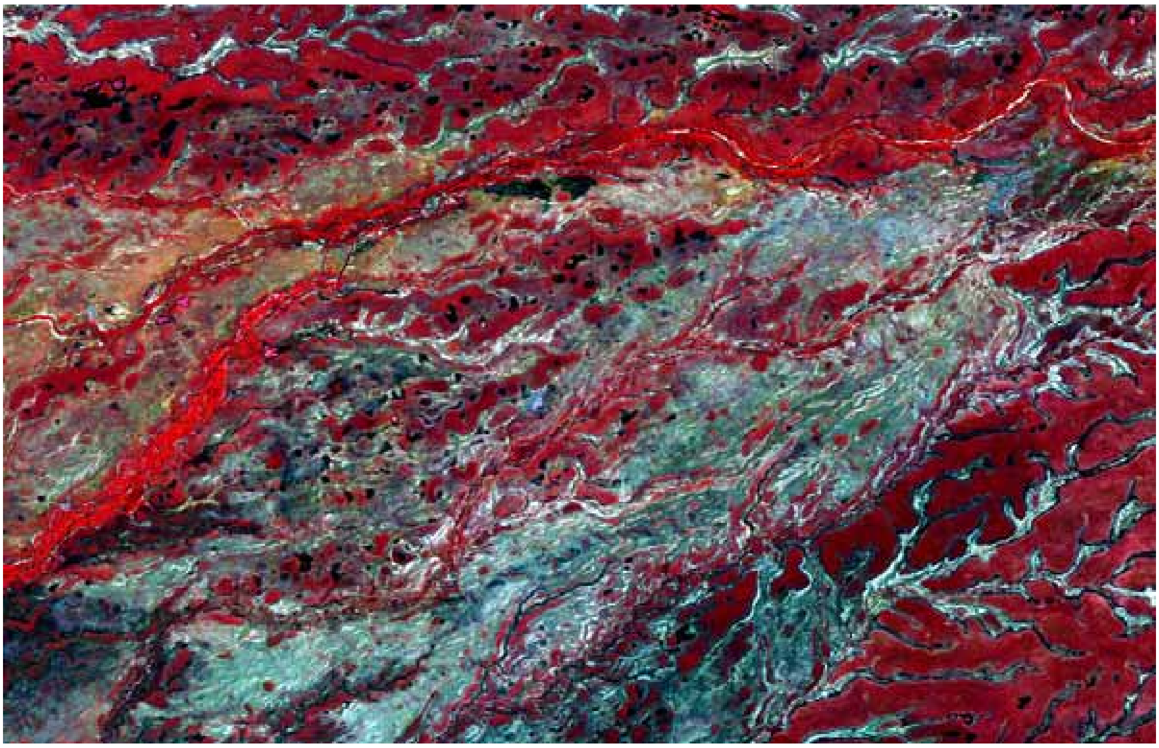
Report prepared by Andrew Brooks and Jon Knight



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Project Summary

Project objectives as identified in the proposal

As outlined in the final report (Brooks et al. 2008) and interim milestone reports (Brooks et al., 2007; Lymburner et al., 2007), some of these original aims were found to be unachievable given the current state of knowledge about riparian zone functioning and dynamics in the wet/dry tropics. Hence, it was not possible to develop definitive metrics for measuring riparian "condition", until we have a better understanding of baseline riparian dynamics and functioning. For this reason the ***focus of the analysis shifted towards establishing a baseline from which future changes can be measured, and towards developing a remote sensing based approach for measuring structural riparian vegetation changes through time***. A refocused set of objectives were subsequently identified:

1. To develop a definition of the extent of the riparian zone applicable to the Northern Gulf Region (Mitchell and Gilbert Catchments)
2. To develop a broad scale method appropriate for the Northern Gulf region for quantifying riparian condition using remote sensing techniques
3. To assess the spatial variability of riparian condition
4. To assess the need to modify existing TRARC protocols for Northern Gulf rivers
5. To undertake TRARC assessments in selected reaches of the Mitchell and Gilbert Rivers
6. To assess the appropriateness of integrating a remote sensing approach for assessing riparian condition in the Gulf Savannah Rivers with the existing on-ground survey approach (TRARC).

The objectives as identified in the original proposal are outlined in Appendix 1 and the attached report, which includes a more detailed discussion of the reasons for the changes.

Summary of methods and modifications

1. Methods

The primary focus of this study was the establishment of the riparian condition baseline state against which future condition trends can be measured, and the development of a robust, repeatable method of analysis. The methods apply at two scales for which riparian condition was being assessed – i.e. remote sensing across the entire catchment and the detailed ground based survey at specific sites using the Tropical Rapid Appraisal of Riparian Condition (TRARC) (Dixon et al., 2006, 2005) approach.

The broad-scale analysis was fundamentally limited by the resolution of the available satellite data, resulting in the use of 25m Landsat imagery. This was primarily due to the fact that Landsat is the only readily available satellite data set with an archive of any length (i.e. two decades +). This length of archive enabled us to gain some understanding of the trends in vegetation and landscapes status and hence begin to gain some understanding of condition.

The study was undertaken in two parts: 1) A remote sensing based approach using Landsat imagery at two time periods (1988 and 2005), to detect gross changes in riparian structure between the two intervals. 2) A ground-based assessment of 175 sites throughout the upper Gilbert (including Einasleigh) River and the upper Mitchell (including Walsh) River.

2. Modifications

Two major modifications to the methodology occurred. The first was the shift from using an existing geomorphic river classification approach for defining the riparian zone, to a new definition that included the broader extent of the floodplain. The second modification was to separate the remote sensing and TRARC research.

A) Riparian zone. Most existing definitions of the riparian zone were found to be too restrictive when applied to the savannah landscapes of the Northern Gulf, given the vast areas of floodplain that are regularly inundated in this landscape, and the fact that a sound case can be made to include entire alluvial plains in the definition. Consequently, we adopted a very inclusive definition of the riparian zone, which in total we refer to as the alluvial zone. The broad alluvial/riparian zone is differentiated into three sub-zones: the **active channel zone** (ACZ); the **in-channel zone** (ICZ); and the **floodplain zone** (FPZ). The definition of the riparian zone comprised objective 1 (see below).

B) TRARC vs. Remote Sensing. Originally we proposed to use remote sensing, using multi-resolution data, to extend the application of an existing on-ground assessment protocol, TRARC, by linking TRARC ground survey parameters to suitable remotely sensed parameters. This objective was modified because of an unforseen difficulty in spatial scalability of TRARC due to a lack of generalisation beyond the individual TRARC survey location. This had the consequence that there was no appropriate method for scaling TRARC to a remote sensing framework, nor, for scaling remote sensing data to TRARC. The remote sensing and TRARC approaches are complementary approaches, but are suited for different sets of objectives.

The sorts of questions that can be addressed using the two approaches are summarized:

TRARC approach.

- Does a specific site show evidence of riparian ecosystem degradation as a result of weed invasion, clearing, over grazing?
- Does a specific site show evidence for system resilience? Is there new recruitment of native plants?
- Do successive surveys at the same site (assuming it is done at sites with relatively stable geomorphology) indicate that the riparian ecosystem is becoming more or less infested with weeds through time?
- Are basic ecosystem functions such as litter production, LWD production, shading etc., changing through time?

Remote Sensing approach

- Does the whole riparian landscape demonstrate there has been a shift over time (i.e. through time series analysis of satellite imagery) in the riparian vegetation community structure or community patch dynamics?
- Is there evidence of increasing/decreasing riparian cover or erosion through time?
- Is there evidence for sustained sedimentation of in-channel pools through time?
- Is there evidence for a change in river channel dynamics within the timeframe of the available data?

Separate analyses are then required to determine the causes of any detected changes at each resolution between successive surveys. Furthermore, identifying the causes of the changes may not be possible at the scale at which the analysis was performed. The drivers of change may be operating at broader or finer spatial scales. Hence, it is crucial that multiple scales of analysis are undertaken when assessing riparian condition- not just the plot scale, or the broad scale.

Summary of Results

Objective 1: To develop a definition of the extent of the riparian zone applicable to the Northern Gulf Region (Mitchell and Gilbert Catchments)

An assessment of published definitions of the term Riparian Zone identified a wide range of interpretations, however a very inclusive view has been adopted by the Land and Water Australia

Riparian Program, based on Malanson (1993), as "any land which adjoins, directly influences, or is influenced by a body of water" (LWA, 1998). As such, this definition included:

- the land immediately alongside small creeks and rivers, including the riverbank itself;
- gullies and dips which sometimes run with surface water (i.e. ephemeral streams);
- areas surrounding lakes; and
- wetlands on river floodplains, which interact with the river in times of flood.

In the Gulf savannah, the application of the LWA definition encompasses a large portion of the landscape. To understand how the riparian zone was defined it is first necessary to give a brief description of the two catchments in which the study was focused. Both catchments can be divided into two broad regions: the uplands, which are characterised by relatively high terrain relief, bedrock or bedrock constrained channels with some alluvial fill valleys upstream of bedrock constrictions; and a megafan (*sensu* (sensu Horton and DeCelles, 2001; Leier et al., 2005)) which dominates the lowlands, and which is characterised by a sequence of nested low gradient alluvial fans. Within the megafan there is a network of channels, palaeo-channels, billabongs and wetlands. Considering this we adopted a very inclusive definition of the riparian zone, which in total we referred to as the **alluvial zone**. The broad alluvial/riparian zone was differentiated into three sub-zones (see Fig 1). For a full outline of the method for delineating the various zone classes see the attached report (Brooks et al., 2008).

- the **active channel zone** (ACZ) (i.e. the zone which shows geomorphic evidence that it has been occupied by the river channel in the recent geomorphic past);
- the **in-channel zone** (ICZ), or the zone encompassing the portion of the current channel that is actively conveying bedload material under the current flow regime;
- the **floodplain zone** (FPZ) – the remainder of alluvial land not encompassed within the other two categories and is not necessarily synonymous with the land that is inundated by the current flood regime – i.e. it may also include alluvial sediments deposited under a former flood regime.

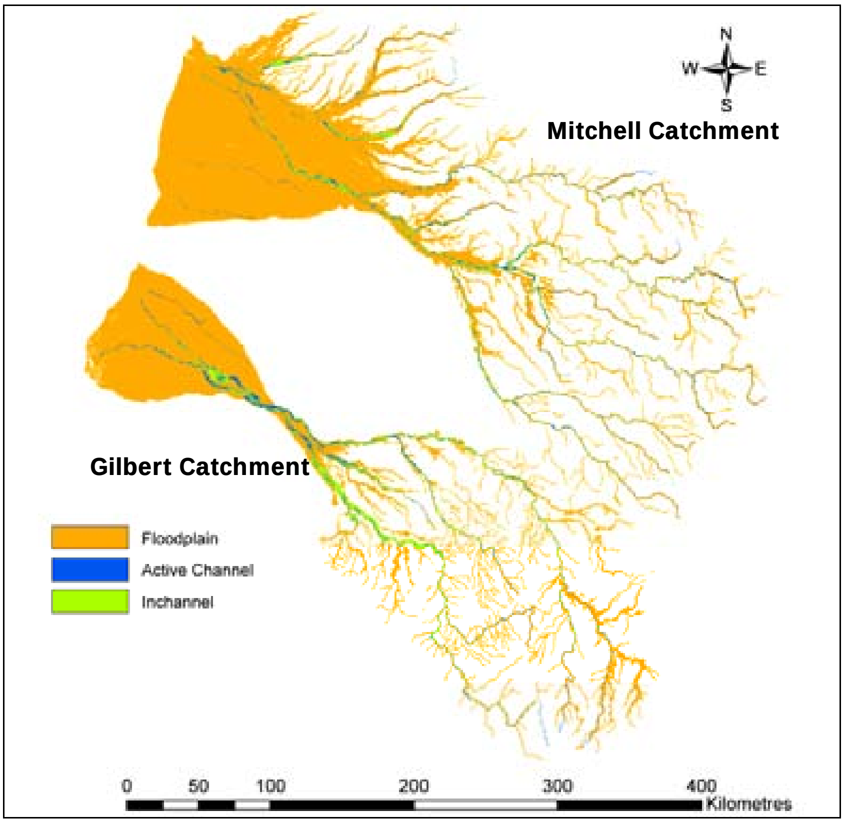

Figure 1 Map showing the three categories of riparian zone analysed within this study.

Objective 2: To develop a broad scale method appropriate for the Northern Gulf region for quantifying riparian condition using remote sensing techniques

The objectives of the remote sensing study were twofold: 1) the establishment of the baseline state against which future condition trends can be measured, and the development of a robust, repeatable method for undertaking analysis in the future. A remote sensing based approach using Landsat imagery at two time periods (1988 and 2005) was developed, to detect gross changes in riparian structure between the two intervals at a catchment scale. The Landsat archive provides a reasonably long historical record ranging from 1972 through to 2005, and unlike aerial photography is a dataset that can be relatively easily analysed over large spatial extents (100s of thousands of square km). The dataset for Landsat TM, which has a 25m pixel size[1] covers the period from 1988 to 2005. Landsat TM mosaics from 1988 and 2005 were analysed to assess the degree of vegetation and land cover change that had occurred in the Mitchell and Gilbert catchments of the Northern Gulf region during the 17 year period. Interpretation and validation of the Landsat TM data was carried out using airborne tri-spectral scanner data acquired for this project and in conjunction with project GRU37. An archive of MODIS satellite imagery was also used to assess the growth dynamics, inundation dynamics and fire dynamics[2]. Given the 25m pixel resolution of the Landsat base data set, there are a limited suite of indicators that can be derived as the basis for a condition assessment. Landsat imagery can be used to differentiate vegetation community classes in the manner of Specht (1981). A simplified set of six classes were used, including: closed forest, open forest, woodland, open woodland, grassland and bare ground (including gully and scald erosion as well as river sand deposits). River sand was subsequently separated from the other bare ground, using Landsat thermal bands, while the gully erosion subset of the bare ground class was delineated from the output of a separate gully mapping project (GRU37). In addition to these vegetation classes, water bodies were also quantified.

The method developed involved a 6 stage process as summarised below:

1. Understanding the relationship between land cover and Landsat TM reflectance
2. Training the classification of the 2005 Landsat imagery using tri-spectral scanner data
3. Assessing the accuracy of the 2005 image classification
4. Classifying the 1988 Landsat imagery
5. Defining the change detection classes
6. Interpretation of the change detection classes

The first step was to use airborne scanner imagery to understand what the trees, shrubs, grasses, river sand, bare ground and water looked like in the Landsat TM data. The second step was to establish a relationship between the combination of grasses, trees and bare ground etc. and the way these areas reflect sunlight (as measured by the Landsat TM sensor). The third step was to assess whether this relationship was stable, in other words, did a mix of 30% trees and 70% grass in one area of the catchment look the same as an area with 30% trees and 70% grass elsewhere within the catchment? The fourth step was to make the assumption that an area with 30% tree cover and 70% grass cover would reflect sunlight the same way in the mid dry season of 1988 as it did in the mid dry season of 2005. The fifth step was to examine how much the land cover had changed between 1988 and 2005 *i.e.* Did the area that contained 30% tree cover and 70% grass in 1988 now contain 20% tree cover and 80% grassland? Or 50% tree cover and 30% grass and 20% bare soil. The final step was analysis of the land cover changes to gain insight into how different drivers may be influencing land cover change.

A detailed description of the results of the riparian condition assessment is provided in the final report attached. In summary, the study demonstrated that in the period 1988 – 2005, there has been a

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[1] As distinct from Landsat MSS (1972-1988) which has a 80 metre pixel size

[2] Fire frequency analysis was carried out by Peter Thompson from the Cape York Peninsula Development Association

universal increase in woody vegetation density across all sub-catchments, and within all riparian zone categories (i.e. ICZ, ACZ, and FPZ). The fact that we found such a consistent pattern of increased woody vegetation across all riparian sub-categories and across all sub-catchments was quite a surprise, and suggests that there is either some systematic error in our study approach, or that the trends are real, and that there is some broad regional forcing mechanism at play here (e.g. rainfall). Either way, the fact that these results are so emphatic clearly indicates that a much more detailed investigation is warranted, allowing us to a) confirm the trend; and b) investigate the mechanisms driving the observed trends (should they be confirmed).

Key Results
Mitchell Catchment
ICZ

Vegetation change

There was a **net** increase of in-channel vegetation (all classes combined) of 6950 ha over the 17 year interval assessed or 13.5% of the total area of the ICZ (51565 ha). This net gain is comprised of a total increase of 11262 ha of in-channel vegetation, which is offset by a loss (via channel erosion) of 4310 ha of in-channel vegetation over the same period. Hence, there has been a considerable turnover of in-channel vegetation during this period. In annualised terms, the net vegetation increase was 409 ha/yr, or 0.79% of the total area of the in-channel zone.

In-channel Sedimentation

Based on the relative areas of in-channel sand, water bodies and vegetation between the two time slices, there is a clear trend towards net accumulation of sediment within the channel in most sub-catchments and minor net scour in others

The upper Mitchell and the Mitchell fan reach, have both experienced considerable net bar deposition between 1988 and 2005, with net increases of 9.23 km^2 and 3.89 km^2 respectively. The Alice and the Lynd Rivers also experienced considerable net sediment accumulation, with sand bar area increasing 3.69 km^2 and 1.89 km^2 respectively. Both the Walsh and Palmer have experienced net increase in pool area of 0.32 and 0.75 km^2respectively, suggesting there has been net export of sediment from these streams.

In total across the whole Mitchell catchment, there is 17.7 km^2 more bar area in 2005 compared with 1988. In other words, across the Mitchell catchment, there has been an average decline in pool area of 1.04 km^2 per annum over the last 17 years. When converted to a volume, using the moderate 3m estimate of average scour/deposition depth (see Brooks et al., 2008 attached), this represents somewhere in the order of 3.1 M m^3 of excess sediment deposition within the channel per annum over the study period (or a total of 53 M m^3 over the 17 year period).

These data indicate that at the overall catchment level there are some distinct patterns in the way different tributaries are behaving through time. The Walsh and Palmer rivers appear to have experienced a net export of sediment over the last 17 years, possibly reflecting the reworking of mining related sediment pulses delivered to each tributary over the last century. The Lynd and Alice Rivers, on the other hand, would appear to have experienced net sediment accumulation. Without further evidence of sediment sources we can only speculate at this stage on what might be the drivers of these changes, but it is likely a combination of the differing geology and flood regimes in each tributary coupled with the different land use intensity, particularly the grazing and fire regime. The graph shown in Figure 2 suggests that land-use may be an important driver of the observed changes over the study period, if the road/land-use intensity relationship can be further validated – and a causal mechanism derived.

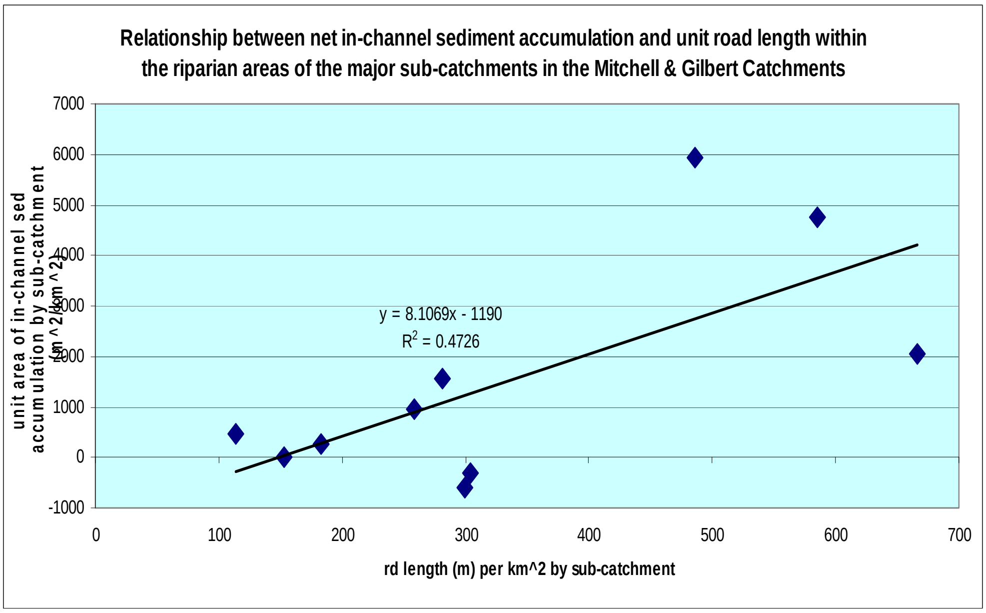

Figure 2 *Relationship between unit road length (i.e. land-use proxy) within each sub-catchment, and net change in pool/bar extent for all subcatchment in the Mitchell and Gilbert Riverss (per unit area). Note that the Mitchell & Gilbert Fans has been left out of the analysis, as it was assumed that this part of the catchment was receiving the cumulative impacts of the upstream contributing sub-catchments, and a direct relationship between fan land-use intensity and channel change, would not be expected.*

FPZ

<u>Vegetation change</u>

Net change towards higher canopy density on floodplains is demonstrated throughout all sub-catchments within the Mitchell. When all the data are aggregated, a total of 2683 km^2 of floodplain (or 13% of the total floodplain area) has experienced a net shift towards a woody vegetation community over the 17 year period 1988 - 2005. If this trend can be independently validated, it represents a significant increase in woody biomass, which could have important implications for ecosystem processes within the Mitchell floodplain.

Gilbert Catchment
ICZ

<u>Vegetation change</u>

As was the case in the Mitchell, the data indicate there has been a large net increase in the area of in-channel vegetation across all sub-catchments. In terms of absolute area this represents a net increase of in-channel vegetation of 12040 ha over the 17 year interval assessed or 19.4% of the total area of the ICZ (62099 ha). This net gain is comprised of a total increase of 16270 ha of in-channel vegetation, which is offset by a loss (via channel erosion) of 4230 ha of in-channel vegetation over the same period. Hence, there has been a considerable turnover of in-channel vegetation during this period. In annualised terms, the net vegetation increase is 708 ha/yr, or 1.14% of the total area of the in-channel zone.

<u>In-channel Sedimentation</u>

Unlike the situation in the Mitchell all sub-catchments within the Gilbert catchment demonstrate that they have experienced a net increase in bar area, and by inference sediment accumulation over the study period. Respectively, the upper Gilbert, the Gilbert fan, and the Einasleigh River sub-catchments have experienced net bar area increases of 7.82 km^2, 7.64 km^2 and 4.68 km^2. The two smaller sub-catchments only contribute an additional 0.44 km^2. In total there is 20.6 km^2 more bar area in 2005 compared with 1988. This represents an annual average increase in bar area of 1.21 km^2. When converted to a volume, using the moderate 3m estimate of average scour/deposition depth (See table 11, Brooks et al., 2008b) scour estimate (see Brooks et al, 2008), this represents somewhere in the order of 3.6 M m^3 of excess sediment deposition per annum over the study period (or a total of 61.8M m^3 over the 17 year period). As outlined previously, there is a need for field validation of the depth of scour data, but, even using the most conservative estimate, there appears to have been a substantial volume of net bed material accumulation over the study period.

FPZ

The considerable changes in floodplain vegetation community density identified for the Mitchell catchment are also apparent in the Gilbert. All sub-catchments experienced increases in canopy cover during the study period, albeit dominated by the more moderate increase/decrease categories. In aggregate, a total of 1090 km^2 of floodplain (or 10% of total floodplain area) has experienced a net shift towards a woody vegetation community during the study period. The same caveats outlined for the Mitchell regarding spatial variability of the trends apply, and hence there is also a clear need for more detailed multi-temporal analysis of the trends to verify the trends apparent in the Gilbert River.

Objective 3: To assess the spatial variability of riparian condition

The analysis described above reports the net changes in riparian vegetation density at the subcatchment scale. An additional analysis was also carried out in which the channel network was broken down into 10km segments and the change reported for the individual segments. As can be seen in Figure 3 – there is spatial variability in the patterns of change, which warrant closer analysis to explain the underlying processes causing these changes.

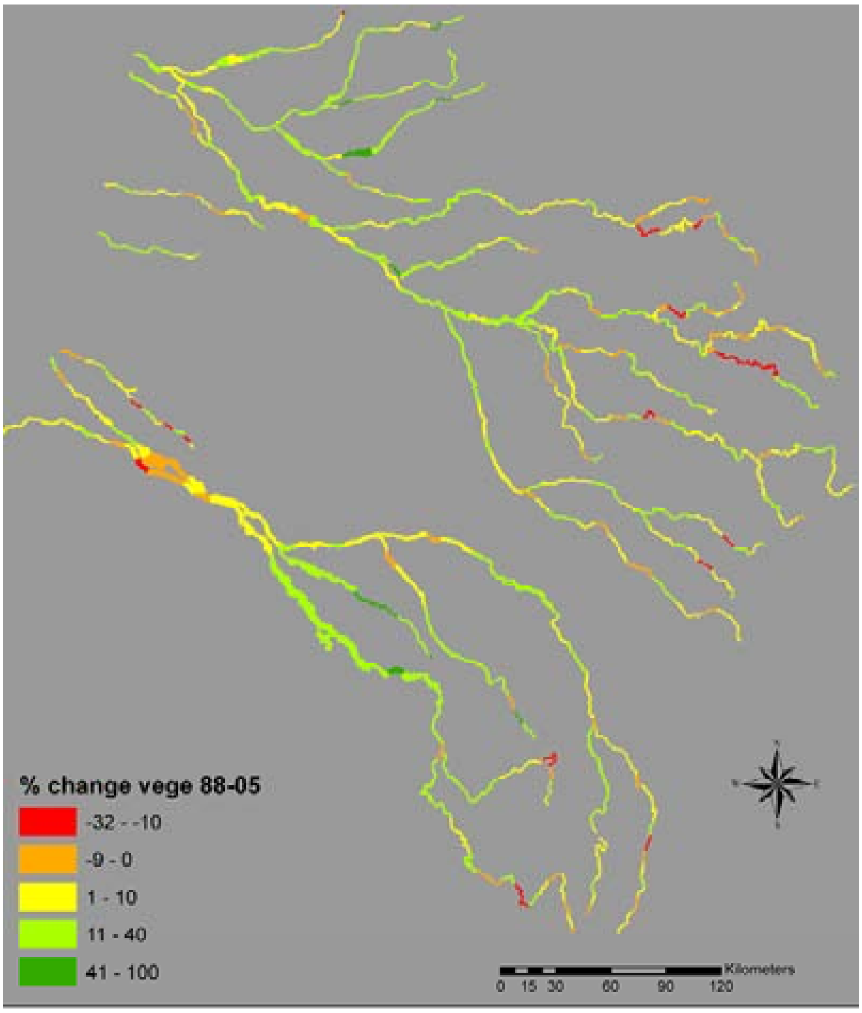

Figure 3 *Map of both the Mitchell and Gilbert River catchments showing the spatial variability of in-channel vegetation change between 1988 and 2005 within the ICZ and ACZ combined.*

Objective 4: To assess the need to modify existing TRARC protocols for Northern Gulf rivers

Limitations were identified with regards the scale of both the catchment and river channel at which TRARC assessment can be effectively used. In large river channels, such as the main stem channel on the Mitchell River, where the in-channel zone may by 2km wide, and highly dynamic, with the low flow channel shifting hundreds of meters in successive years, repeat surveys of transects and quadrats of 100m in length were not going to be of much use for shedding light in trajectories of change, without a bigger picture view as well.

Given this problem, and the need for large numbers of replicate samples for a given channel segment, we concluded that this technique was not very practical in large rivers. It was no longer a "rapid appraisal" technique when 15 or 20 transects were required to adequately represent one channel segment. Nevertheless, multiple transects in a reach can shed light on whether the channel segment was becoming infested with weeds, or provide insights into other higher resolution ecosystem functions not detectable from moderate resolution remote sensing data. Hence, we do not rule out this approach altogether in larger river channels. Ongoing monitoring of multiple transects in a few segments of large channels could be very informative.

However, as a method for undertaking regional assessment of riparian condition in large areas like the Northern Gulf, TRARC is not a practical approach. Rather, TRARC is best focused in particular parts of a catchment, preferably the lower order streams, where it is scale appropriate, and where repeat samples at a site are likely to detect changes associated with, for example, changing land use pressure. As a result, there was no need to modify the existing TRARC protocol, but there was a need to recognise TRARC has a limited application, primarily to upper river reaches where riparian strips manifest in a simple form having a more homogenous structure and forming a patch either side of a stream comprising a single strip of vegetation adjacent to the channel. There will clearly be exceptions to this general rule, as some larger rivers may have a relatively consistent structure, with little by way of structural complexity. Hence, TRARC could be used in these settings, or, as outlined above, in specific sites on larger rivers where the observation of site specific trends might be desirable.

Objective 5: To undertake TRARC assessments in selected reaches of the Gilbert and Mitchell Rivers

Summary of TRARC approach

The status of riparian vegetation at 172 sites in the Gilbert River and Mitchell River catchments was assessed based on the Tropical Rapid Appraisal of Riparian Condition (TRARC) method. The TRARC method provides data on a number of measurable ecological attributes, such as regeneration of native species, weed distribution and intensity, litter distribution, and ground-cover composition. These attributes can subsequently be isolated and examined with regard to their individual effects on Condition. The method provides a quantified score (0-100) with a higher score implying better Condition. As outlined in Milestone 2 (Brooks et al., 2007), the relationship between these scores and some independent measure of "condition" has yet to be established in the Gulf catchments, and as such we will not use the term condition within this report (notwithstanding the fact that the TRARC method implies we are assessing condition). Instead the raw scores alone will be presented. This is not to say that a higher score may not equate to a better "condition", rather that more work is required to clearly establish this relationship against an agreed definition of ecological condition (or indeed some other type of condition). The allocation of scores, however, does allow for comparison between sites, individual streams and catchments. The TRARC method is organized into 24 measurable indicators which are arranged into the four sub-indices of Plant Cover (7 indicators), Regeneration (5 indicators), Erosion (5 indicators) and Weeds (7 indicators). Either a single indicator, a group of indicators or a sub-index can be statistically analysed to estimate their effect on the overall score. In other words, the score of a particular site can be analysed to see which indicator, or indicators, are having the most impact on the overall score, either as a positive or negative aspect.

This project had two primary aims associated with assessing riparian status:

1. to estimate riparian status at a number of specific sites using the TRARC method (Dixon *et al*. 2006) for 172 headwater sites in both the Gilbert River (72 sites) and Mitchell River (100 sites) catchments and provide a rating and analysis of those sites.

2. to test the variability of the TRARC scores for different vegetation cover types [closed forest, open forest, woodland, open woodland] as defined by the remote sensing methodology. Vegetation cover types were determined at 78 sites within the Gilbert River catchment, with 16 closed forest sites, 37 open forest sites, 13 woodland sites and 6 open woodland sites. These vegetation cover class sites will be further developed with regard to spatial analysis independently of the TRARC but with attention to riparian characterisation based on remotely sensed methods.

Results

Riparian status, as estimated by the TRARC method at the 72 sites in the Gilbert River catchment, scored in the 50-79 range at 90% of sites. It was estimated using a Least Square Fit statistical analyses, that scores of the four sub-indices were influencing the TRARC Condition in a statistically significant manner at all 72 sites combined, and therefore no single sub-index could be identified as the primary influence on the TRARC Condition score. However, within the 16 closed forest sites in the Gilbert River catchment, two sub-indices, namely Plant Cover and Regeneration, had a statistically significant effect on the TRARC Condition score, whilst one, Erosion, had a significant effect but otherwise of a lesser impact than the former two sub-indices, and the third, Weeds, had no statistically significant impact on the TRARC Condition score. On the face of it these results appear to suggest that “condition” can be determined simply on examination of Plant Cover and Regeneration factors, whereas Erosion and Weeds are less likely to have an impact on the Condition score. On the basis of the data collected and analysed thus far, such a conclusion, would be an extremely dangerous one to draw from the overall study, given that it is based on a small subset of the overall data, specifically designed to test the variability of a single vegetation class, as defined from the remote sensing data. Furthermore, there are some major issues of scale that are yet to be sorted out regarding the appropriateness of the erosion indices in the savannah environment. If further work was to establish the broader validity of this conclusion, one implication of it is that remotely sensed data, which can only determine Plant Cover with any acceptable accuracy, may therefore be a cheaper and similarly accurate substitute for ground survey Condition assessment such as that provided by the TRARC method.

The TRARC method records the presence and abundance of weeds at a site: The most prevalent dominant weeds recorded at the Gilbert River catchment sites were Rubber Vine (*Cryptostegia grandiflora*) which was recorded at 27 of the 72 sites, Hyptis (*Hyptis suaveoloens*) (6 sites) and Noogoora Burr (*Xanthium occidentale*) (6 sites).

For the 100 sites assessed in the Mitchell River catchment, TRARC Condition scores were calculated in the 50-79 score range for 85% of sites. The Mitchell River catchment sites were in somewhat more heterogeneous habitats than the Gilbert River sites, and the area can be divided into three distinct areas based on rainfall, soil types, topography and land-use regimes. These different conditions are reflected in the allocation of TRARC scores, the distribution patterns of weeds and the varying impact of the indicators used to derive the TRARC Condition score. The most widespread weed was Guinea Grass (*Megathrysus maximus*) which was recorded at 76 of the 100 sites and distributed throughout the catchment study area. Other significant weeds included Noogoora Burr (*Xanthium occidentale*) at 36 sites, Hyptis (*Hyptis suaveolens*) at 32 sites, and Rubber Vine (*Cryptostegia grandiflora*) at 24 sites. These latter weeds were mainly confined to the Walsh River sites. Both Weeds and Regeneration scores were variable across all sites.

For the 16 closed forest sites in the Gilbert River catchment, riparian status scores fell within the 65-100 range. Canopy cover was recorded as approaching 100% thus confirming the prediction by remotely-sensed data that the sites were indeed closed forest. The dominant canopy tree species were She Oak (*Casuarina cunninghamiana*) and Broad-leaved Paperbark (*Melalueca leucadendra*), which together accounted for about 86% of total canopy cover. Other widespread canopy species included River Red Gum (*Eucalyptus camaldulensis*), Narrow-leaved Paperbark (*Melaleuca trichostachya*) and Swamp Oak (*Lophostemon grandiflorus*). Despite the wide-spread distribution of these latter species, they accounted for less than 8% of total canopy cover because of their smaller stature or narrow crowns, or were otherwise very scattered within the catchment. The TRARC scores for the closed forest sites were all within the 65-100 score range [average of 77.15/100] , and were within the upper 40% of scores for the total 72 sites in the Gilbert River catchment [average of 65.87/100].

Objective 6: To assess the appropriateness of integrating a remote sensing approach for assessing riparian condition in the Gulf Savannah Rivers with the existing on-ground survey approach (TRARC).

At the outset of this project it was assumed that TRARC would form the basis for undertaking the ground validation component for remote sensing purposes, and that the insights gained from on ground TRARC surveys would provide a basis for extrapolation of these site-specific findings to much larger areas. Following extensive discussion it was decided that the initial assumption that we could effectively superimpose these two approaches to riparian assessment was constrained by the huge complexity of the riparian landscapes in the northern Gulf. The variability in the landscape meant that huge numbers of TRARC sites (e.g. thousands) would have been required to make it statistically rigorous enough to use these data as a basis for extrapolation across the whole landscape. Furthermore, it was decided that it was probably not the most appropriate method for ground validating the remote sensing analysis given the resolution at which this was carried out. In short, there was a fundamental mismatch in the scale, resolution and objectives of the two approaches. TRARC was primarily designed for establishing the baseline condition at a specific site and monitoring the change through time at that location. In rivers that are relatively homogeneous, the site based transect assessment approach can be representative of the reach. However, in more complex river reaches, typical in the northern Gulf, numerous transects would be required to gain a representative snapshot of the state or condition of a relatively small reach. This is not to say that the two approaches cannot complement one another.

To maximise the benefit to the Northern Gulf – a strategic decision was made to target our on-ground TRARC assessments in headwater areas, at a scale more in line with the scale of river for which the procedure was designed, but also perceived to be at greatest risk from development pressure over the short to medium term. The sites selected constituted a pilot study into the applicability of the TRARC assessment method in the northern Gulf, but in addition were used to test some of the assumptions regarding the variability of particular vegetation classes in the northern Gulf, as mapped in the remote sensing component.

Three areas were targeted for relatively intense on-ground assessment, the upper Walsh River irrigation area, the Upper Mitchell River wet tropics area (Mitchell Catchment), and the upper Einasleigh River (Gilbert Catchment).

In moving away from using TRARC as a method for undertaking ground validation of the RS analysis, a more appropriate ground validation methodology was then designed that better matched the resolution of the remote sensing and enabled more ground to be covered, albeit in less detail. In addition, resources were directed towards the collection of high resolution airborne remote sensing data to augment the ground survey data, and ultimately provided one of the best data sets for validating the remote sensing, across a large enough sample of the landscape to make it statistically viable.

Outline of how outputs can be adopted and summary of communication

The outcomes of this research have already been incorporated into the new Resource Investment Strategy document for the Northern Gulf Resource Management Group (NGRMG). This has come about through our close collaboration with the regional bodies throughout the life of the project, and culminated in the PIs involvement in a strategic planning workshop with the NGRMG in late 2007, and a review of their RIS in early 2008. Several new projects building on this project have been included into the new *Caring For Country* RIS document. A project extending the work undertaken in this project was recently funded through the NGRMGs interim CFOC round.

The outcomes of the work have been presented at a number of community forums over the last two years, including:

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Brooks, A., Knight, J., Spencer, J. and Shellberg. J (2007) "A remote sensing approach to riparian condition assessment in the Northern Gulf region." Presentation to the Northern Gulf NRM Group Annual General Meeting, Mt Surprise, Nov 23 2007.

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Brooks, A., Knight, J., Spencer, J. and Shellberg. J (2007) Presentation at a 2 day workshop for ~ 30 Stakeholders within the Mitchell River catchment on gully erosion and riparian condition assessment in the Mitchell and Gilbert River catchments. Mareeba, Nov. 2007.

Lymburner, L., Dixon, I. Dowe, J. & Burrows, D. (2007) – The application of TRARC in the Gulf Savanna – an overview of results from the Mitchell and Gilbert Catchments. Presentation at a 2 day workshop for ~ 30 Stakeholders within the Mitchell River catchment on gully erosion and riparian condition assessment in the Mitchell and Gilbert River catchments. Mareeba, Nov. 2007.

Brooks, A., Knight, J., Spencer, J. and Shellberg. J (2006) "A remote sensing approach to riparian condition assessment in the Northern Gulf region –Progress report." Presentation to the Northern Gulf NRM Group Annual General Meeting, Undarra, Oct, 2006.

Assessment of commercial potential

The outcomes of this research have significant implications for our understanding of the development potential of Northern Australia (or the limits to development). An understanding of the current landscape status and its response to historical land use pressures \is crucial for our understanding of landscapes and ecosystem responses to future land-use intensification. The tools (and system understanding) developed in this project provide a means for both understanding changes to date and monitoring future impacts in this landscape, be they through direct impacts of resources development or indirect impacts such as climate change.

Outputs and Communication

Publications

Brooks, A.P., J. Spencer, J.G. Shellberg, J. Knight, & L. Lymburner (in press). Using remote sensing to quantify sediment budget components in a large tropical river - Mitchell River, Gulf of Carpentaria. 'Sediment Dynamics in Changing Environments' (Proceedings of a symposium held in Christchurch, New Zealand, December 2008). IAHS Publ. 325, 2008.

Brooks AP, Lymburner L, Dowe J, Burrows D, Dixon I, Spencer J and Knight JM (2008). "Development of a Riparian Condition Assessment Approach for Northern Gulf Rivers using Remote Sensing and Ground Survey. Final Report to Land Water Australia for project GRU 38" Australian Rivers Institute, Griffith University, Nathan, Qld, Australia

Brooks AP, Knight JM, Spencer J, Burrows D, Lymburner L, Dowe J, Dixon I, Douglas M (2007) 'Development of a Riparian Condition Assessment Protocol for Northern Gulf Rivers using Remote Sensing and Ground Survey. Milestone Report 2 to Land Water Australia for project GRU 38.' Australian Rivers Institute, Griffith University, Nathan, Qld, Australia.

Brooks, A.P.; Shellberg, J.G., Spencer, J.; Knight, J (2007) Alluvial gully erosion: a landscape denudation process in northern Australia. Extended abstract for the IV International Symposium on Gully Erosion, Universidad Publica de Navarra, Sept 17 – 19th 2007

Brooks, A., Spencer, J., Knight, J., (2007). Alluvial gully erosion in Australia's tropical rivers: a conceptual model as a basis for a remote sensing mapping procedure. Proceedings of the 5th Australian Stream Management Conference Proceedings, Albury, NSW May 2007

Knight, J., Spencer, J. Brooks, A. & Phinn, S. (2007). Large-Area, High-Resolution Remote Sensing Based Mapping of Alluvial Gully Erosion in

Australia's Tropical Rivers. Proceedings of the 5th Australian Stream Management Conference Proceedings, Albury, NSW May 2007

Spencer, J., Brooks, A.,& Knight, J., (2007). Towards an objective approach for a regional - continental scale geomorphic river classification. Proceedings of the 5th Australian Stream Management Conference Proceedings, Albury, NSW May 2007.

Lymburner, L., Brooks,A., Burrows,D., Dowe, J. Spencer, J. and Knight, J.. 2008. Assessing Riparian Condition in the Northern Gulf Catchments. Presentation at 1-day workshop on aquatic research needs hosted by the Burdekin Dry Tropics NRM Board, Townsville, 31 January 2008.

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Appendix 1

Original Objectives as identified in the proposal

Given the importance of riparian zones to regional ecosystems and economies (through the ecosystem services they provide) the aims of this project are as follows:

1. To develop a robust definition of the extent of the effective riparian zone for different river reach types (i.e. geomorphic reach classes) in the Northern Gulf Region

   Modified to : 1. To develop a definition of the extent of the riparian zone applicable to the Northern Gulf Region (Mitchell and Gilbert Catchments).

2. To identify a small set of metrics for quantifying riparian condition, that can be measured using remotely sensed data (e.g. 4 – 6 parameters)

   Objective deleted.

3. To develop a broad scale method appropriate for the Northern Gulf region for quantifying riparian condition using remote sensing techniques

   Objective unchanged.

4. To assess the extent to which these metrics vary with geomorphic river reach type

   Modified to: 3. To assess the spatial variability of riparian condition

5. To identify reference reaches for the various reach types in the Northern Gulf region

   Objective deleted.

6. To assess the need to modify existing TRARC protocols for the different river reach types found in the Northern Gulf region

   Objective unchanged.

7. To undertake TRARC assessments using a spatially stratified sample design based on reach geomorphology in the Mitchell and Gilbert Rivers

   Modified to: 5. To undertake TRARC assessments in selected reaches of the Mitchell and Gilbert Rivers

8. To provide an example of a fully integrated remote sensing/on-ground survey approach for assessing riparian condition in the Gulf Savannah.

   Modified to: 6. To assess the appropriateness of integrating a remote sensing approach for assessing riparian condition in the Gulf Savannah with the existing on-ground survey approach (TRARC).