National Land and Water Resources Audit

A Natural Heritage Trust Initiative

Rangeland Monitoring

Contract 1.1
Ecosystem Function Analysis of Rangeland Monitoring Data
OR
Rangelands Audit Project 1.1

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David Tongway and Norman Hindley

CSIRO Wildlife and Ecology
GPO Box 284
Canberra, ACT 2601

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1 EXECUTIVE SUMMARY

Rangeland monitoring must address the needs of a broad client base, not just the current user. The types of monitoring data collected by the States and the Northern Territory overall have a moderate to high potential to identify indices of change in landscape function at the site scale. The capacity varies from State to State and also within individual indicators. Some vegetation-based methods inherently provide very little information about landscape function *per se*, and make assumptions or "black-box" a chain of implications about the substantive informing capacity of the monitoring data. Very little evidence was provided which showed broad-based causal relationships. Nonetheless, specific local statistical (allometric) relationships between existing vegetation-based data and landscape function could be developed on a biome by biome basis, thus making use of the existing database. Soil-based methods, as a group, were much more amenable to direct landscape function interpretation.

The description of landscape types and their spatial distribution, based on land-system survey protocols is fairly uniform across the board, so that aggregating site scale monitoring information to regional scale would be a relatively straight-forward process. Land system surveys enable landscape types of similar ecological characteristics to be mapped. Substantial areas of the rangelands have been so mapped using very similar protocols. Monitoring data from a number of sites of similar type but different functional status would permit regional summaries to be made. Interpretations of landscape type in terms of a continuum between "robust" and "fragile" would be one of the outcomes of this analysis. Current and future developments in remote sensing and GIS will aid this process, enabling the broader extrapolation of site-based estimates. A biophysical explanation in terms of a landscape function response curve would be available for each landscape type, permitting an interpretation of current status and possible future status, given various scenarios.

The information supplied shows that considerable thought and research has gone into the selection of data type and field protocols, but very little into using the data to derive critical threshold values. However, the capacity to identify and specify critical thresholds with the existing monitoring data set would appear to be possible by adopting an appropriate interpretational framework. The concept of a critical threshold implies the existence of a sharp change in the response of a system such that spontaneous reversal in landscape condition or function is beyond the management time frame. Soil surface monitoring data now being analysed may assist in this process. Establishing the changes in landscape function in response to a change of stresses and disturbances, in the form of a landscape function curve, is of paramount importance, if the issue of critical thresholds is to be resolved. An example of such an exercise is described. We recommend that the use of sigmoidal curves should be investigated because their defining parameters intrinsically provide a number of values with high potential use for the purposes defined in the Audit objectives for this project, and have both intuitive and experimental attraction.

2 INTRODUCTION

The Pastoral Industry is the traditional user of the bulk of Australian rangelands since European settlement, with mining operations occupying small but highly disturbed areas. However more recently other significant uses, such as conservation, tourism and military occupation have been established in sections of the rangelands, and Aboriginal communities have control of significant parts of their traditional lands (Ash, 1996).

The need to use rangelands in a sustainable manner has gained broad acceptance. Recently there has been a heightened public awareness of issues like the effects of global change, loss of endangered species and/or biodiversity, secondary salinity and desertification. "Clean, green" products are seen as having a marketing advantage. Importantly, there is a realisation that action needs to be taken to avoid cutting off options for future generations.

The National Land and Water Resources Audit has been charged with the task of reviewing current rangeland monitoring data with the goal of "developing a rigorous assessment of landscape trend through measures of change in landscape function"(Holm 1998).

This task is made difficult by the ever-present problem of how to assess the vast expanse of rangelands adequately with cost-effective yet reliable methods and make that information available at a range of scales from paddock to region.

The guidelines for this report were specified as:

(i) Using existing State/Territory monitoring site data, identify indices of depression in landscape function at the site scale and methods to aggregate these data for regional summaries.

(ii) Identify first-pass critical thresholds in landscape function for tropical, subtropical and temperate grasslands and semi-arid shrublands using monitoring site data and recommend methods to aggregate these data for regional summaries.

These are ambitious objectives. The concept of landscape function is a relatively new one and probably not explicit in the minds of those who devised the various State and Territory monitoring programs. The State monitoring procedures have a solid history of both concept and method development, for example Wilson *et al.* (1987), Friedel (1991) and Hacker (1992) provide useful reviews of a considerable body of work. All the State programs were adopted with the best available informing science at the time and with a distinct bias towards a purely pastoral industry use.

This report provides a generic approach to all four biomes and addresses how the State and Territory data can be summarised on a regional scale.

3 WHAT IS LANDSCAPE FUNCTION?

The words "ecosystem function" and landscape function" appear in both of the set objectives of project 1.1, but they are being treated as having the same scope. The concept of ecosystem function has been growing during the emergence of landscape ecology as a recognisable branch of science (Forman and Godron 1986, Risser 1987). However its roots may be traced to Jenny (1941) and even to the father of soil science Dokuchaef. Noy-Meir (1973, 1981) pioneered key ecological concepts that advocated the need to understand the role of spatial heterogeneity in landscapes in terms of the availability of water, to support perennial plant communities in rangeland landscapes that typically have low and unreliable rainfall. In particular, the notions of temporal resource pulses and of a soil-based reserve of seeds and other resources were central to the understanding of the functioning of these ecosystems.

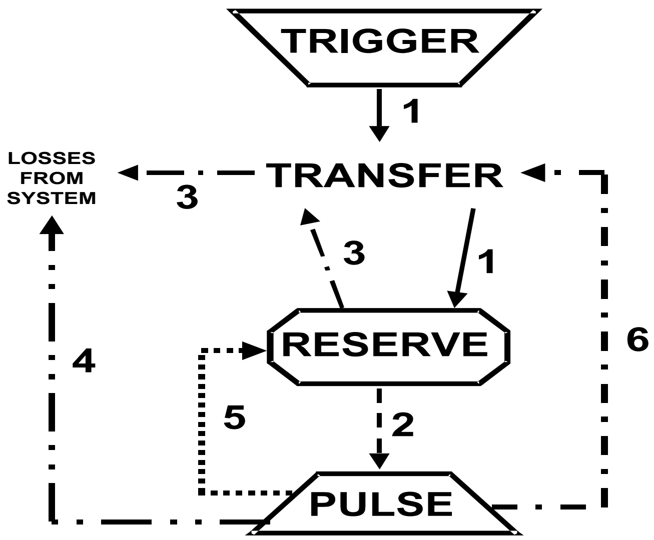
Briefly, landscape function is concerned with understanding how well a landscape is working **as a system** (Ludwig *et al.* 1997). It is explicitly spatial and dynamic in concept, seeking to establish cause and effect relationships. Rangelands are by definition, resource-poor, so the efficient use of scarce, vital resources at the landscape scale is essential. The building blocks of landscapes are units of land linked by their source/sink or runoff/runon relationships. In turn these basic building blocks are linked as a network in a watershed. Resources such as water, topsoil and litter are mobilised from a source zone, transferred and deposited in the conjugate downslope sink zone. This style of analysis can be applied to any rangeland landscape. Function is therefore intrinsically concerned with the dynamics of processes, the consequent "quality" of the source and sink zones, and the resultant consequences for the biota. A landscape may be judged to be highly functional if the source/sink relationship leaks few resources in the transfer process. Resources mobilised from source zones will be small per event and their flux slow enough to be captured by the sink zone. That is, there is an organisation of biotic and abiotic components in the landscape, which permits this outcome. A satisfactory species composition would be interpreted in terms of an effective interaction between climatic events, topography and soil quality, the plants themselves providing effective feedback processes.

Landscape dysfunction refers to leakage or loss of resources. For example, a source patch may yield large quantities of resources so quickly that the sink zone is unable to absorb them and they flow out of the system. Additionally, the sink patch itself may be subject to dispersal of long-accumulated resources such as topsoil, organic matter and seeds.

Changes to function may come about by management/climate interactions. Runon zones have also been called "fertile patches", and are the manifestation of effective resource accumulation and cycling over time. A continuum exists between the highest degree of function and the lowest. In this context, biota are both contributors to processes underlying ecosystem function and also the beneficiaries of ecosystem services derived from ecosystem function.

It is an objective of landscape function analysis to account for or explain changes in, say, vegetation species composition both in terms of ecosystem processes referred to above and in the quality of the edaphic habitat. A change may signify a major landscape function shift with major consequences for production and biodiversity, or may be a much less significant issue, that is spontaneously reversible in management time. For example, a particular plant species may be grazed out locally, due to the physiological stress of persistent grazing but re-colonises when grazing pressure is relieved. This implies that function was affected minimally. It is an objective of landscape function analysis to understand the underlying reasons for this differential behaviour. Disturbances such as fire, clearing and grazing are interpreted in terms of changes in process rates, the spatial distribution of vital resources and in soil properties to constitute an appropriate plant habitat.

To make these sorts of judgements from field data, a conceptual framework for interpreting landscape function is essential. Ludwig *et al.* (1997) described such a conceptual framework (trigger-transfer-reserve-pulse) expressing landscape function in terms of the sequence of processes involving vital resources and included feedback (or controlling) loops in a systematic way (Figure 3.1). This framework was originally derived from landscape pattern analysis and measurement of a number of environmental variables confirming that pattern implied both processes and properties related to edaphic habitat quality (Tongway and Ludwig, 1990; Greene, 1992; Anderson and Hodgkinson, 1997).



Ref	Process
1	· Run-on · Storage/Capture · Deposition · Saltation capture
2	· Plant germination, growth · Nutrient mineralisation · Uptake processes
3	· Run-off into streams · Rill flow and erosion · Sheet erosion out of system · Wind erosion out of system
4	· Herbivory · Fire · Harvesting · Deep drainage
5	· Seed pool replenishment · Organic matter cycling/Decomposition processes · Harvest/Concentration by soil micro-fauna
6	· Physical obstruction/Absorption processes

Figure 3.1: A conceptual framework representing sequences of ecosystem processes and feedback loops. The table lists some of the processes operating at different locations in the framework.

There is some disparity between the concepts of ecosystem function and those underlying some monitoring procedures, particularly those that rely entirely upon plant species as the source of information, as the latter are not explicitly related to processes, but may have weak, implied connections. These will be examined in more detail below in the sections on existing monitoring methods.

The landscape function approach is comprised of explicit linkages between measured ecosystem variables, the conceptual ecosystem functional framework incorporating pattern and process, indicators of function and the interpretation of landscape function for the use by a potentially broad range of landusers.

The whole process of assessment of landscape function for specified purposes is intended to be an adaptive process. Figure 3.2 indicates that the process is intended to be on going, self-improving and inclusive of the participants.

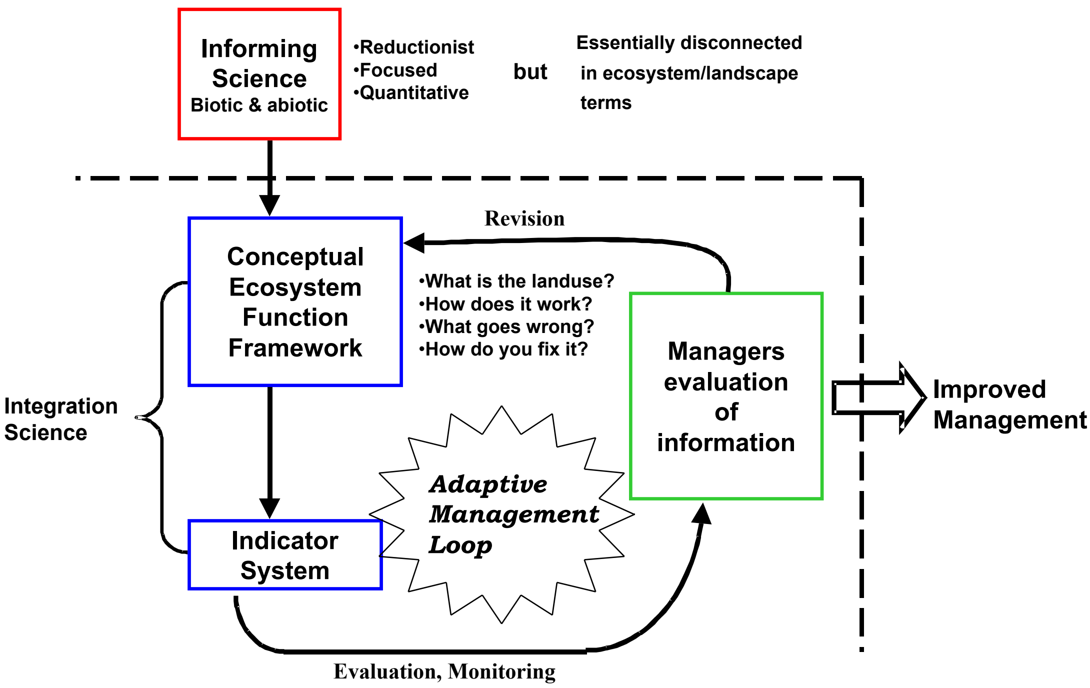


Figure 3.2: An example of an adaptive loop in the development of an appropriate conceptual framework for the ecosystem to be managed, linking users and scientists. Multiple iterations of the loop are expected.

4 OVERVIEW OF EXISTING NATIONAL MONITORING PROCEDURES.

Existing monitoring programs have been subject to extensive scrutiny in recent times. Issues of methodology, data acquisition and interpretation have been examined by the National Rangeland Monitoring Program (1997). Table 4.1 is a summary of the site properties recorded in State and Northern Territory monitoring procedures. These are characterised by a strong degree of similarity between States and adherence to the protocols of the Australian Soil and Land Handbook. There is a strong link to land system mapping, which has a long and respected place in surveying Australia's natural resources in the rangelands.

Table 4.1. A comparison of site characterisation and monitoring methodologies employed by the respective State and Northern Territory Agencies.

Site parameters	WA grassland	WA shrubland	NSW	QLD	NT	SA	VIC
Location - permanently marked	Yes	Yes	Yes	Yes	Yes	Yes	Yes
- GPS located	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area of site (ha)	0.2	0.17	25.0	9.0	1.0	4.0	x
Site designed to ground truth satellite imagery	Yes	Yes	Yes	Yes	Yes	Yes	x
Photopoints	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rainfall characterisation (eg. Ave annual)	homestead	homestead	monthly	Yes	x	x	Yes
Land unit(LU)/Land system (LS) description	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Topography classification	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Position in landscape	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Slope	x	x	x	Yes	Yes	Yes	Yes
Geology	Yes (part of LS descrip.)	Yes (part of LS descrip.)	x	x	x	Yes	Yes
Grazing characterisation (type, pressure)	Yes	x	Yes	Yes	Yes	Yes	Yes
Distance from permanent water	Yes	Yes	Yes	Yes	Yes	Yes	
Biological impact of - fire	Yes	Yes	Yes	Yes	Yes	Yes	
- flood	Yes	Yes	Yes	Yes	Yes	x	
- insects	x	x	Yes	x	x	x	
Site condition rating	Yes	x	Yes	x	Yes	Yes	
Seasonal rating - rainfall	x	x	Yes	Yes	Yes	x	x
- index	NOAA	NOAA	Yes	x	x	Yes	x
Soil - description	Yes	Yes	Yes	Yes	Yes	Yes	Yes
- surface condition	some site	Yes	Yes	Yes	Yes	x	Yes
Vegetation - original present	LU	LU	LU	Yes	LU	LU	Yes