Development of information products for rangeland managers

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Development of Information Products for Rangeland Managers

NHT Project 953024

A contract with Agriculture Western Australia to develop and recommend methods for the summary and presentation of Landscape Function Analysis (LFA) data for the Western Australian Rangeland Monitoring System (WARMS)

April 2001

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Executive Summary

Recommendations for LFA data presentation in standard WARMS reports and for interpreting change in LFA data at the site scale.

1. Group WARMS vegetation types and pasture groups into five main country-types based on vegetation structure and main mode of resource control: hummock grassland, tussock grassland, southern sandplain, shrub-steppe and mulga hardpan.

2. Classify each patch-type as resource-capturing or resource-shedding based on definitions provided in this report.

3. From each transect log, calculate a resource-capturing index as one of the key indicators of landscape function. RC Index = Σ length of resource-capturing patches/total transect length

4. Calculate site-scale LFA indicators (stability, infiltration and nutrient cycling) based on proportional lengths of patch-types and respective LFA ratings for each patch-type.

5. Replace existing WARMS presentations of landscape function with a more visual product. Examples of suggested presentations are provided in Appendix 2

Recommendations for summarising, presenting and interpreting LFA change data at the vegetation community / district level.

1. Examples of suggested summary tables and graphical presentations based on vulnerability of the site to disturbance and changes in RC index and/or stability rating are presented.

2. An interpretive matrix is provided based on the RC index and Stability rating.

Plotting the regional/vegetation type LFA profiles for WA rangelands and recommendations on the importance of completing the curves for particular vegetation types.

1. Some weak linear relationships, but no sigmoidal relationships, were found between LFA ratings and disturbance indicators of distance from water, grazing intensity and RC index.

2. It is unlikely that any further analysis of WARMS data using available indicators of disturbance will greatly strengthen the relationships presented in this report.

3. More sophisticated independent indicators of disturbance are required which could include stocking histories associated with particular sites, selected to cover the range of LFA ratings and RC indices. The likely success of such an

approach is problematic, especially given the very limited success of the approach tested here and is not recommended.

4. Meanwhile, the approach adopted in this report based on frequency distributions of sites is a reasonable first pass and will suffice until more data becomes available or alternative approaches are identified.

Recommendations for frequency of LFA recordings.

1. Landscape function be assessed at each scheduled sampling i.e. every three to four years on grassland sites and every five to six years on shrub-steppe sites.

Recommendations for cutting down the LFA sampling set.

1. Consider discontinuing infiltration/runoff and nutrient cycling ratings and specific soil surface assessment attributes associated with these ratings i.e. perennial plant cover (grassland), soil cover – flow (shrubland), litter source, litter incorporation, microtopography and soil texture.

2. Soil surface assessment be restricted to resource-shedding patches (fetch) in both grassland and shrubland sites.

3. Greater attention be given to classifying and logging patches as resource-capturing and resource-shedding based on the definitions provided. All significant fetch zone – types to be logged and sampled.

The relationship between LFA and vegetation data.
Importance of testing relationships between species composition and LFA.

1. Frequency cannot be used in place of transect logging to establish the RC index.

2. Higher frequencies are associated with higher stability and infiltration ratings on tussock grassland as expected, and in these situations provide complementary information.

3. In general, shrub density provides complementary information on landscape function, however this information is not sufficiently robust to be used with confidence in reporting landscape function.

4. A provisional framework for interpreting change in species composition and trends in landscape function is provided.

5. Two simultaneous sets of data are required to report change for pastoral purposes, one set dealing with landscape function and the other with vegetation change. While some inferences may be made between these data sets, these two data sets should be assessed and reported independently.

6. Mounting a major research program to investigate relationships between species composition and landscape function is not recommended.

Contents

Contract Brief:

The following tasks will be reported in a single document, which will act as the contract report and its delivery will be considered the final milestone.

These tasks will be reviewed during the term of the contract, and the detail may be amended, on the basis of recommendations from Dr Holm and in discussion with Dr Watson.

The tasks apply to both WARMS SHRUBLANDS and GRASSLAND sites, although in many cases the findings will be identical.

1) Recommendations for LFA data presentation in standard WARMS reports (i.e. as produced by WARMS database).

1a) set of MS ACCESS queries to extract data as per recommendations in 1).

2) Recommendations for interpreting change in LFA data at the site scale. These will be in the form of a set of “rules” weighting the relevant importance of various LFA attributes recorded.

3) Recommendations for summarising, presenting and interpreting LFA change data at the vegetation community / district level. Examples of such presentation will be included.

4) Discussion of the relationship between LFA and vegetation data. Are they indicating complementary changes, reinforcing similar interpretations or providing information on different parameters?

5) Consider Tongway and Hindley's Audit recommendations in the context of WARMS. How would one go about plotting the regional/vegetation type LFA profiles for WA rangelands as Tongway and Hindley suggest? (AGWEST to supply Dr Holm with a copy of Tongway and Hindley’s report, 2000).

6) Recommendations for how frequently LFA should be recorded within each of the WARMS groups.

7) Recommendations for cutting down the LFA sampling set. For example, can 20% of the attributes assessed give us 80% of the information required to show change?

8) Express some written views on how important it is to test the relationship between species composition and LFA. If, after discussion between the Contractor and the AGWEST Officer it is considered this is an important research question - draft a 1-2 page Preliminary Research Proposal for AGWEST to progress.

9) Based on 5 above, provide some recommendations on the importance of completing the curves for particular vegetation types. If, after discussion between the Contractor and the AGWEST Officer it is considered this is an important research question - draft a 1-2 page Preliminary Research Proposal for AGWEST to progress.

General approach

WARMS and grassland data were provided by AGWEST in MS Access format.

Data was generally accepted as correct, however several errors were detected and corrected during processing and Mr Philip Thomas advised.

In developing the suggested products I produced several tables in MS ACCESS as examples of query outputs. My approach to MS ACCESS queries is a stepwise process that does not lend itself to generation of one-pass query statements. Therefore, I have not attempted to provide the queries themselves but have provided detail on how the outputs are produced.

The outputs and tables are provided as examples, they are derived from 'real' data but have not been checked and will contain errors. All outputs and tables should therefore be rebuilt.

Statistical analyses were performed using SSPS (SPSS Inc, 1999) and graphs were produced either in SSPS or in Sigma Plot.

Copies of all relevant outputs and tables are provided on CD.

Recommendations for LFA data presentation in standard WARMS reports.

Defining reporting groups

Monitoring sites have been classified on the basis of pasture groups (e.g. MSGF – mulga short grass forb and WARMS groups (EB9 – mulga shrubland). These groupings were used to allocate sites to the following broad country types (based on structural form of the vegetation (e.g. clumps or groves) and transport mechanisms.

Table 1: Recommended country-type groups for landscape function reporting

Country type	Landscape characteristics
Southern shrubland	
Sandplain	Individual shrubs and trees, clumps of shrubs and trees, perennial grasses and/or spinifex. High infiltration rates with little overland flow
Shrub-steppe	Individual shrubs of clumps of shrubs, usually with few trees. Sheet flow and wind transport.
Mulga hardpan	Groves of shrubs and trees, individual shrubs and trees. Sheet flow, broad drainage flow zones.
Grassland	
Tussock grassland	Individual tussocks or clumps of tussocks, few to many trees.
Hummock grassland	Spinifex often with other perennial grasses, usually on deep sandy soils.

Sites were allocated to these major groups, firstly on the basis of WARMS groupings as shown in Table 2. Secondly, pasture groups were also allocated to country types and used to modify the primary allocation. For example, sites allocated to WARMS group EB9 contained sites on wandarrie banks, which were reallocated to 'sandplain'. Many sites were not classified either by WARMS group or pasture group. I used transect data to classify some of these sites.

MS ACCESS table : alecpasture_groups.table

Defining patch types

Resource-capturing patches consist of perennial plants –living, standing dead and fallen dead. The resource-capturing patches are the soil-surface footprints below these plants where nutrient cycling is active, water infiltrates, and organic matter and soil nutrients are concentrated. These patches maybe single plants, clumps, mats and groves. Resource-shedding patches are the interspaces between the resource-capturing patches where resources are more or less uniformly distributed. Annual species dominate these patches. Measures of landscape patchiness have been shown to provide good indicators of landscape function whereby loss of resource-capturing patches often leads to loss of resources from the landscape, especially in non-resilient landscapes.

Table 2: Allocation of WARMS groups to country types

WARMS Group	Description	Country type
EB1	Spinifex grassland	Hummock grassland
EB2	Salt lakes, rocks and heath	
EB3	Short bunch grass savanna	Tussock grassland
EB4	Chenopod shrubland	Shrub-steppe
EB5	Other Acacia woodland	Sandplain
EB7	Eucalypt chenopod shrubland	Shrub-steppe
EB9	Mulga shrubland	Mulga hardpan
EB10	Nullarbor	Shrub-steppe
NB1	Inaccessible hills, mud flats	
NB2	Frontage grass	Tussock grassland
NB3	Curly spinifex	Tussock grassland
NB4	Pindan	Tussock grassland
NB5	Mitchell grass	Tussock grassland
NB6	Limestone grass	Tussock grassland
NB8	Soft spinifex grassland	Hummock grassland

WARMS assessors have used a plethora of terms to describe patch-types (108 terms!). Several of these, especially pre-1997, are ill-defined, for example ‘soil surface and grass’. I allocated each of these terms to either resource-capturing patches or resource-shedding patches

MS ACCESS tables : ALEC_SOIL_CODES.

Calculation of site index of resource-capture

I summed intervals of resource-capturing and resource-shedding patches from transect logs to obtain resource-capturing indices for each site:

Resource-capturing index = Σ Length of resource-capturing patches/Total transect length.

MS ACCESS tables: alec_rc_w; alec_rc_g

Calculation of LFA ratings for patch and site

Mean LFA ratings of stability, infiltration/runoff and nutrient cycling were calculated for resource-capturing and resource-shedding patches on each site, using modified MS ACCESS queries.

MS Access table alec_ratings_patch_g and alec_ratings_rc_patch_w

These LFA ratings were combined into site ratings by pro-rata based on the resource-capturing index for each site.

Site LFA ratings (stability, infiltration, nutrient cycling) = LFA rating resource-capturing patches X resource capturing index + LFA rating resource-shedding patches X (1-resource capturing index).

Note, resource-capturing patches are not generally sampled in Grassland sites and site LFA ratings were not calculated.

MS ACCESS table: alec_ratings_rc_site_w

Distribution of LFA ratings and resource-capturing indices

LFA ratings and resource-capturing indices for each date of recording were plotted as frequency histograms (Figures 1-6). All LFA ratings were normally distributed, while resource-capturing indices were strongly skewed in that there were far more sites with low scores. Distribution patterns for WARMS sandplain and mulga-hardpan country-types were similar and these have plotted together.

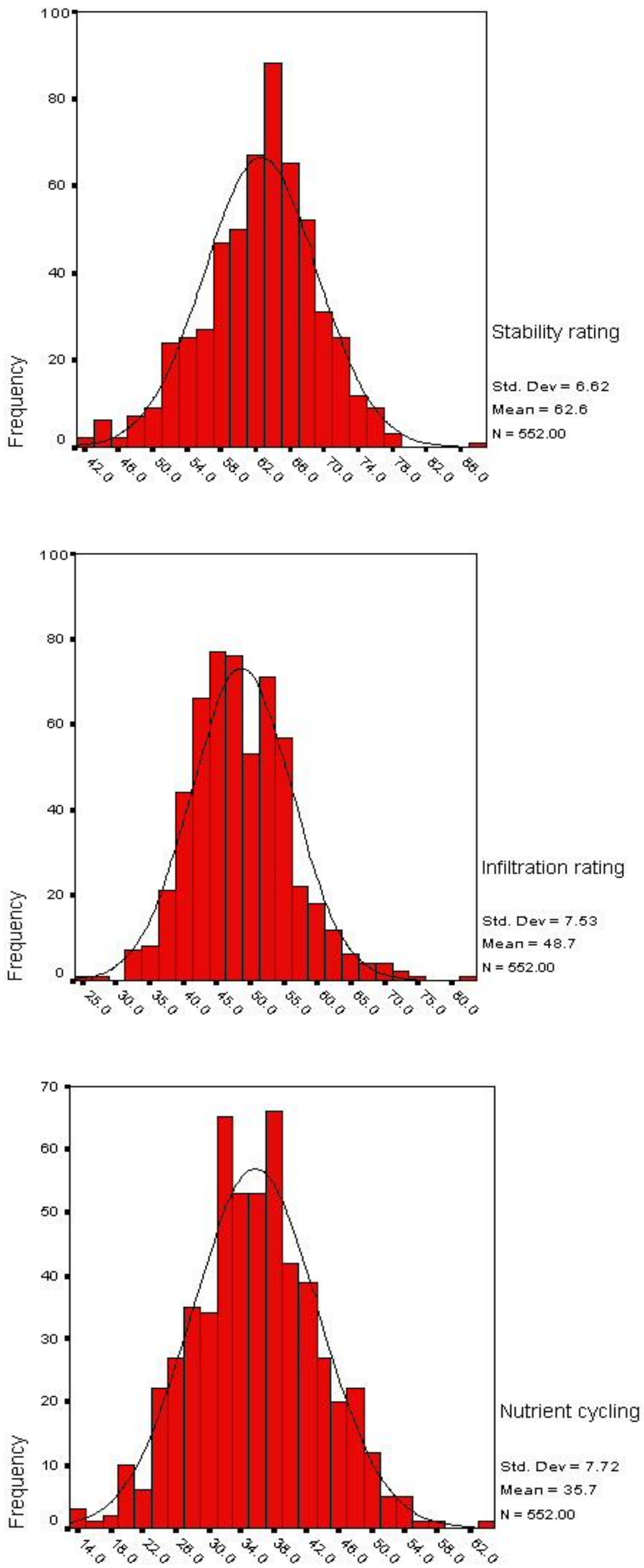

Figure 1: Frequency distribution of LFA ratings for shrubland monitoring sites – shrub steppe country type

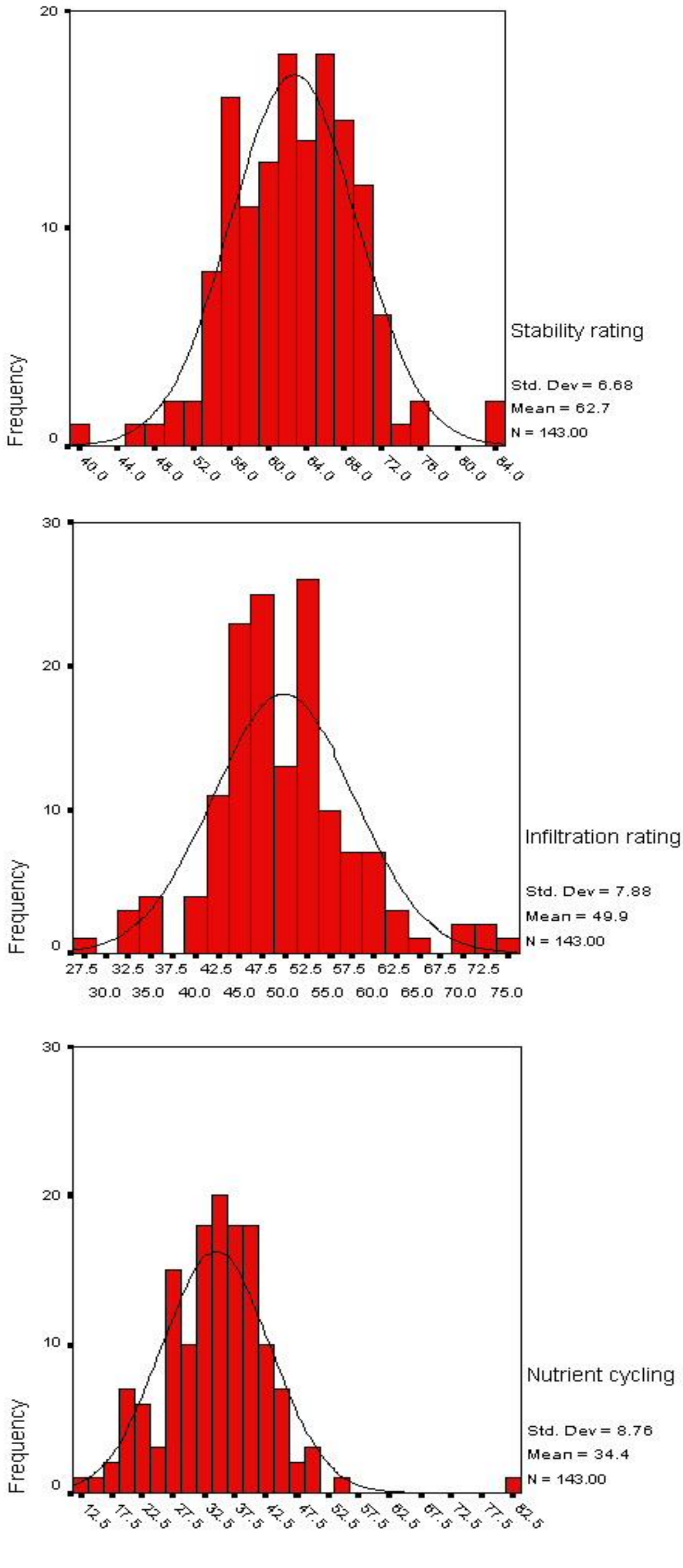

Figure 2: Frequency distribution of LFA ratings on shrubland sites – sandplain and mulga

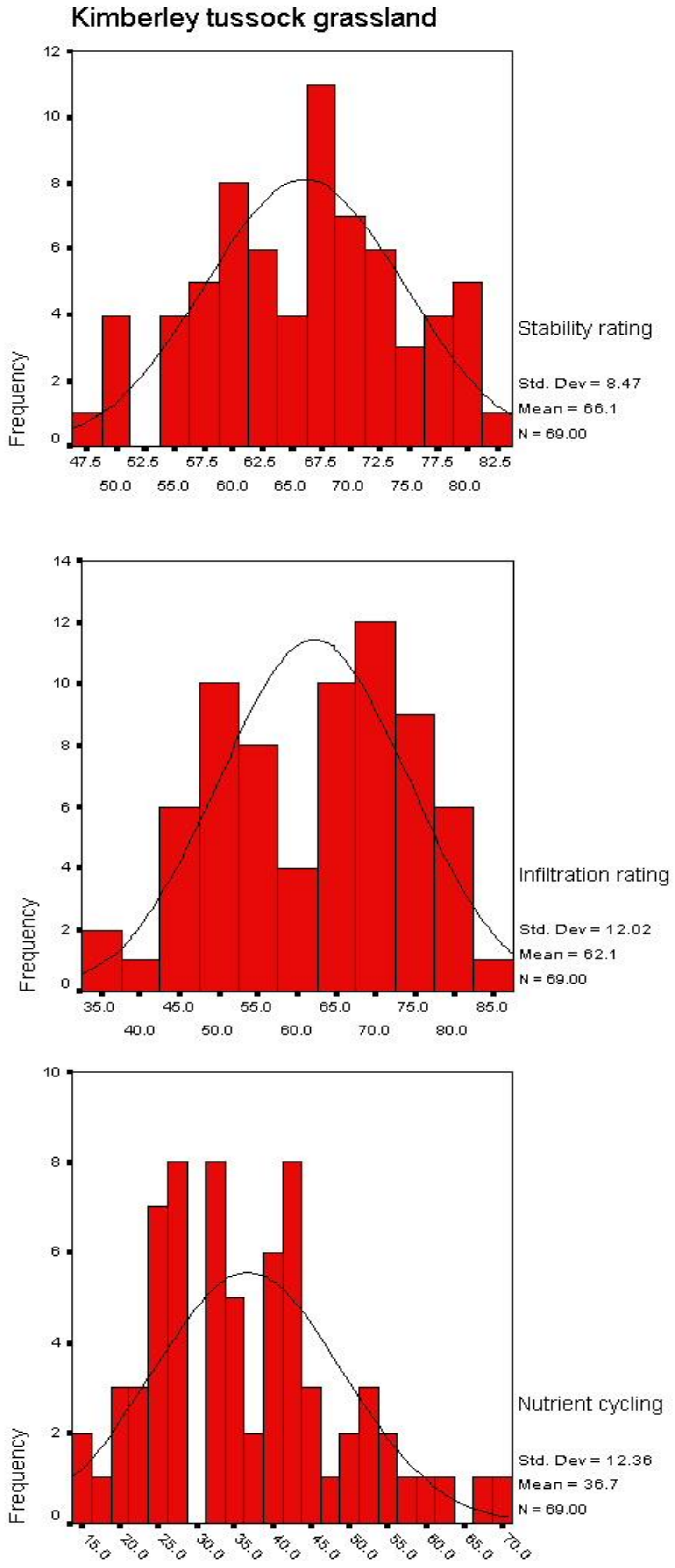

Figure 3: Frequency distribution of LFA ratings on Kimberley sites - tussock grassland

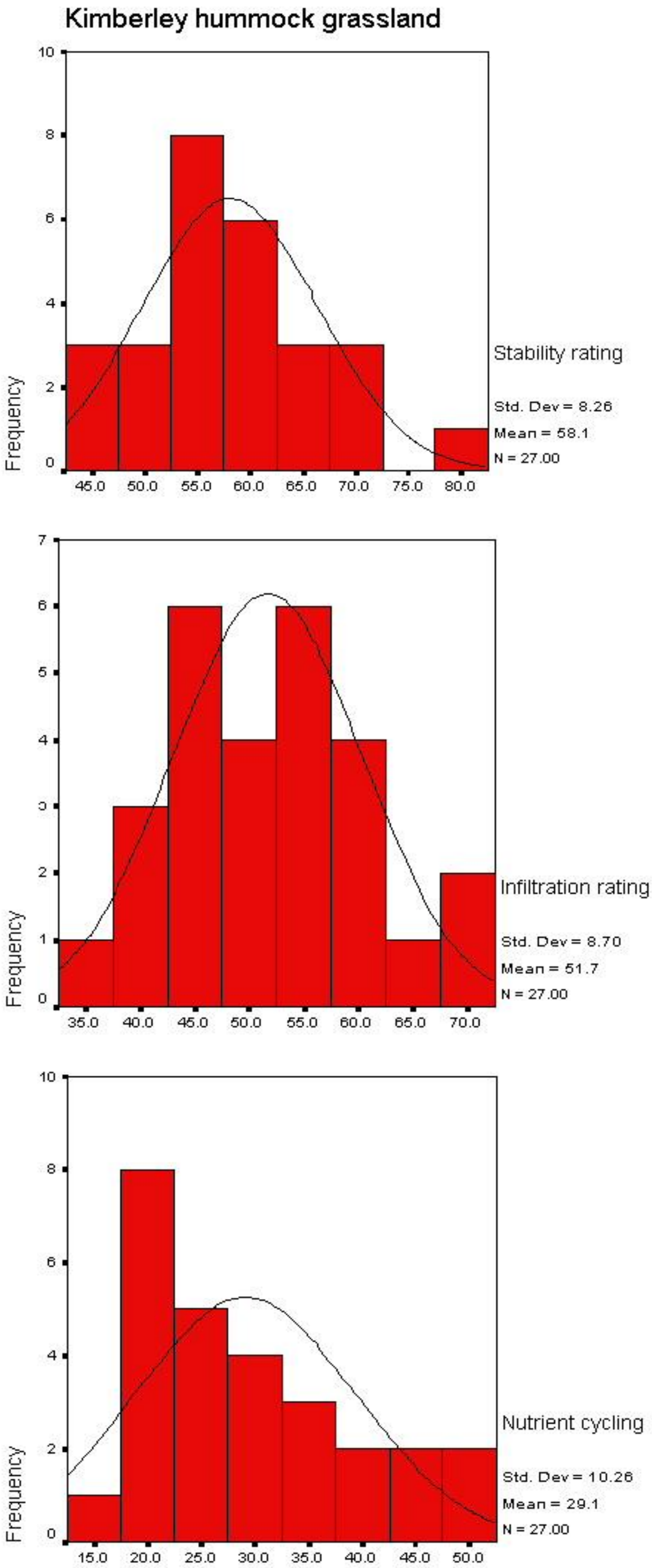

Figure 4: Frequency distribution of LFA ratings for Kimberley sites – hummock grassland

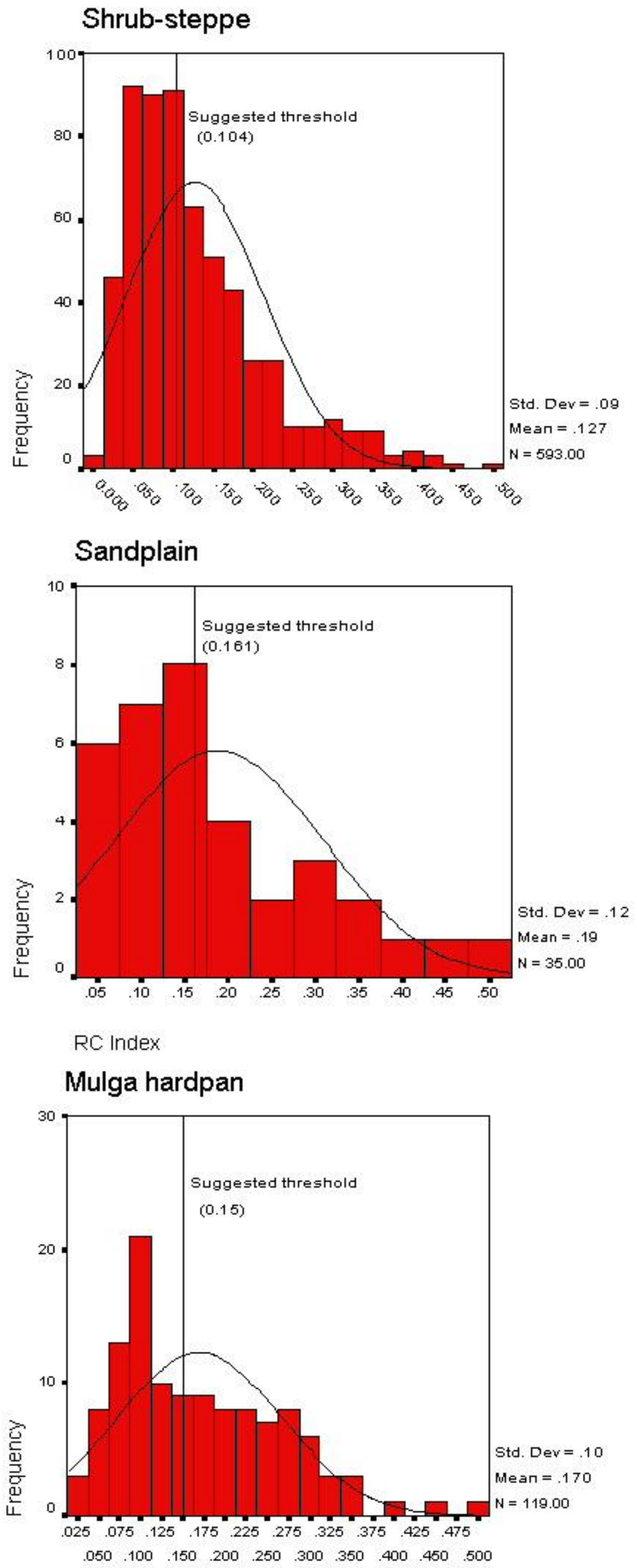

Figure 5: Frequency distributions of resource-capturing indices (RC index) on southern monitoring sites.

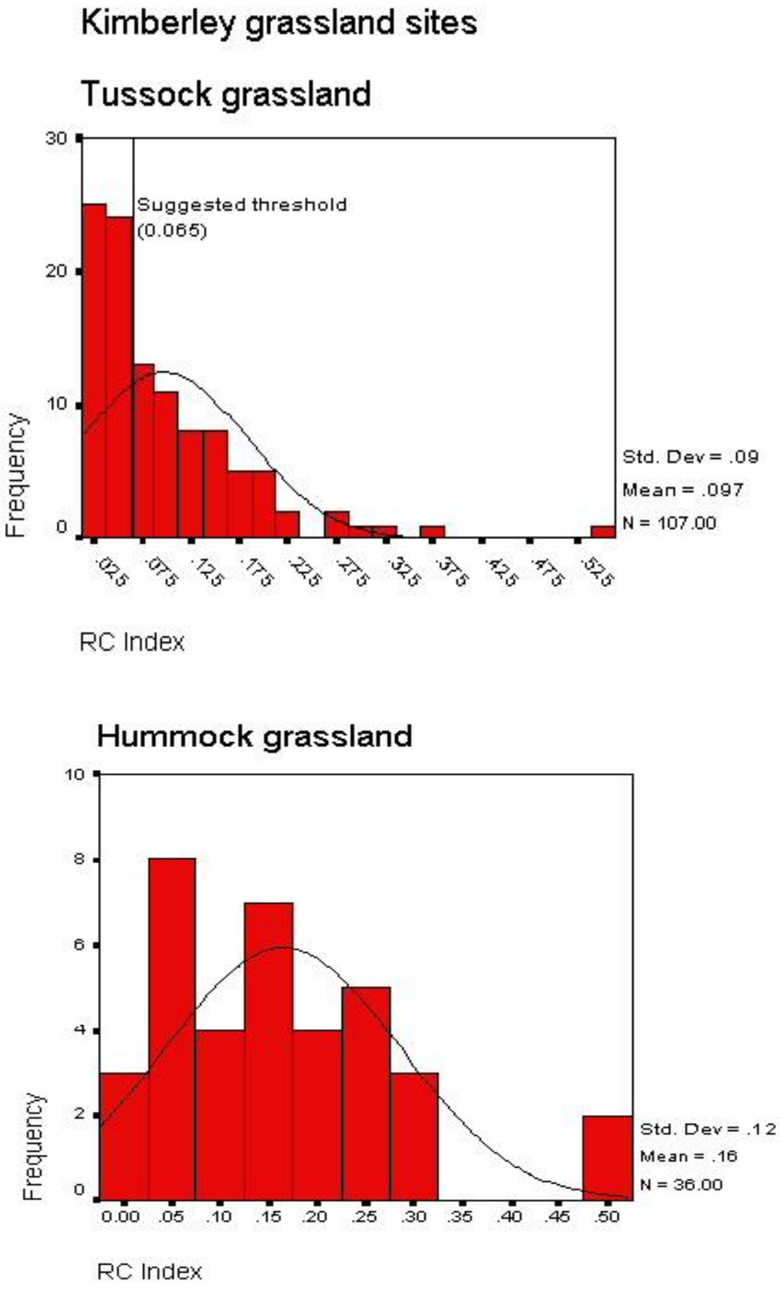

Figure 6: Frequency distributions of resource-capturing indices (RC index) of Kimberley sites

Recommendations for interpreting change in LFA data at the site scale.

Background

Landscape function at the site-scale maybe inferred from both LFA ratings (stability, infiltration/runoff and nutrient cycling) and indices of resource-capture. Additional information maybe derived from density of shrubs or frequency of perennial grasses, and this will be discussed under point 4. I suggest that temporal variability of each of these ratings and indices is likely to be significantly different and will influence how change is interpreted (Table 3)

Interpretation of change in nutrient cycling rating is likely to be seasonally dependent and highly uncertain, especially with infrequent sampling. I therefore recommend that less importance be given to change in nutrient cycling ratings.

Infiltration rating depends on soil texture and slaking (largely invariant), microtopography (uncertain properties under grazing or other disturbance), soil cover (related to resource-capturing index but confounded by inclusion of rocks and other invariant features), and litter cover (seasonally dependent). While the infiltration rating for the site provides useful information on how the site might respond to rainfall, it is difficult to interpret change in this rating. Again, I recommend less importance be given to change in infiltration rating.

Stability rating is composed of several indicators that are related to grazing in complementary ways and with similar temporal variance. I recommend greater importance be given to change in stability rating.

As mentioned before, grazing directly influences change in RC index. However, these changes must be interpreted within a broad-scale understanding of structural transitions such as change from grassland to shrubland or fine-scale shrubland to coarse-scale shrubland. Thus grazing may initially result in loss of perennial shrubs or grasses and consequent decline in RC index. Subsequently however, these degraded landscapes may be resorted at broader scales, associated with ingress of other species, and the restoring of RC index and landscape function.

A framework to interpret change in landscape function is recommended based on the RC index and stability rating (Table 4). Interpretation is maybe aided by vegetation information, which is discussed later.

Change is arbitrarily (but leniently) defined as greater than one standard deviation difference in either RC index or stability rating between sampling dates.

All sites that were below both the median RC index and Stability rating were classed as vulnerable to disturbance while others were either less vulnerable or resilient to disturbance.

MS ACCESS tables: alec_rc_ratings_w; alec_function_dens_change_9500;

Table 3: Likely temporal variability in ratings and indices of landscape function and soil surface indicators

Landscape function indicators	Temporal variability	Comment
Resource-capturing index	Very low	Trends evident >5 years – changes grazing induced
Ratings:		
Stability	Low	Soil and litter cover variable other soil surface factors much less variable
Infiltration/runoff	Low	Litter cover variable, others much less variable
Nutrient cycling	High	Especially on resource-shedding patches
Soil surface indicators		
Soil cover (interception)	Moderate	Related to RC index and to seasonal conditions
Soil cover (overland flow)	Low	Related to RC index but also includes rocks and other invariant objects
Crust broken-ness	Low-moderate	Probably influenced by grazing
Cryptogam cover	Low-moderate	Influenced by grazing, confounded by litter (ie high litter – low cryptogams)
Erosion features	Low	Grazing induced
Eroded materials	Low	Grazing induced
Litter cover	High	Seasonally dependent
Litter origin	High	Seasonally dependent
Litter incorporation	Low – moderate	Disproportionate effect on rating
Soil microtopography	Low	Largely invariant, some grazing impact
Surface nature	Low	Uncertain relationship to grazing or other disturbance
Slake test	Very low	Grazing exposes sodic soils
Soil texture	Very low	Mostly invariant.

Table 4 An interpretive framework for assessing change in landscape function

Stability rating	RC index		RC index	
	Low -	-ve change*	Medium-high	- ve change
Low	Highly vulnerable to further disturbance	Requires urgent remedial action	Moderately vulnerable to disturbance	Alert – precautionary action recommended
High	Degraded but stable and probably productive	Alert – precautionary action recommended	Stable	Noted

* Negative change in either or both stability and RC index. Contradictory changes are less urgent.

Thresholds in landscape function

Later in this report (point 5/9) I investigate sigmoidal response curves in landscape function as suggested by Tongway and Hindley (2000). No significant relationships were established. Alternatively, I have suggested thresholds for the main country types based subjectively on the frequency distributions. These thresholds are provisionally set at the modal value (e.g. Figure 5 and Figure 6).

Presentation of landscape function data at site-scale

I recommend existing WARMS presentations of landscape function be replaced with a more visual product. Examples of suggested presentations are provided in Appendix 2

Recommendations for summarising, presenting and interpreting LFA change data at the vegetation community / district level.

Summary tables and graphical presentations based on vulnerability of the site to disturbance and changes in RC index and/or stability index are proposed.

I suggest the data be presented within the five structural country types (southern sandplain, shrub-steppe, mulga hardpan, hummock grassland communities and tussock grassland). Data maybe further sub-divided at district levels when sufficient sites have been re-sampled, although it is possible to allocate all sites to vulnerability classes on the basis of one sampling.

An example presentation for the southern rangeland is presented in Table 5. Sites shown as changing significantly, were those with changes greater than one SD in either RC Index or stability rating.

MS ACCESS tables: alec_rc_ratings_w; alec_function_dens_change_9500; alec_regionalsummary_w

Table 5 Landscape function status of WARMS sites in southern rangeland of Western Australia sampled between 1995 and 2000 and trends in landscape function of re-sampled sites

	Total sites	Vulnerability of site to disturbance				Re-sampled 1999/2000		Significant change
		Moderate to High		Low or stable				
	Number of sites and percentages							
Sandplain	35	13	37%	22	63%	8	23%	2 (25%) ↑ 6 (75%) NC
Shrub-steppe	593	187	32%	406	68%	19	3%	2 (10%) ↑ 1 (5%) ↓ 16 (85%) NC
Mulga hardpan	119	35	29%	84	71%	10	8%	1 (10%) ↓ 9 (90%) NC

A suggested graphical presentation of this same data is provided in Figure 7. In this presentation, sites are arranged along the X axis 1) within broad categories of vulnerability to disturbance based on Table 4, modal thresholds in RC Index and Stability rating were used to establish the four categories; and 2) by ranking on RC index – i.e. lowest ranking sites to the left.

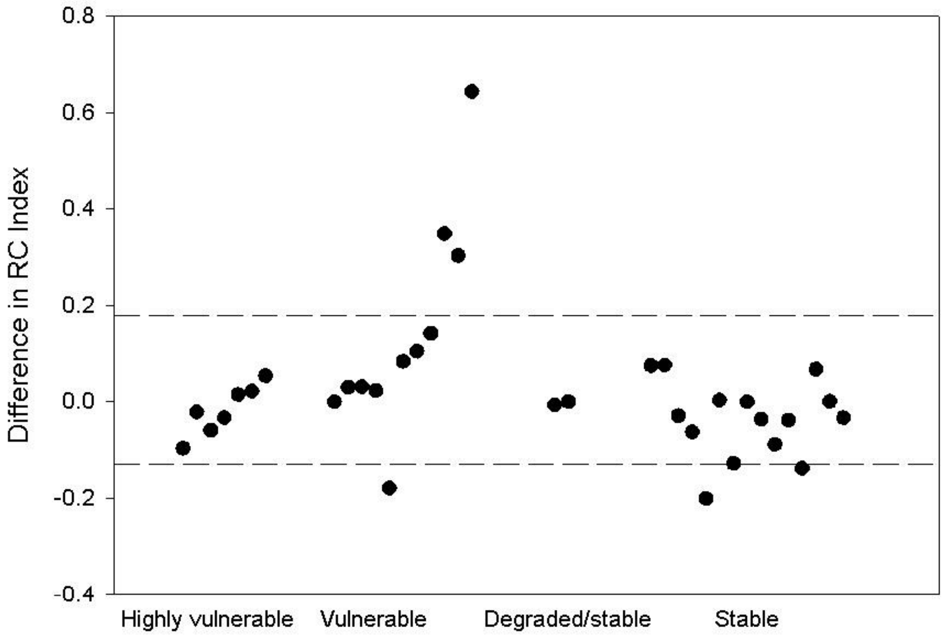

Figure 7: Regional trends in landscape function (differences in resource-capturing index) in monitoring sites in the southern rangeland. Sites are arranged along the X axis from most to least vulnerable to disturbance. Sites changing greater than one SD (dotted line) are considered to have changed significantly.

Plotting the regional/vegetation type LFA profiles for WA rangelands as Tongway and Hindley suggest and provide recommendations on the importance of completing the curves for particular vegetation types

Background:

Tongway and Hindley (2000) suggest that 'establishing the changes in landscape function in response to change of stresses and disturbances, in the form of a landscape function curve, is of paramount importance.' Further, they suggest that sigmoidal response curves be fitted to establish thresholds where there are sharp discontinuities between landscape function and disturbance. Such thresholds are intuitively appealing and have been suggested for several years (Friedel, 1991), but there has been no progress on their derivation. Attempts to relate LFA ratings to various disturbance indicators (soil nutrients and RC index) in Western Australian rangeland have been previously unsuccessful (Holm *et al.*, 2001). On the other hand, there was a significant relationship between soil nutrients and RC index in this study, however this was not sigmoidal.

Approach

One of the difficulties in attempting to derive these relationships between disturbance and landscape function, is to quantify 'disturbance' in non-experimental situations.
For this report, I used data from the WARMS sites to establish RC index, frequency of perennial grass, (both log transformed), distance from water, and a derived index of grazing intensity (10/distance from water squared) as surrogates for disturbance from grazing, and plotted these against LFA ratings. I also examined the relationship between RC index and the other surrogates of grazing intensity. Both linear and sigmoidal relationships were examined. I also used multiple regression approaches using country type, RC index, frequency or shrub density, grazing intensity and salinity of water as the variables likely to affect each of the LFA ratings

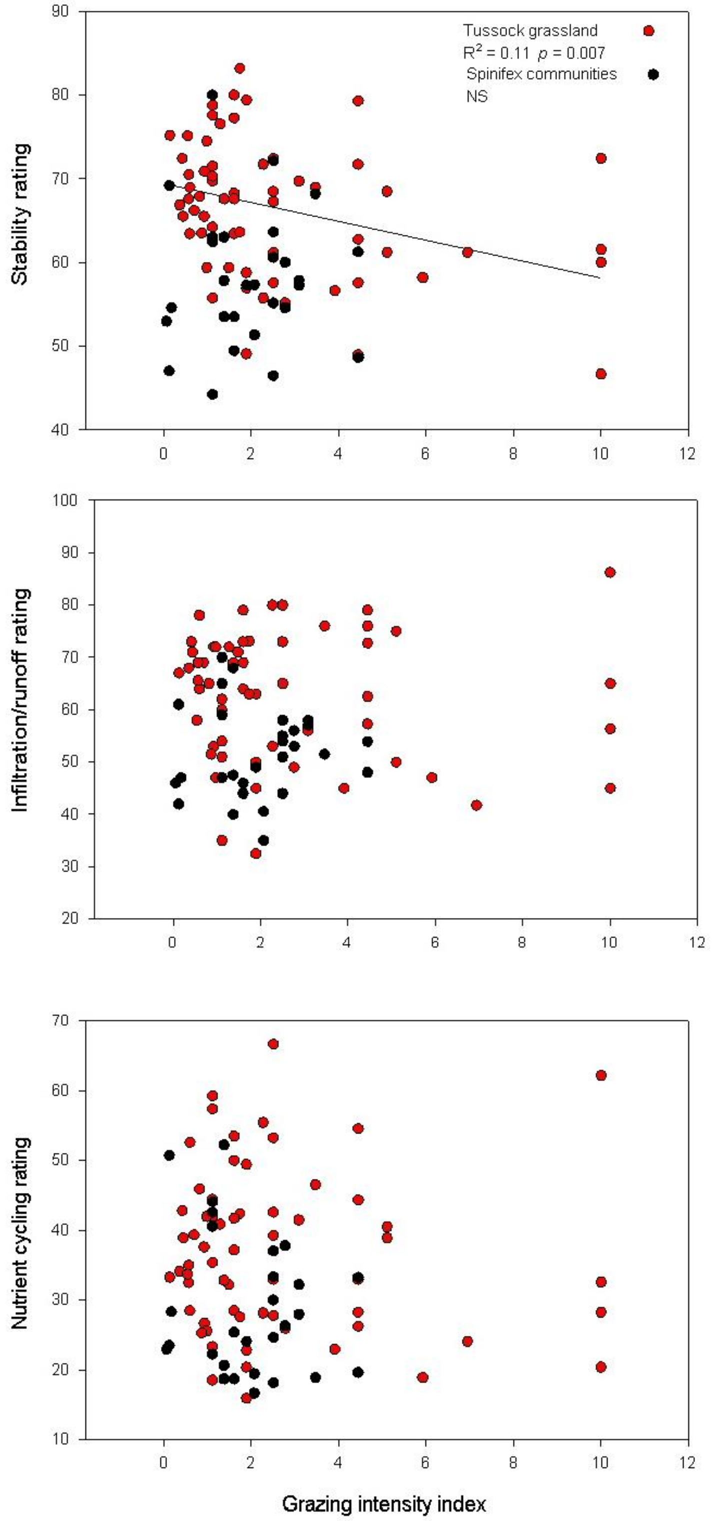

Figure 8: Relationship between LFA ratings and grazing intensity (10/distance from water squared) for Kimberley grassland sites

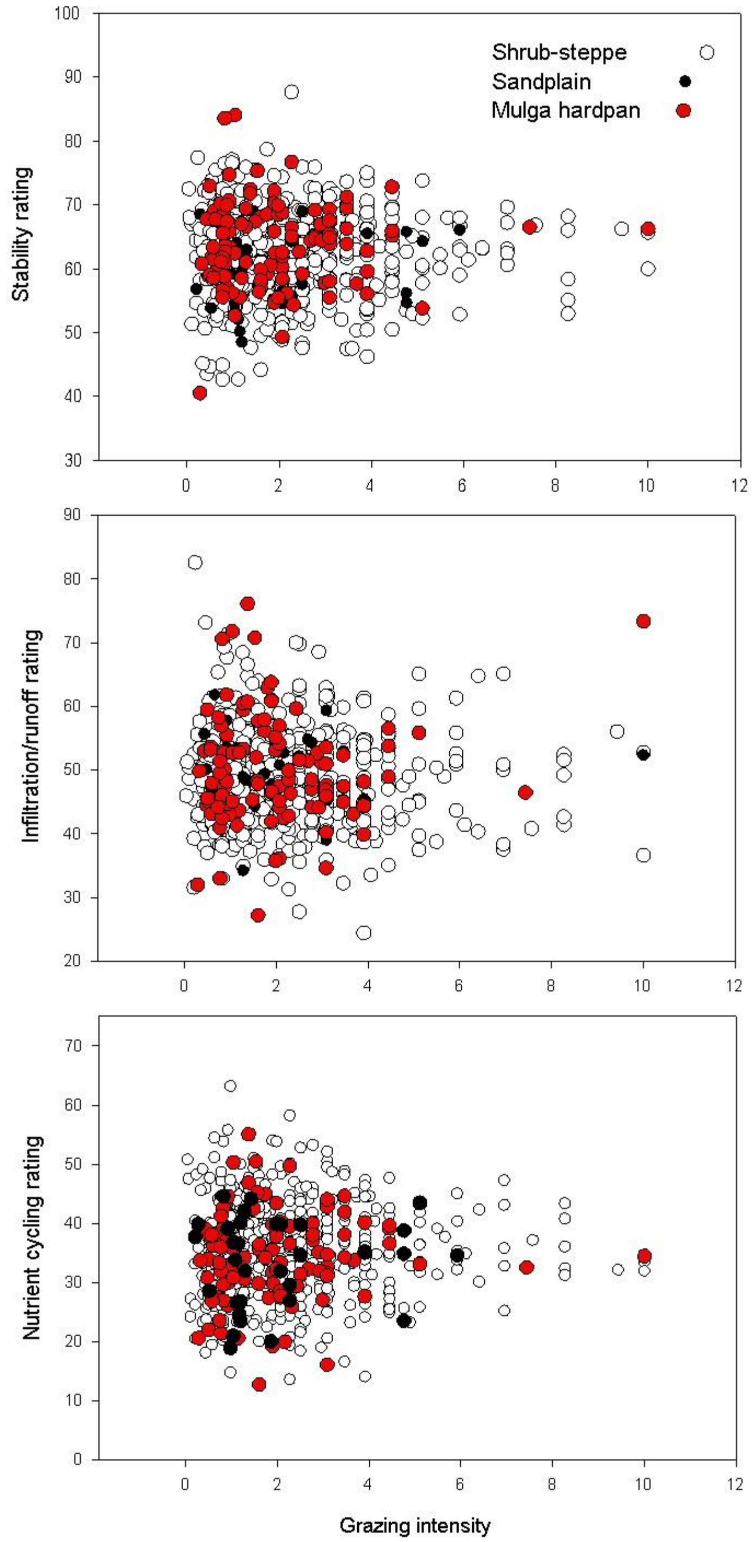

Figure 9: Relationship between LFA ratings and grazing intensity (10/distance from water squared) for shrubland monitoring sites in southern rangeland. Some extreme values not shown.

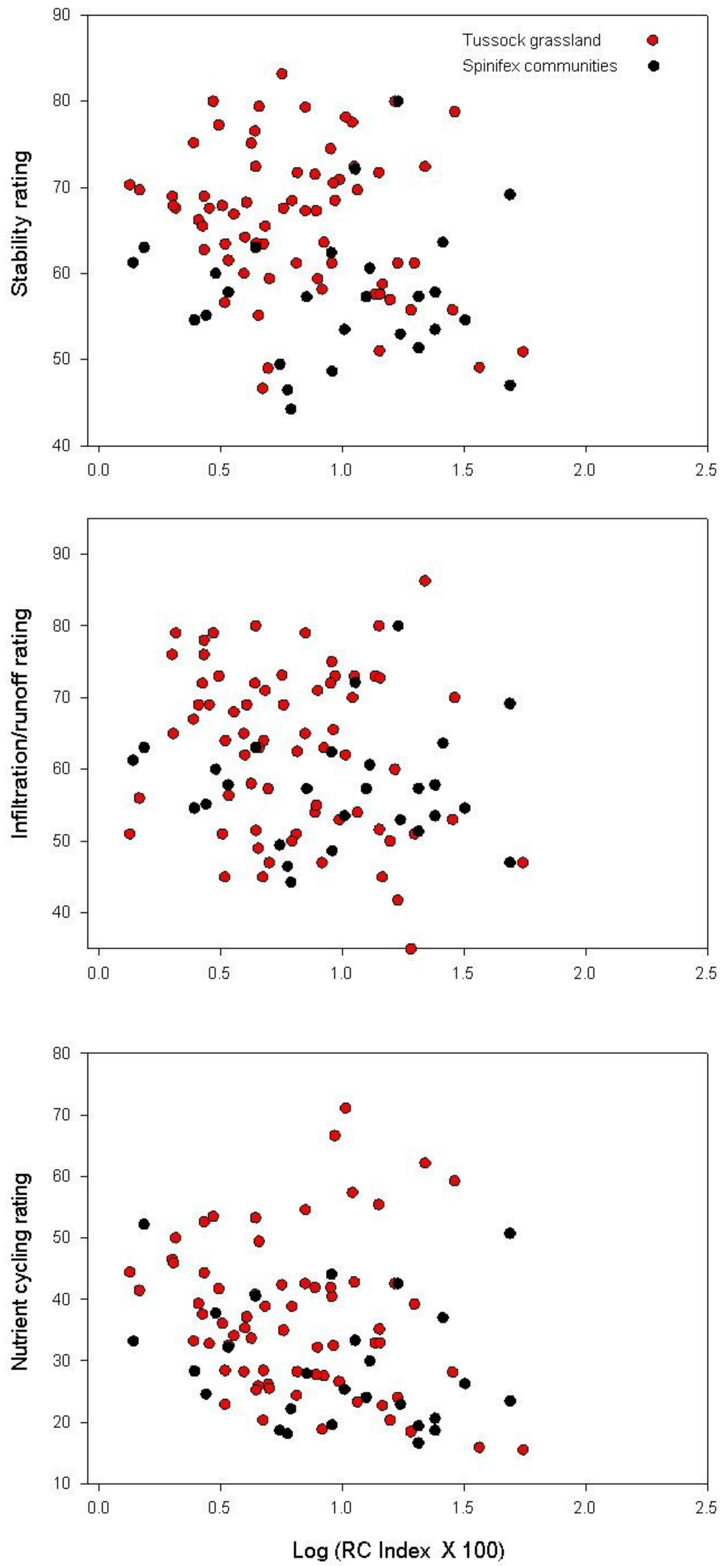

Figure 10: Relationship between LFA ratings and resource-capturing index (expressed as log RC Index X 100) for Kimberley grassland sites.

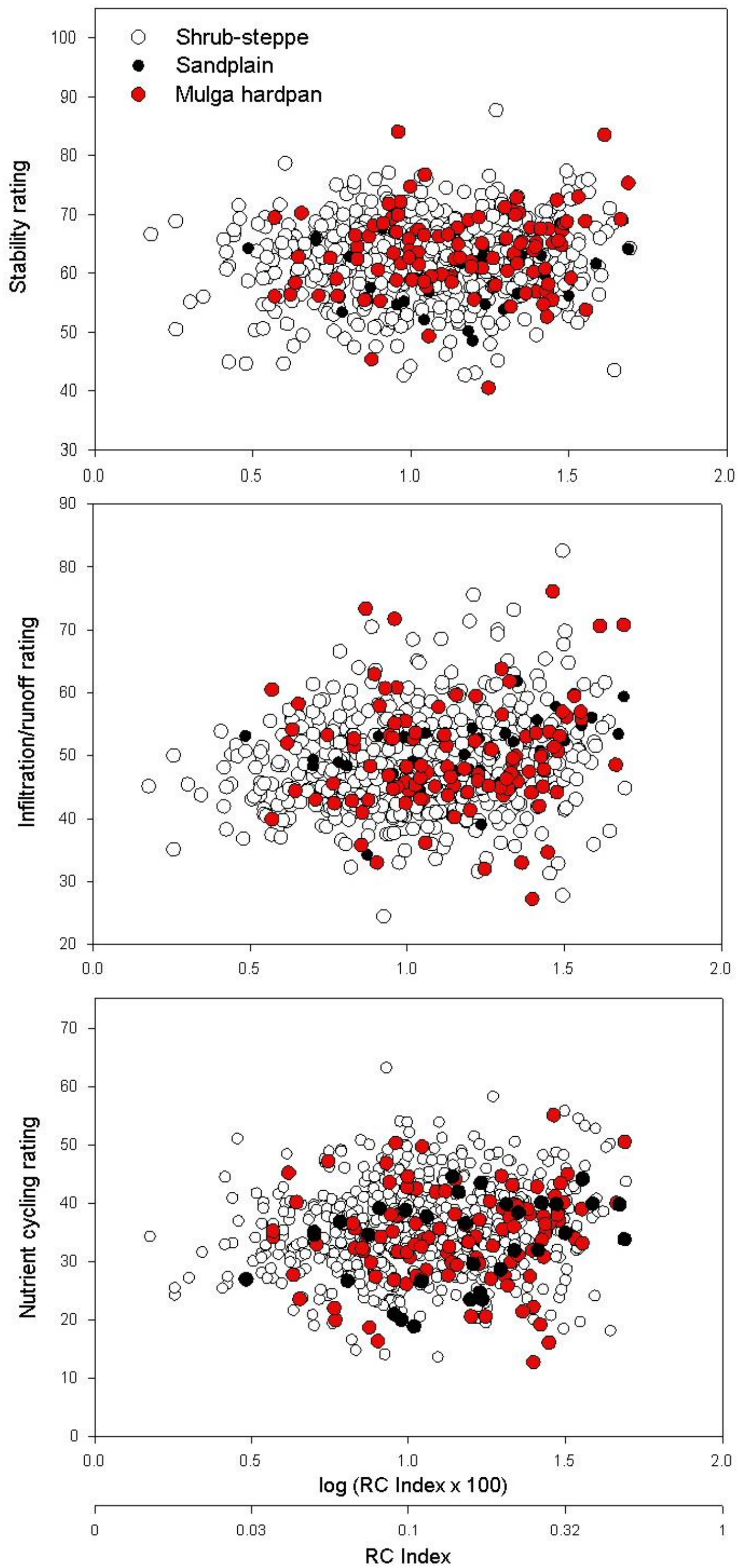

Figure 11: Relationship between LFA ratings and resource-capturing index for shrubland monitoring sites in southern rangeland.

Results

Most relationships between LFA ratings and the surrogate variables of disturbance were non-significant (Figure 8 - Figure 11). The few exceptions were stability and grazing intensity on tussock grassland, which were negatively related ($r^2 = 0.11$, $p = 0.007$ Figure 8). RC index was weakly negatively related to grazing intensity on hummock grassland sites ($r^2 = 0.16$; p = 0.016 Figure 12), and on shrub-steppe sites ($r^2 = 0.01$; p = 0.02 Figure 13) i.e. sites closer to water generally had lower RC Indices.

There were no sigmoidal relationships between indices or ratings of landscape function and indices of disturbance.

Multiple regression analyses also failed to establish any strong relationships between LFA ratings and disturbance indictors (Table 6)

Table 6: Multiple regression relationships between indictors of landscape function and variables likely to affect disturbance by grazing. Relationships derived from data collected on WARMS sites from 1992 – 2000

Landscape function indicator/rating	Significant terms	Variance accounted for by model	Significance of model (*p*)
Grassland sites			
Stability	78.5 ! 2.8 –9.4 ! 1.8 (if hummock grassl.) – 1.0 ! 0.4 grazing intensity	0.26	0.000
Infiltration/runoff	70.1 ! 4.2 + 0.08 ! 0.04 frequency – 22.1 ! 12.8 RC Index – 8.1 ! 2.7 (if hummock grassl.)	0.24	0.000
Nutrient cycling	44.0 ! 3.6 – 7.2 ! 2.6 (if hummock grassl.)	0.08	0.007
RC index	0.06 ! 0.03 + 0.06 ! 0.02 (if hummock grassl.) – 0.007 ! 0.003 grazing intensity – 0.0005 ! 0.000 frequency	0.16	0.000
Shrub-steppe sites			
Stability	62.1 ! 0.4 + 0.0001 ! 0.000 density – 2.2 ! 1.3 (if sandplain) + 1.6 ! 0.8 (if mulga)	0.02	0.05
Infiltration/runoff	50.0 ! 0.5 – 0.003 ! 0.000 salinity	0.01	0.04
Nutrient cycling	34.7 ! 0.4 + 0.0002 ! 0.000 density	0.02	0.001
RC index	0.15 ! 0.01 + 0.00005 ! 0.000 density + 0.06 ! 0.01 (if shrub-steppe) + 0.004 ! 0.002 grazing intensity	0.16	0.000

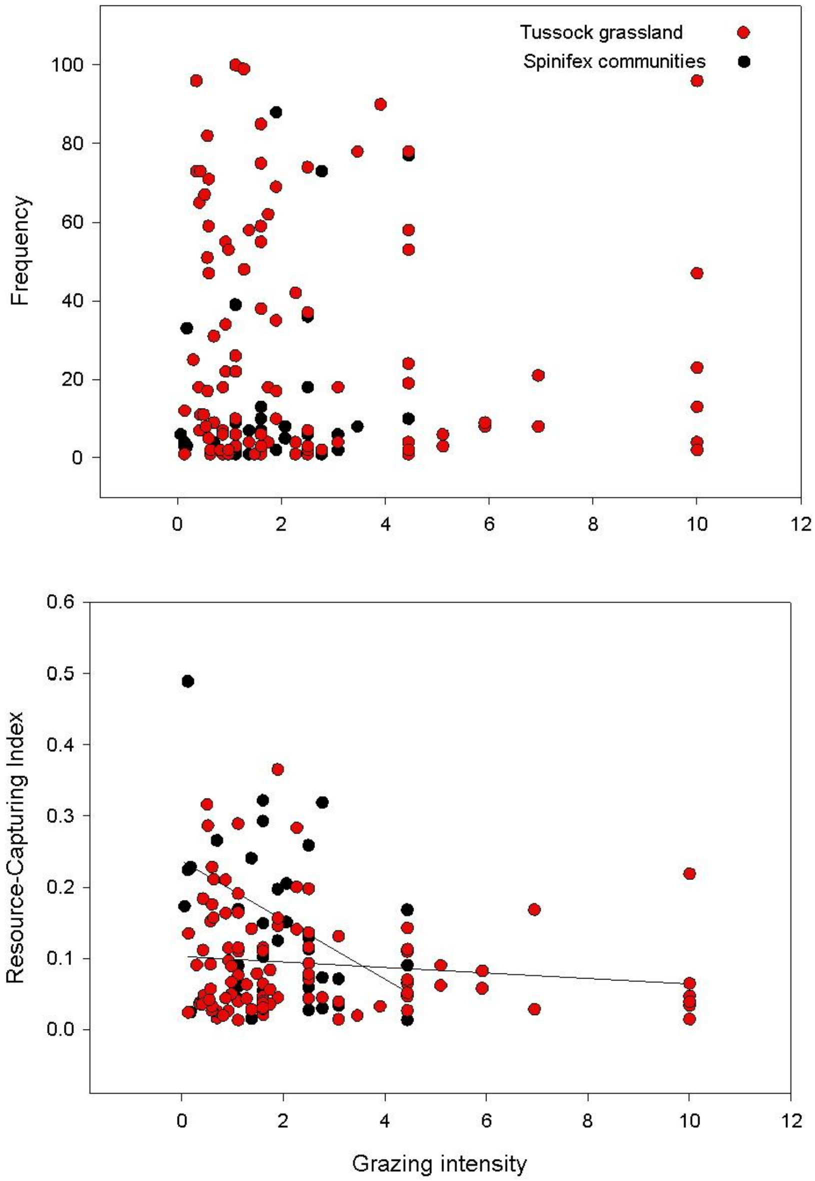

Figure 12: Relationships between grazing intensity (10/ distance from water squared) and perennial grass frequency (top) and resource-capturing index (bottom). Data are from Kimberley grassland sites.

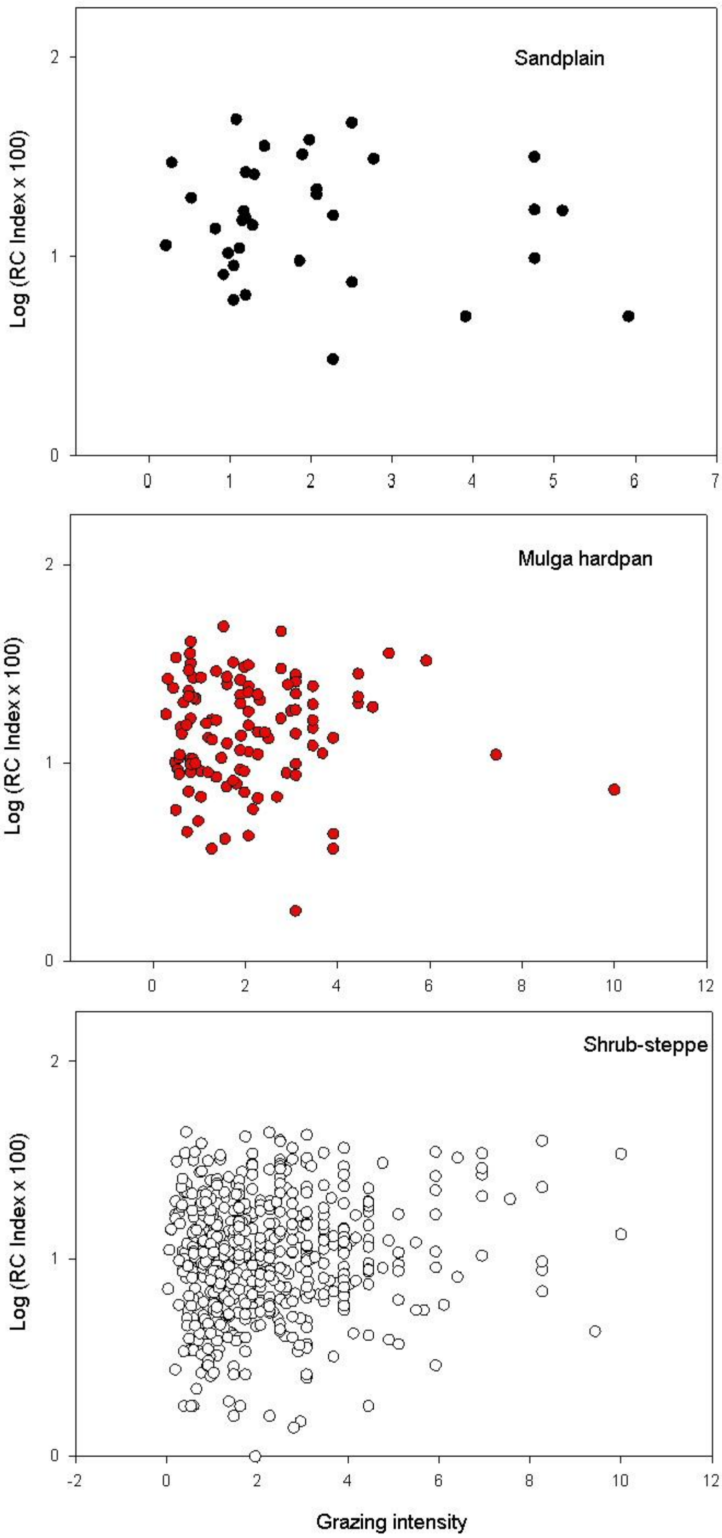

Figure 13: Relationship between grazing intensity (10/distance from water squared) and resource-capturing index (expressed as log RC Index x 100), for shrubland sites.

Recommendations:

It is unlikely that any further analysis of WARMS data will greatly strengthen these relationships using available indicators of disturbance. More sophisticated independent indicators of disturbance are required which could include stocking histories associated with particular sites, selected to cover the range of LFA ratings and RC indices. The likely success of such an approach is problematic, especially given the very limited success of the approach tested here.

Meanwhile, the approach adopted in this report based on frequency distributions of sites is a reasonable first pass and will suffice until more data becomes available or alternative approaches are identified.

Recommendations for how frequently LFA should be recorded within each of the WARMS groups.

Background:

Assessment of change on monitoring sites requires simultaneous information on both changes in biological capacity of sites to support the selected land use (e.g. change in species composition is important for grazing), and changes in physical or geophysical capacity of landscapes to support vegetation (landscape function).

Recommendation

Landscape function be assessed at each scheduled sampling i.e. every three to four years on grassland sites and every five to six years on shrub-steppe sites.

Recommendations for cutting down the LFA sampling set.

Background:

Landscape function assessment requires both a measure of patchiness (Resource-capturing index) and soil surface attributes –i.e. the current approach of transect logging and LFA soil surface assessment (Tongway, 1994; Tongway & Hindley, 1995). I suggest some modifications to these assessments that if adopted, will reduce the time required to complete these assessments, but only by a matter of minutes per site.

Possible reduction in soil surface attributes that are assessed

If the recommendations within this report are adopted, then less importance will be placed on the infiltration/runoff and nutrient cycling ratings and more importance on the RC index and stability rating. This could be taken to the extreme whereby, all soil surface assessment indicators not associated with stability rating could be dropped. These are: perennial plant cover (grassland), soil cover – flow (shrub-steppe), litter source, litter incorporation, microtopography and soil texture.

Relationship between LFA ratings at patch and site-scales – shrub-steppe sites

Tongway and Hindley (1995) do not assess the resource-capturing patches (i.e. perennial grass butts) in their LFA analysis of grassland sites. In their view, 'the quality of soil associated with a perennial grass is high and does not vary much with overall site condition; the big variation is in the quality of the fetch zones' (fetch zones analogous with resource-shedding patches). This raises the question, whether LFA assessments in shrubland might also be restricted to the resource-shedding patches without serious loss of information. Certainly the errors associated with measurement and spatial variability of these measurements are likely to be higher within the resource-capturing patches.

I examined correlations between the LFA ratings within resource-capturing and resource-shedding patches for WARMS shrub-steppe sites (Table 7). In general equivalent ratings were highly correlated (r = 0.65 – 0.73), suggesting that most of the information could be derived from only assessments of resource-shedding patches. I have presented frequency tables of for both site-scale and patch-scale ratings and suggest that presentations be based on resource-shedding patches for both grassland and shrub-steppe sites (Appendix 1).

Table 7: Correlations between LFA ratings for resource-capturing patches and resource-shedding patches in shrubland monitoring sites

		Resource-shedding patches			Resource-capturing patches		
		Stability	Infiltration	Nutrient	Stability	Infiltration	Nutrient
Resource- shedding							
Stability	Correlation	1.000	.479	.547	.698	.285	.314
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000
	N	932	932	932	932	932	932
Infiltration	Correlation		1.000	.310	.279	.730	.207
	Sig. (2-tailed)			.000	.000	.000	.000
	N			932	932	932	932
Nutrient	Correlation			1.000	.407	.199	.647
	Sig. (2-tailed)				.000	.000	.000
	N				932	932	932
Resource- capturing							
Stability	Correlation				1.000	.455	.541
	Sig. (2-tailed)					.000	.000
	N					932	932
Infiltration	Correlation					1.000	.452
	Sig. (2-tailed)						.000
	N						932
Nutrient	Correlation						1.000
	Sig. (2-tailed)						
	N						

Transect logging and simplification of fetch zones

As discussed previously, patch types along site transects are to be classified firstly as either resource-capturing or resource-shedding (i.e. fetch) based on the definitions provided in section 1. Tongway and Hindley (1995) then require fetch zones to be further sub-divided into fetch zone-types and recommend a minimum of 5 queries per fetch-zone type. Excessive splitting of fetch-zones is not recommended. There is no point in logging a zone type if it is too small to be sampled. For example, the occasional ant bed that occupies less than say 5% of the monitoring site should be excluded. Conversely, if a zone-type is significant, it must be logged and sampled to enable calculation of LFA ratings for the site based on the proportional lengths of each fetch-zone type.

Recommendations

1. Consideration be given to discontinuing infiltration/runoff and nutrient cycling ratings and the specific soil surface assessment attributes associated with these ratings i.e. perennial plant cover (grassland), soil cover – flow (shrubland), litter source, litter incorporation, microtopography and soil texture.

2. Soil surface assessment be restricted to resource-shedding patches (fetch) in both grassland and shrubland sites.

3. Greater attention be given to classifying and logging patches as resource-capturing and resource-shedding based on the definitions provided. All significant fetch zone – types to be logged and sampled.

Relationship between LFA and vegetation data.

Importance of testing the relationship between species composition and LFA.

Background

Increasingly, monitoring of the environment is seen to involve firstly an assessment of the capacity of the landscape to convert rainfall into plant biomass (landscape function) and secondly an assessment of the biodiversity that these landscapes support. While a common approach to assessment is reasonable for all land uses in the first phase, assessment techniques for the second phase depend on the nature of the land use. Thus, on pastoral land used for grazing, biodiversity assessment requires a focus on changes in species composition that affects grazing value. Such changes include loss of useful perennial species and replacement of these species by unpalatable species, or herbaceous annuals. Many of these transitions do not necessarily result in loss of landscape function – the efficiency of conversion of rainfall into biomass is maintained on so-called resilient landscapes. On less resilient landscapes, loss of perennial species precipitates significant soil loss, and accelerated runoff resulting in loss of landscape function – i.e. lower efficiency of conversion of rainfall into biomass. In time, even non-resilient landscapes may again stabilize and become re-vegetated with alternative species often at broader spatial scales. Interpretation of monitoring data from land used for pastoralism therefore requires an understanding of where a monitoring site sits within the transition matrix and must include data on landscape function and species composition.

A key indicator of landscape function is change in the proportional area occupied by resource-capturing patches i.e. patches predominately occupied by perennial shrubs trees and/or grasses – RC Index. Additional information on soil surface properties is required to reveal if loss of patches is associated with accelerated soil loss or if the landscape is stable and losses are minimal.

The questions addressed in this section include:

1. Is there a relationship between RC Index (as an indicator of landscape function) and shrub density or perennial grass frequency?
2. Are LFA ratings related to shrub density or perennial grass frequency?
3. Is species composition related to landscape function?
4. Provide a framework for interpreting change in landscape function and in species diversity and/or abundance.

Relationship between RC Index, LFA ratings and shrub density or perennial grass frequency

Approach

I examined these relationships using correlation and regression analyses of all available site data for resource-shedding patches on all monitoring sites and on resource-capturing patches on shrubland sites.

Unexpectedly, frequency of perennial grass was negatively correlated with resource-capturing index on both hummock grassland (logs; - 0.24 $p = 0.004$) and tussock grassland although the later was not significant. (Table 8 and Table 9).

Frequency of perennial grass was significantly correlated with LFA ratings for stability and infiltration/runoff, but not nutrient cycling on both hummock grassland and tussock grassland (Table 8 and Table 9).

On resource-shedding patches, density of shrubs and trees was significantly positively correlated with resource-capturing index on all country-types (sandplain: Table 10, shrub-steppe: Table 11and mulga hardpanTable 12). Regression analysis indicates that these relationships are strongest on shrub-steppe Figure 14). There was generally no correlation between density and LFA ratings (Table 10 -Table 12). There were only marginal differences in these correlations for resource-capturing patches (Table 13 - Table 15

Conclusion:

It might be expected that higher frequency or density of perennial species and all indicators of landscape function should be positively related. More perennial grass or shrubs should result in higher infiltration, more nutrient cycling and less movement of soil and soil nutrients. Furthermore, one would expect resource-capturing index on a site to be positively related to the frequency or density of plants.

On grassland monitoring sites, perennial grass frequency provides confusing information about landscape function. Generally the higher frequencies are associated with lower RC indices, although this is highly variable. My only explanation for this is that perhaps higher frequencies indicate smaller plants with smaller basal areas. Whatever the explanation, it is apparent that frequency cannot be used in place of transect logging to establish the RC index. On the other hand, higher frequencies are associated with higher stability and infiltration ratings on tussock grassland as expected, and in these situations provide complementary information.

On southern monitoring sites, shrub density is associated with higher RC indices, but associations with LFA ratings are weak or non-existent. It might be expected that the associations with LFA ratings should be stronger in resource-capturing patches where shrubs directly influence infiltration, nutrient cycling and perhaps stability. There is some suggestion that this is so in shrub-steppe country-types but the correlations are weak.

In general, shrub density does provide complementary information on landscape function, however this information is not sufficiently robust to be used with confidence in reporting.

Table 8: Correlations (Pearson) among variables recorded on Kimberley grassland sites: tussock grassland – shed patches

		Frequency	Log freq	RC Index	Log RC I	Stability	Infiltration	Nutrient	Distance	Grazing Int
Frequency	Correlation	1.000	.886	.004	-.083	.112	.261	-.016	.050	-.059
	Sig. (2-tailed)	.	.000	.966	.395	.358	.030	.894	.620	.559
	N	107	107	107	107	69	69	69	100	100
Log freq	Correlation	.886	1.000	-.047	-.134	.178	.218	-.006	.051	-.045
	Sig. (2-tailed)	.000	.	.628	.170	.144	.071	.964	.615	.658
	N	107	107	107	107	69	69	69	100	100
RC Index	Correlation	.004	-.047	1.000	.894	-.281	-.298	-.179	.077	-.126
	Sig. (2-tailed)	.966	.628	.	.000	.019	.013	.142	.446	.212
	N	107	107	107	107	69	69	69	100	100
Log RC I	Correlation	-.083	-.134	.894	1.000	-.213	-.256	-.140	.050	-.117
	Sig. (2-tailed)	.395	.170	.000	.	.079	.033	.251	.622	.247
	N	107	107	107	107	69	69	69	100	100
Stability	Correlation	.112	.178	-.281	-.213	1.000	.573	.700	.317	-.335
	Sig. (2-tailed)	.358	.144	.019	.079	.	.000	.000	.011	.007
	N	69	69	69	69	69	69	69	64	64
Infiltration	Correlation	.261	.218	-.298	-.256	.573	1.000	.713	.131	-.085
	Sig. (2-tailed)	.030	.071	.013	.033	.000	.	.000	.304	.505
	N	69	69	69	69	69	69	69	64	64
Nutrient	Correlation	-.016	-.006	-.179	-.140	.700	.713	1.000	.025	-.083
	Sig. (2-tailed)	.894	.964	.142	.251	.000	.000	.	.846	.515
	N	69	69	69	69	69	69	69	64	64
Distance	Correlation	.050	.051	.077	.050	.317	.131	.025	1.000	-.700
	Sig. (2-tailed)	.620	.615	.446	.622	.011	.304	.846	.	.000
	N	100	100	100	100	64	64	64	100	100
Grazing Int	Correlation	-.059	-.045	-.126	-.117	-.335	-.085	-.083	-.700	1.000
	Sig. (2-tailed)	.559	.658	.212	.247	.007	.505	.515	.000	.
	N	100	100	100	100	64	64	64	100	100

Table 9 Correlations (Pearson) among variables recorded on Kimberley grassland sites: hummock grassland – shed patches

		Frequency	Log freq	RC Index	Log RC I	Stability	Infiltration	Nutrient	Distance	Grazing Int
Frequency	Correlation	1.000	.839	-.293	-.392	-.002	.038	.140	-.124	.205
	Sig. (2-tailed)	.	.000	.083	.016	.994	.849	.485	.464	.223
	N	37	37	36	37	27	27	27	37	37
Log freq	Correlation	.839	1.000	-.245	-.302	.051	.021	.173	-.022	.099
	Sig. (2-tailed)	.000	.	.150	.070	.801	.918	.389	.898	.558
	N	37	37	36	37	27	27	27	37	37
RC Index	Correlation	-.293	-.245	1.000	.894	.045	-.190	-.020	.404	-.399
	Sig. (2-tailed)	.083	.150	.	.000	.827	.353	.921	.015	.016
	N	36	36	36	36	26	26	26	36	36
Log RC I	Correlation	-.392	-.302	.894	1.000	.118	-.270	-.286	.227	-.231
	Sig. (2-tailed)	.016	.070	.000	.	.558	.173	.148	.176	.170
	N	37	37	36	37	27	27	27	37	37
Stability	Correlation	-.002	.051	.045	.118	1.000	.713	.665	-.108	.031
	Sig. (2-tailed)	.994	.801	.827	.558	.	.000	.000	.590	.879
	N	27	27	26	27	27	27	27	27	27
Infiltration	Correlation	.038	.021	-.190	-.270	.713	1.000	.868	-.114	.032
	Sig. (2-tailed)	.849	.918	.353	.173	.000	.	.000	.571	.875
	N	27	27	26	27	27	27	27	27	27
Nutrient	Correlation	.140	.173	-.020	-.286	.665	.868	1.000	.085	-.201
	Sig. (2-tailed)	.485	.389	.921	.148	.000	.000	.	.673	.314
	N	27	27	26	27	27	27	27	27	27
Distance	Correlation	-.124	-.022	.404	.227	-.108	-.114	.085	1.000	-.733
	Sig. (2-tailed)	.464	.898	.015	.176	.590	.571	.673	.	.000
	N	37	37	36	37	27	27	27	37	37
Grazing Int	Correlation	.205	.099	-.399	-.231	.031	.032	-.201	-.733	1.000
	Sig. (2-tailed)	.223	.558	.016	.170	.879	.875	.314	.000	.
	N	37	37	36	37	27	27	27	37	37

Table 10: Correlations (Pearson) among variables recorded on shrubland monitoring sites: sandplain - shed patches

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.392	.086	.238	.223	.911	.274	-.050	.125	.206
	Sig. (2-tailed)	.	.015	.543	.086	.109	.000	.096	.769	.462	.251
	N	53	38	53	53	53	53	38	37	37	33
RC Index	Correlation	.392	1.000	.068	.150	.064	.395	.936	-.146	.139	.345
	Sig. (2-tailed)	.015	.	.686	.370	.702	.014	.000	.388	.413	.050
	N	38	38	38	38	38	38	38	37	37	33
Stability	Correlation	.086	.068	1.000	.404	.318	.111	-.019	-.135	.171	-.427
	Sig. (2-tailed)	.543	.686	.	.003	.020	.427	.908	.427	.312	.013
	N	53	38	53	53	53	53	38	37	37	33
Infiltration	Correlation	.238	.150	.404	1.000	.333	.234	.177	.147	-.097	-.017
	Sig. (2-tailed)	.086	.370	.003	.	.015	.092	.287	.385	.567	.926
	N	53	38	53	53	53	53	38	37	37	33
Nutrient	Correlation	.223	.064	.318	.333	1.000	.220	.067	.011	.210	-.182
	Sig. (2-tailed)	.109	.702	.020	.015	.	.114	.690	.948	.211	.310
	N	53	38	53	53	53	53	38	37	37	33
Log den	Correlation	.911	.395	.111	.234	.220	1.000	.325	.019	.071	.130
	Sig. (2-tailed)	.000	.014	.427	.092	.114	.	.046	.913	.675	.470
	N	53	38	53	53	53	53	38	37	37	33
Log RC I	Correlation	.274	.936	-.019	.177	.067	.325	1.000	-.066	.064	.394
	Sig. (2-tailed)	.096	.000	.908	.287	.690	.046	.	.698	.705	.023
	N	38	38	38	38	38	38	38	37	37	33
Distance	Correlation	-.050	-.146	-.135	.147	.011	.019	-.066	1.000	-.757	-.046
	Sig. (2-tailed)	.769	.388	.427	.385	.948	.913	.698	.	.000	.798
	N	37	37	37	37	37	37	37	37	37	33
Grazing Int	Correlation	.125	.139	.171	-.097	.210	.071	.064	-.757	1.000	-.110
	Sig. (2-tailed)	.462	.413	.312	.567	.211	.675	.705	.000	.	.544
	N	37	37	37	37	37	37	37	37	37	33
Salinity	Correlation	.206	.345	-.427	-.017	-.182	.130	.394	-.046	-.110	1.000
	Sig. (2-tailed)	.251	.050	.013	.926	.310	.470	.023	.798	.544	.
	N	33	33	33	33	33	33	33	33	33	33

Table 11 Correlations (Pearson) among variables recorded on shrubland monitoring sites: shrub-steppe – shed patches

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.265	.069	.017	.148	.838	.337	-.078	.088	.136
	Sig. (2-tailed)	.	.000	.061	.637	.000	.000	.000	.072	.043	.005
	N	732	564	732	732	732	732	564	537	535	433
RC Index	Correlation	.265	1.000	-.020	-.010	.027	.278	.860	-.046	.076	.074
	Sig. (2-tailed)	.000	.	.621	.815	.508	.000	.000	.276	.068	.112
	N	564	605	605	605	605	564	605	571	569	458
Stability	Correlation	.069	-.020	1.000	.507	.493	.053	-.019	.050	-.038	.039
	Sig. (2-tailed)	.061	.621	.	.000	.000	.149	.632	.230	.370	.406
	N	732	605	776	776	776	732	605	571	569	458
Infiltration	Correlation	.017	-.010	.507	1.000	.281	-.007	-.023	.059	-.021	-.094
	Sig. (2-tailed)	.637	.815	.000	.	.000	.847	.571	.157	.622	.044
	N	732	605	776	776	776	732	605	571	569	458
Nutrient	Correlation	.148	.027	.493	.281	1.000	.136	.042	-.005	-.027	.039
	Sig. (2-tailed)	.000	.508	.000	.000	.	.000	.301	.909	.525	.403
	N	732	605	776	776	776	732	605	571	569	458
Log den	Correlation	.838	.278	.053	-.007	.136	1.000	.397	-.047	.083	.137
	Sig. (2-tailed)	.000	.000	.149	.847	.000	.	.000	.278	.056	.004
	N	732	564	732	732	732	732	564	537	535	433
Log RC I	Correlation	.337	.860	-.019	-.023	.042	.397	1.000	-.035	.070	.121
	Sig. (2-tailed)	.000	.000	.632	.571	.301	.000	.	.410	.095	.010
	N	564	605	605	605	605	564	605	571	569	458
Distance	Correlation	-.078	-.046	.050	.059	-.005	-.047	-.035	1.000	-.637	-.020
	Sig. (2-tailed)	.072	.276	.230	.157	.909	.278	.410	.	.000	.671
	N	537	571	571	571	571	537	571	571	569	454
Grazing Int	Correlation	.088	.076	-.038	-.021	-.027	.083	.070	-.637	1.000	.003
	Sig. (2-tailed)	.043	.068	.370	.622	.525	.056	.095	.000	.	.947
	N	535	569	569	569	569	535	569	569	569	452
Salinity	Correlation	.136	.074	.039	-.094	.039	.137	.121	-.020	.003	1.000
	Sig. (2-tailed)	.005	.112	.406	.044	.403	.004	.010	.671	.947	.
	N	433	458	458	458	458	433	458	454	452	458

Table 12 Correlations (Pearson) among variables recorded on shrubland monitoring sites: mulga hardpan – shed patches

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.105	.098	-.085	.135	.759	.104	.025	-.032	-.007
	Sig. (2-tailed)	.	.313	.288	.359	.143	.000	.320	.816	.767	.955
	N	119	94	119	119	119	119	94	87	87	77
RC Index	Correlation	.105	1.000	.005	.154	-.001	.260	.899	-.020	-.040	.095
	Sig. (2-tailed)	.313	.	.963	.111	.992	.011	.000	.844	.695	.376
	N	94	108	108	108	108	94	108	98	98	88
Stability	Correlation	.098	.005	1.000	.507	.522	.037	.083	.031	-.083	-.026
	Sig. (2-tailed)	.288	.963	.	.000	.000	.693	.393	.761	.414	.812
	N	119	108	139	139	139	119	108	98	98	88
Infiltration	Correlation	-.085	.154	.507	1.000	.521	-.071	.101	.093	-.249	-.119
	Sig. (2-tailed)	.359	.111	.000	.	.000	.442	.297	.361	.014	.268
	N	119	108	139	139	139	119	108	98	98	88
Nutrient	Correlation	.135	-.001	.522	.521	1.000	.048	-.005	.026	-.173	-.033
	Sig. (2-tailed)	.143	.992	.000	.000	.	.605	.961	.800	.088	.763
	N	119	108	139	139	139	119	108	98	98	88
Log den	Correlation	.759	.260	.037	-.071	.048	1.000	.253	.160	-.068	-.090
	Sig. (2-tailed)	.000	.011	.693	.442	.605	.	.014	.140	.531	.438
	N	119	94	119	119	119	119	94	87	87	77
Log RC I	Correlation	.104	.899	.083	.101	-.005	.253	1.000	-.048	-.032	.160
	Sig. (2-tailed)	.320	.000	.393	.297	.961	.014	.	.641	.757	.136
	N	94	108	108	108	108	94	108	98	98	88
Distance	Correlation	.025	-.020	.031	.093	.026	.160	-.048	1.000	-.651	-.213
	Sig. (2-tailed)	.816	.844	.761	.361	.800	.140	.641	.	.000	.049
	N	87	98	98	98	98	87	98	98	98	86
Grazing Int	Correlation	-.032	-.040	-.083	-.249	-.173	-.068	-.032	-.651	1.000	.057
	Sig. (2-tailed)	.767	.695	.414	.014	.088	.531	.757	.000	.	.605
	N	87	98	98	98	98	87	98	98	98	86
Salinity	Correlation	-.007	.095	-.026	-.119	-.033	-.090	.160	-.213	.057	1.000
	Sig. (2-tailed)	.955	.376	.812	.268	.763	.438	.136	.049	.605	.
	N	77	88	88	88	88	77	88	86	86	88

Table 13 Correlations (Pearson) among variables recorded on shrubland monitoring sites: sandplain – resource-capturing patches correlations –

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.381	.179	.235	.255	.915	.263	-.033	.106	.184
	Sig. (2-tailed)	.	.022	.228	.112	.084	.000	.122	.850	.536	.315
	N	47	36	47	47	47	47	36	36	36	32
RC Index	Correlation	.381	1.000	.181	.127	.260	.382	.937	-.142	.132	.337
	Sig. (2-tailed)	.022	.	.277	.448	.114	.021	.000	.401	.435	.055
	N	36	38	38	38	38	36	38	37	37	33
Stability	Correlation	.179	.181	1.000	.483	.496	.193	.061	-.285	.337	-.241
	Sig. (2-tailed)	.228	.277	.	.000	.000	.194	.716	.087	.042	.176
	N	47	38	49	49	49	47	38	37	37	33
Infiltration	Correlation	.235	.127	.483	1.000	.583	.231	.076	.105	.070	.103
	Sig. (2-tailed)	.112	.448	.000	.	.000	.118	.649	.535	.680	.568
	N	47	38	49	49	49	47	38	37	37	33
Nutrient	Correlation	.255	.260	.496	.583	1.000	.295	.243	-.055	.190	.184
	Sig. (2-tailed)	.084	.114	.000	.000	.	.044	.141	.745	.259	.306
	N	47	38	49	49	49	47	38	37	37	33
Log den	Correlation	.915	.382	.193	.231	.295	1.000	.309	.043	.046	.098
	Sig. (2-tailed)	.000	.021	.194	.118	.044	.	.066	.803	.790	.595
	N	47	36	47	47	47	47	36	36	36	32
Log RC I	Correlation	.263	.937	.061	.076	.243	.309	1.000	-.055	.052	.381
	Sig. (2-tailed)	.122	.000	.716	.649	.141	.066	.	.746	.758	.029
	N	36	38	38	38	38	36	38	37	37	33
Distance	Correlation	-.033	-.142	-.285	.105	-.055	.043	-.055	1.000	-.760	-.061
	Sig. (2-tailed)	.850	.401	.087	.535	.745	.803	.746	.	.000	.738
	N	36	37	37	37	37	36	37	37	37	33
Grazing Int	Correlation	.106	.132	.337	.070	.190	.046	.052	-.760	1.000	-.103
	Sig. (2-tailed)	.536	.435	.042	.680	.259	.790	.758	.000	.	.568
	N	36	37	37	37	37	36	37	37	37	33
Salinity	Correlation	.184	.337	-.241	.103	.184	.098	.381	-.061	-.103	1.000
	Sig. (2-tailed)	.315	.055	.176	.568	.306	.595	.029	.738	.568	.
	N	32	33	33	33	33	32	33	33	33	33

Table 14: Correlations (Pearson) among variables recorded on shrubland monitoring sites: shrub steppe – resource-capturing patches

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.236	.138	.080	.107	.842	.317	-.078	.094	.130
	Sig. (2-tailed)	.	.000	.001	.048	.008	.000	.000	.080	.037	.009
	N	620	524	620	620	620	620	524	500	498	405
RC Index	Correlation	.236	1.000	.050	.060	.014	.242	.869	-.054	.076	.058
	Sig. (2-tailed)	.000	.	.239	.159	.750	.000	.000	.217	.081	.233
	N	524	557	557	557	557	524	557	528	526	426
Stability	Correlation	.138	.050	1.000	.446	.496	.167	.081	.017	.025	.042
	Sig. (2-tailed)	.001	.239	.	.000	.000	.000	.055	.689	.568	.387
	N	620	557	654	654	654	620	557	528	526	426
Infiltration	Correlation	.080	.060	.446	1.000	.457	.098	.118	.026	.000	-.106
	Sig. (2-tailed)	.048	.159	.000	.	.000	.015	.005	.557	.999	.028
	N	620	557	654	654	654	620	557	528	526	426
Nutrient	Correlation	.107	.014	.496	.457	1.000	.084	.073	-.046	.036	-.011
	Sig. (2-tailed)	.008	.750	.000	.000	.	.037	.085	.290	.413	.820
	N	620	557	654	654	654	620	557	528	526	426
Log den	Correlation	.842	.242	.167	.098	.084	1.000	.348	-.043	.080	.135
	Sig. (2-tailed)	.000	.000	.000	.015	.037	.	.000	.340	.074	.007
	N	620	524	620	620	620	620	524	500	498	405
Log RC I	Correlation	.317	.869	.081	.118	.073	.348	1.000	-.036	.063	.118
	Sig. (2-tailed)	.000	.000	.055	.005	.085	.000	.	.414	.150	.015
	N	524	557	557	557	557	524	557	528	526	426
Distance	Correlation	-.078	-.054	.017	.026	-.046	-.043	-.036	1.000	-.633	-.024
	Sig. (2-tailed)	.080	.217	.689	.557	.290	.340	.414	.	.000	.616
	N	500	528	528	528	528	500	528	528	526	424
Grazing Int	Correlation	.094	.076	.025	.000	.036	.080	.063	-.633	1.000	.019
	Sig. (2-tailed)	.037	.081	.568	.999	.413	.074	.150	.000	.	.702
	N	498	526	526	526	526	498	526	526	526	422
Salinity	Correlation	.130	.058	.042	-.106	-.011	.135	.118	-.024	.019	1.000
	Sig. (2-tailed)	.009	.233	.387	.028	.820	.007	.015	.616	.702	.
	N	405	426	426	426	426	405	426	424	422	426

Table 15 Correlations (Pearson) among variables recorded on shrubland monitoring sites: mulga hard pan – resource shedding patches

		Density	RC Index	Stability	Infiltration	Nutrient	Log den	Log RC I	Distance	Grazing Int	Salinity
Density	Correlation	1.000	.096	.142	-.097	.138	.772	.093	.027	-.035	-.006
	Sig. (2-tailed)	.	.363	.162	.340	.175	.000	.379	.804	.749	.956
	N	99	92	99	99	99	99	92	85	85	75
RC Index	Correlation	.096	1.000	-.023	.135	-.027	.246	.908	-.040	-.036	.081
	Sig. (2-tailed)	.363	.	.814	.172	.788	.018	.000	.703	.729	.464
	N	92	104	104	104	104	92	104	94	94	84
Stability	Correlation	.142	-.023	1.000	.587	.560	.183	.126	.032	-.061	.048
	Sig. (2-tailed)	.162	.814	.	.000	.000	.070	.204	.760	.559	.663
	N	99	104	113	113	113	99	104	94	94	84
Infiltration	Correlation	-.097	.135	.587	1.000	.404	.011	.207	.155	-.229	-.037
	Sig. (2-tailed)	.340	.172	.000	.	.000	.915	.035	.136	.027	.740
	N	99	104	113	113	113	99	104	94	94	84
Nutrient	Correlation	.138	-.027	.560	.404	1.000	.161	.028	.125	-.217	.085
	Sig. (2-tailed)	.175	.788	.000	.000	.	.112	.777	.229	.036	.444
	N	99	104	113	113	113	99	104	94	94	84
Log den	Correlation	.772	.246	.183	.011	.161	1.000	.245	.187	-.089	-.087
	Sig. (2-tailed)	.000	.018	.070	.915	.112	.	.019	.086	.420	.458
	N	99	92	99	99	99	99	92	85	85	75
Log RC I	Correlation	.093	.908	.126	.207	.028	.245	1.000	-.089	-.021	.143
	Sig. (2-tailed)	.379	.000	.204	.035	.777	.019	.	.392	.843	.194
	N	92	104	104	104	104	92	104	94	94	84
Distance	Correlation	.027	-.040	.032	.155	.125	.187	-.089	1.000	-.649	-.232
	Sig. (2-tailed)	.804	.703	.760	.136	.229	.086	.392	.	.000	.036
	N	85	94	94	94	94	85	94	94	94	82
Grazing Int	Correlation	-.035	-.036	-.061	-.229	-.217	-.089	-.021	-.649	1.000	.063
	Sig. (2-tailed)	.749	.729	.559	.027	.036	.420	.843	.000	.	.573
	N	85	94	94	94	94	85	94	94	94	82
Salinity	Correlation	-.006	.081	.048	-.037	.085	-.087	.143	-.232	.063	1.000
	Sig. (2-tailed)	.956	.464	.663	.740	.444	.458	.194	.036	.573	.
	N	75	84	84	84	84	75	84	82	82	84

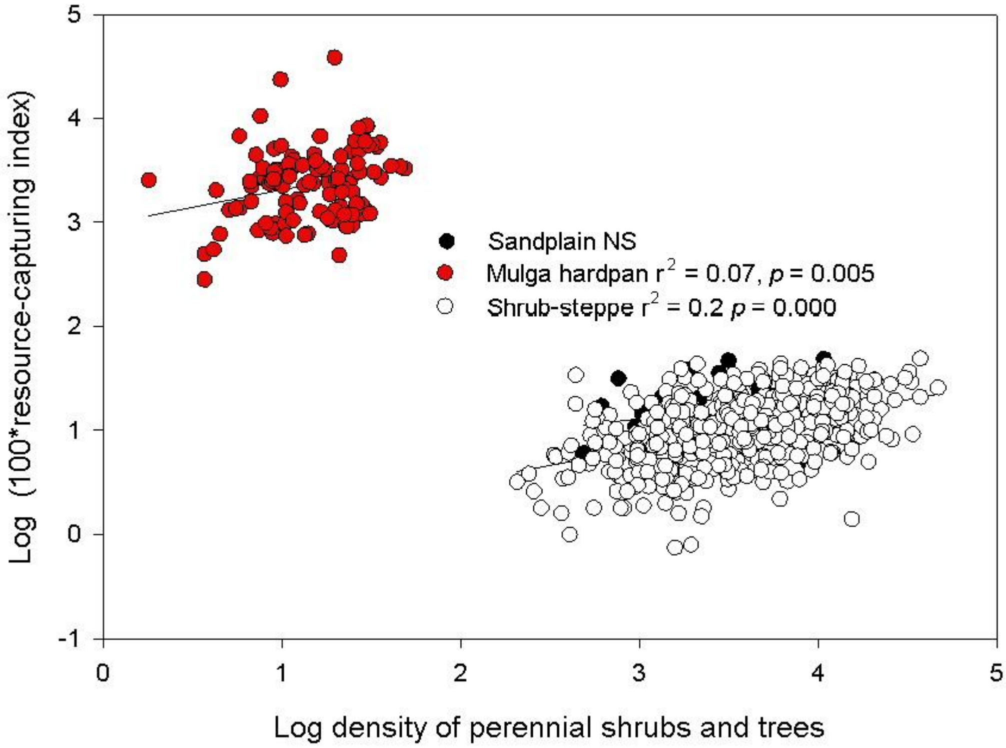

Figure 14: Relationships between shrub density and RC Index on shrubland monitoring sites

Species composition and landscape function

Background

Most studies on effects of species composition on ecosystems function (mostly in terms of total productivity) have examined the effect of numbers of species rather than large shifts in structural composition. (These studies have produced conflicting information.) Our interest is not whether number of species is affecting landscape function, but whether shifts in structural composition are important (e.g. shifts from multi-stemmed shrubs to single stemmed shrubs, or from fire sensitive species to fire tolerant species). It is unlikely that less significant change, for example substitution of *Aristida* spp for *Astrebla* spp, will affect landscape function in any measurable way.

Approach

I outline some examples of structural change and the likely impacts on RC index and Stability rating in Table 16.

Table 16 Examples of structural change in vegetation and likely impacts on landscape function as indicated by RC index and Stability rating

Structural transition in vegetation composition	Change in landscape function		
	RC index	Stability rating	
		Resilient landscapes	Non-resilient landscapes
Tussock grassland to annual herb/grass	↓	NC or ↓	↓
Tussock grassland to tussock grassland and woody species	NC	NC	NC
Hummock grassland to shrubland	↓	NC	↓
Shrubland/woodland to annual herb/grass	↓	NC or ↓	↓
Annual herb/grass to shrubland (coarse-scale) – non-resilient landscape	↑	NC	↑
Annual herb/grass to annual herb/grass – resilient landscape	NC	NC	NC

NC: no change

Table 16 may be used as a provisional framework for interpreting change in species composition and trends in landscape function. In many cases these major shifts in structural composition are associated with a change in the RC index. Regional scale reporting should focus on these major shifts.

Relationships between reporting of landscape function and reporting for pastoral production

Earlier I showed that there was a reasonable relationship between shrub/tree density and landscape function, but an ambiguous relationship with perennial grass frequency. In reporting change on monitoring sites it is important to firstly establish if the physical or geo-physical capacity of the landscape to support and produce vegetation has been altered (i.e. change in landscape function) and then secondly, to assess change in the biological capacity of the landscape to support the selected land use (plant species composition and abundance are the important biological characteristics for pastoral land use). Thus two simultaneous sets of data are required to report change for pastoral purposes, one set dealing with landscape function and the other with vegetation change. While some inferences may be made between these data sets, as shown above, generally these two data sets should be treated and assessed independently. I see little purpose at this stage in mounting a major research program to investigate relationships between species composition and landscape function.

While these data sets are assessed independently, they should be reported simultaneously to provide a complete overview. I have outlined a simple approach to scoring change in species density and composition from a pastoral perspective and included this in the pro-forma for reporting change on each southern monitoring site (Appendix 2). A similar approach could be used for reporting change in frequency of perennial grasses.

Table 17: Suggested ratings for pastoral land-use for change in density of 'desirable and 'undesirable' perennial shrubs.

Significant change*				
Desirables	Undesirables		Rating	Display code
↑	↓		9	+ + +
↑	NC		8	+ + +
↑	↑	Δ D > Δ U	7	+ +
NC	↓		6	+
NC	NC		5	0
↑	↑	Δ D ≤ Δ U	4	—
NC	↑		3	— —
↓	NC		2	— —
↓	↑		1	— — —

Change deemed 'significant' if the following 'rules' are met:

Number of desirable or undesirable plants on the site	Change from assessment 1 to assessment 2 %
> 50	> 10
> 20 – 50	> 20
10 ≥ 20	> 50
< 10	NS

MS Access tables:alec_function_dens_change_9500; alec_density_w_DIU_ass1_ass2; DES_INDEX.

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Appendices

Appendix 1 Frequency tables.

Frequency distribution of tussock grassland – resource-shedding patches

		RC Index	FREQ	STAB	INFIL	NUTS
N	Valid	107	107	69	69	69
	Missing	0	0	38	38	38
Mean		9.7097E-02	28.69	66.0749	62.1045	36.7254
Median		6.5200E-02	17.00	67.2727	64.0000	35.1852
Mode		.027	1	61.21	51.00	20.37
Percentiles	5	2.0066E-02	1.00	50.0000	43.3750	18.7037
	10	2.6920E-02	1.80	55.1515	47.0000	22.7778
	15	2.9720E-02	2.00	56.8025	49.5000	24.2593
	20	3.5012E-02	3.00	58.1818	51.0000	25.5556
	25	3.8907E-02	4.00	59.6970	51.2500	27.1296
	30	4.2816E-02	5.00	61.2121	53.0000	28.2609
	35	4.5373E-02	6.80	63.1034	55.5000	30.3502
	40	4.9568E-02	8.00	63.6364	58.0000	32.8261
	45	6.0463E-02	10.60	65.8621	62.2500	33.4823
	50	6.5200E-02	17.00	67.2727	64.0000	35.1852
	55	7.8358E-02	18.40	67.7325	65.0000	37.3913
	60	9.0748E-02	23.80	68.4848	68.0000	39.2593
	65	.10993	34.20	69.3312	69.0000	41.1755
	70	.11498	45.00	70.4981	71.0000	41.9565
	75	.13619	53.00	71.7241	72.0000	42.7093
	80	.14842	59.00	72.4138	73.0000	45.9259
	85	.16768	70.60	75.8621	74.0625	51.3043
	90	.20249	78.00	78.1818	78.0000	54.5652
	95	.28536	88.00	79.6970	79.5000	60.7166

Frequency distributions of hummock grassland – resource-shedding patches

		RC Index	FREQ	STAB	INFIL	NUTS
N	Valid	36	37	27	27	27
	Missing	1	0	10	10	10
Mean		.16464	12.76	58.0560	51.6831	29.0874
Median		.15044	5.00	57.3574	51.5000	26.2963
Mode		.205	1	53.51	44.00	18.70
Percentiles	5	1.5053E-02	1.00	45.1400	37.0000	17.2593
	10	2.8450E-02	1.00	46.9189	40.4444	18.5926
	15	3.9447E-02	1.00	48.8108	42.4000	18.7407
	20	5.7017E-02	2.00	50.5946	44.0000	19.2222
	25	6.3841E-02	2.00	52.9730	46.0000	19.6296
	30	7.4991E-02	2.40	53.5135	46.4000	21.2778
	35	9.0469E-02	3.00	54.3784	47.0000	22.8148
	40	.11079	4.00	55.1351	47.6000	23.6296
	45	.12801	4.10	57.2973	48.6000	24.8519
	50	.15044	5.00	57.3574	51.5000	26.2963
	55	.16877	6.00	57.8378	53.3556	28.1111
	60	.17817	6.80	59.5676	53.9778	29.6667
	65	.20540	7.00	60.7371	55.2000	32.4239
	70	.22267	8.00	61.9590	56.6000	33.2922
	75	.23768	9.50	63.0303	58.0000	37.0370
	80	.25174	11.20	63.2727	58.4000	38.8889
	85	.27825	22.50	67.2727	60.6000	42.1852
	90	.32022	45.80	69.7756	65.6000	45.4074
	95	.48960	78.10	76.8485	69.2000	51.6296

Frequency distributions of sandplain – site-scale

		RC Index	STAB	INFIL	NUTS
N	Valid	35	33	33	33
	Missing	0	2	2	2
Mean		.1887	60.01	50.56	33.58
Median		.1610	61.63	50.81	34.90
Mode		.05	49	34	19
Percentiles	5	4.610E-02	49.69	37.63	19.73
	10	5.630E-02	52.62	44.87	22.02
	15	6.815E-02	53.94	45.86	23.65
	20	8.280E-02	54.64	47.12	26.22
	25	9.500E-02	54.95	47.60	26.84
	30	.1028	55.84	47.94	28.81
	35	.1124	56.53	48.38	31.69
	40	.1404	57.28	49.05	33.07
	45	.1530	59.29	49.66	34.61
	50	.1610	61.63	50.81	34.90
	55	.1698	61.97	52.32	36.10
	60	.1868	62.85	52.82	37.19
	65	.2100	63.01	53.10	38.47
	70	.2310	63.91	53.38	39.04
	75	.2650	64.28	53.55	39.82
	80	.3072	65.58	54.45	39.87
	85	.3222	66.08	55.58	40.09
	90	.3698	68.16	57.12	42.88
	95	.4736	69.03	60.14	44.28

Frequency distributions of shrub-steppe sites – site-scale

		RC Index	STAB	INFIL	NUTS
N	Valid	593	552	552	552
	Missing	0	41	41	41
Mean		.1272	62.60	48.68	35.75
Median		.1040	63.25	48.14	35.83
Mode		.09	66	24	14
Percentiles	5	3.035E-02	51.07	37.65	23.39
	10	4.070E-02	53.54	40.03	25.76
	15	5.010E-02	55.54	41.29	27.57
	20	5.790E-02	57.49	42.15	29.15
	25	6.450E-02	58.46	43.31	30.86
	30	7.200E-02	59.64	44.48	31.78
	35	8.245E-02	60.84	45.09	32.80
	40	8.800E-02	61.60	46.14	33.54
	45	9.500E-02	62.50	47.27	34.48
	50	.1040	63.25	48.14	35.83
	55	.1154	64.01	48.83	36.71
	60	.1250	64.55	50.27	37.62
	65	.1380	65.18	51.55	38.54
	70	.1509	66.20	52.36	39.46
	75	.1680	66.88	53.33	40.69
	80	.1842	67.86	54.56	41.95
	85	.2120	68.86	55.69	43.90
	90	.2413	70.59	57.88	46.09
	95	.3137	72.60	61.37	48.81

Frequency distributions of mulga-hardpan – site-scale

		RC index	STAB	INFIL	NUTS
N	Valid	35	33	33	33
	Missing	0	2	2	2
Mean		.1887	60.01	50.56	33.58
Median		.1610	61.63	50.81	34.90
Mode		.05	49	34	19
Percentiles	5	4.610E-02	49.69	37.63	19.73
	10	5.630E-02	52.62	44.87	22.02
	15	6.815E-02	53.94	45.86	23.65
	20	8.280E-02	54.64	47.12	26.22
	25	9.500E-02	54.95	47.60	26.84
	30	.1028	55.84	47.94	28.81
	35	.1124	56.53	48.38	31.69
	40	.1404	57.28	49.05	33.07
	45	.1530	59.29	49.66	34.61
	50	.1610	61.63	50.81	34.90
	55	.1698	61.97	52.32	36.10
	60	.1868	62.85	52.82	37.19
	65	.2100	63.01	53.10	38.47
	70	.2310	63.91	53.38	39.04
	75	.2650	64.28	53.55	39.82
	80	.3072	65.58	54.45	39.87
	85	.3222	66.08	55.58	40.09
	90	.3698	68.16	57.12	42.88
	95	.4736	69.03	60.14	44.28

Frequency distributions – sandplain and mulga hardpan – resource shedding patches

		RC Index	Density	Stability	Infiltration	Nutrient
N	Valid	140	145	158	158	158
	Missing	18	13	0	0	0
Mean		.20785	3551.00	60.9923	47.6977	30.7465
Median		.16950	2533.33	60.9029	46.7244	30.2662
Mode		.110	2233	67.57	41.83	21.16
Percentiles	5	5.0500E-02	664.58	50.0775	38.9551	18.8746
	10	7.0000E-02	966.67	53.2987	41.3553	21.0229
	15	8.0500E-02	1197.02	54.4125	41.8944	22.8086
	20	9.4000E-02	1358.33	55.4366	42.7742	24.1906
	25	.10425	1558.33	56.3707	43.4066	25.3086
	30	.11250	1858.33	57.4797	43.8884	25.6314
	35	.12815	2104.17	58.5515	44.4542	26.2917
	40	.14075	2225.00	59.4775	45.3967	27.3364
	45	.15625	2391.67	60.2989	46.1538	28.4259
	50	.16950	2533.33	60.9029	46.7244	30.2662
	55	.19733	2783.33	62.0606	47.7104	31.2091
	60	.20600	3166.67	62.6006	48.3547	32.8796
	65	.21875	3361.11	63.3604	49.7285	33.9142
	70	.24611	3633.33	64.0631	50.5800	34.4481
	75	.26600	4300.00	64.9149	52.0243	35.4167
	80	.27800	4766.67	66.2072	52.5821	36.9907
	85	.31730	5450.00	67.4903	53.3260	38.6185
	90	.43320	6733.33	69.0811	55.2163	40.1663
	95	.54000	8616.67	70.8340	58.2218	43.9373

a Calculated from grouped data.
b Multiple modes exist. The smallest value is shown
c Percentiles are calculated from grouped data.

Frequency distribution –shrub-steppe resource-shedding patches

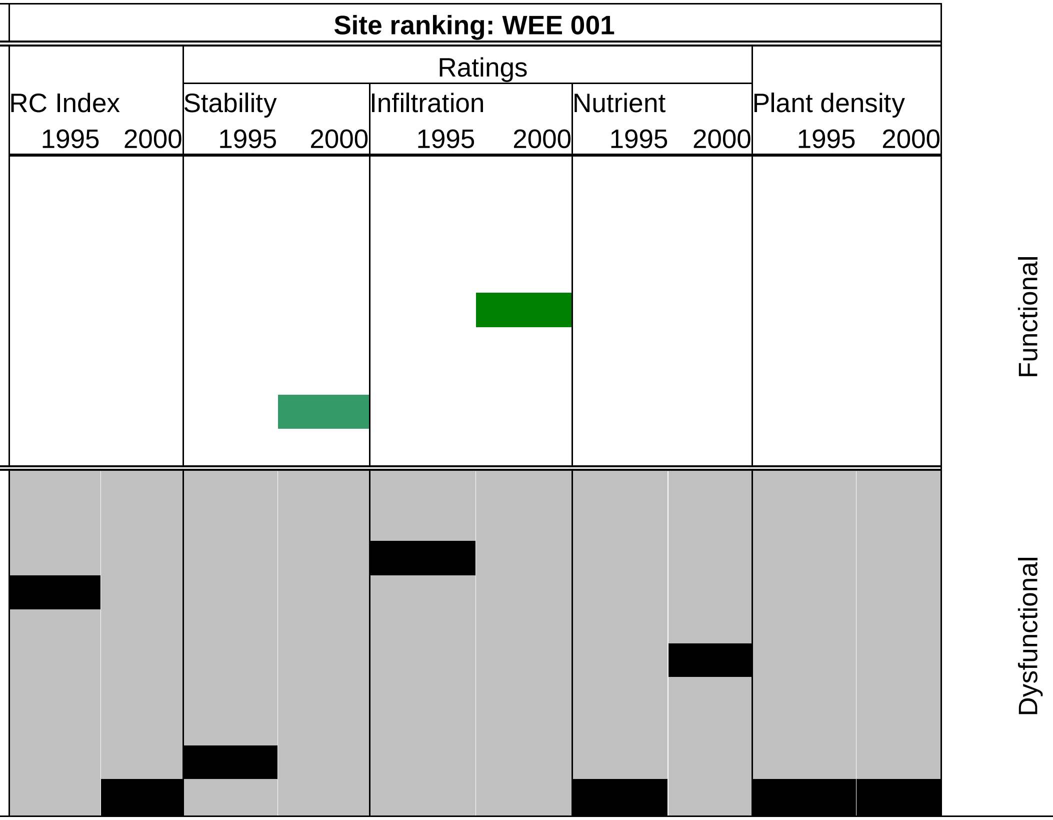
		RC Index	Density	Stability	Infiltration	Nutrient
N	Valid	556	610	643	643	643
	Missing	87	33	0	0	0
Mean		.15340	5526.50	61.1121	47.6941	32.4579
Median		.11767	3633.33	61.8665	47.5221	32.0602
Mode		.087	967	59.46	50.00	25.93
Percentiles	5	3.6933E-02	683.33	48.8243	36.6053	19.1850
	10	4.8600E-02	990.00	52.0202	38.6581	21.4239
	15	5.7225E-02	1350.00	53.8056	39.9985	23.3102
	20	6.5080E-02	1620.83	55.5788	41.1390	24.4013
	25	7.4267E-02	1885.19	56.9444	42.2591	26.1148
	30	8.3717E-02	2185.71	58.1757	43.2265	27.4383
	35	9.0663E-02	2538.89	59.1512	44.2178	28.7556
	40	9.8588E-02	2916.67	60.0809	45.3504	29.8854
	45	.10824	3173.33	60.8246	46.8375	31.0766
	50	.11767	3633.33	61.8665	47.5221	32.0602
	55	.12810	4061.11	62.7266	48.4968	32.8241
	60	.14070	4746.67	63.2993	49.8217	33.6790
	65	.15406	5444.44	64.0764	50.7356	35.1293
	70	.17304	6147.62	64.8462	51.5777	36.7894
	75	.18988	6944.44	65.6530	52.5894	38.2102
	80	.21430	8666.67	66.7093	53.8684	39.8061
	85	.24010	10333.33	67.7318	55.4631	41.8490
	90	.30187	12900.00	69.6021	57.2342	44.4792
	95	.38230	16206.67	71.5541	59.8483	47.3287

a Calculated from grouped data.
b Multiple modes exist. The smallest value is shown
c Percentiles are calculated from grouped data.

Appendix 2: Examples of presentations of landscape function at the site scale

Functional type: Sandplain community

Percentile	RC Index	Stability	Infiltration	Nutrient	Density
N	288	354	354	354	318
95	0.541	76.8	65.4	51.0	8577
90	0.428	73.8	62.1	47.7	6733
85	0.318	71.6	59.6	45.1	5467
80	0.276	69.8	58.2	43.5	4815
75	0.266	68.9	56.7	41.5	4358
70	0.245	67.6	55.8	39.8	3783
65	0.218	66.9	54.3	38.0	3433
60	0.205	65.5	53.3	36.2	3200
55	0.197	64.6	52.6	34.8	2858
50	0.169	63.5	51.8	33.3	2625
45	0.156	62.7	50.5	31.5	2467
40	0.140	62.2	49.4	30.6	2253
35	0.123	61.4	48.1	28.9	2127
30	0.112	60.2	46.8	27.5	1933
25	0.102	58.8	45.9	26.0	1625
20	0.093	57.8	44.2	25.2	1383
15	0.079	56.3	43.2	23.7	1217
10	0.068	54.6	41.8	21.3	967
5	0.050	52.4	38.7	18.1	666

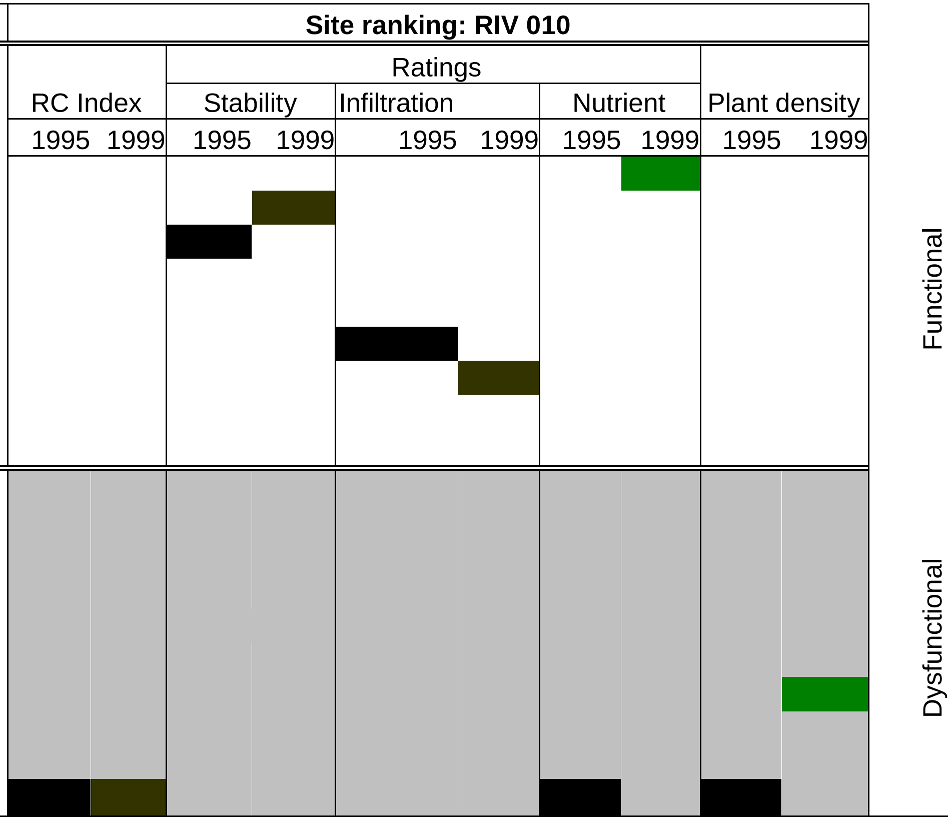


Black to black = no significant change; to green positive change;
to red negative change

Pastoral change rating: 0 (ie no change in long-term pastoral value derived from perennial shrubs)

Functional type: Shrubland (chenopod)

Percentile	RC Index	Stability	Infiltration	Nutrient	Density
N	1162	1430	1430	1430	1352
95	0.384	75.9	66.4	53.9	16058
90	0.300	73.7	63.5	49.6	12667
85	0.239	72.1	61.5	47.2	9894
80	0.213	70.8	59.2	45.4	8100
75	0.187	69.8	57.7	43.5	6733
70	0.171	68.9	56.4	41.7	6063
65	0.153	67.6	55.4	40.1	5235
60	0.140	66.8	53.8	38.4	4609
55	0.127	65.9	53.1	36.9	4000
50	0.116	64.9	51.8	35.5	3533
45	0.107	63.8	51.0	34.0	3067
40	0.097	62.9	50.0	32.7	2785
35	0.088	62.0	48.7	31.3	2383
30	0.081	60.8	47.5	29.8	2098
25	0.072	59.6	46.2	28.0	1817
20	0.063	58.5	44.6	26.2	1567
15	0.055	56.8	43.0	24.1	1267
10	0.045	54.4	40.9	22.2	967
5	0.034	51.2	38.3	19.8	650



Black to black = no significant change; to green positive change; to red negative change

Pastoral change rating: **+ve +ve** (I.e. significant increase in pastoral value derived from perennial shrubs)