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LANDSCAPE FUNCTION ANALYSIS: A SYSTEMS APPROACH TO ASSESSING RANGELAND CONDITION

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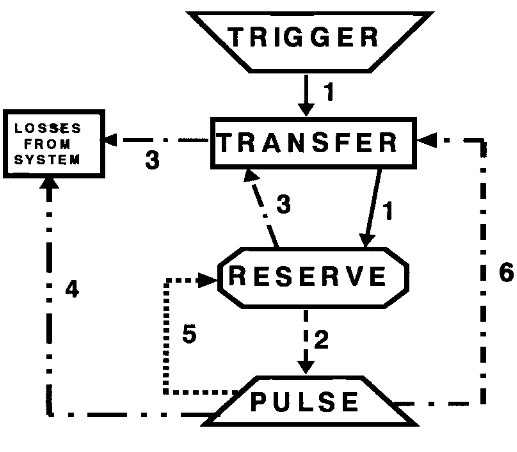
ABSTRACT

We propose a procedure for the assessment of rangeland function, comprised of three components: a conceptual framework, a field methodology and an interpretive framework. The conceptual framework treats landscapes as systems: defining how landscapes work in terms of sequences of processes regulating the availability of scarce resources. The field methodology uses indicators at landscape and patch scale to provide and structure information to satisfy the needs of the conceptual framework. The interpretational framework provides a process to identify critical thresholds in landscape function and thus provide a function-based state and transition landscape assessment. The approach is quick and simple in the field, is applicable to all range landscapes and amenable for use by a wide range of end-users.

INTRODUCTION

Rangeland monitoring has typically been descriptive: restricted to evidence provided by a narrow range of biota or associated with theories of plant succession (Golley 1977). Methods have also been largely tied to pastoralism as the only land-use. This situation is now changing, with a broader societal use of rangelands. Monitoring and comparing landscapes on an inter-regional and national basis, for example the National Land and Water Audit, would be facilitated if the procedures were widely applicable and the data directly comparable. Walker (1996) called for an understanding of how rangelands function by building conceptual models. Ludwig and Tongway (1997) presented a systems-based framework (trigger-transfer-reserve-pulse — TTRP, Figure 1) for the way in which rangelands function, based on how landscapes function to conserve and utilise scarce resources. This framework also facilitated the development of more detailed simulation models (e.g. Ludwig and Marsden 1995), enabling the role of these models to be seen in a wider, landscape context.



Ref	Processes Involved	
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 1. The TTRP framework representing sequences of ecosystem processes and feedback loops. The table lists some of the processes operating at different locations in the framework.

METHOD DEVELOPMENT

The TTRP framework represents a sequence of landscape processes and feedback loops in an inclusive manner, enabling the structuring of environmental information. Methods to assess soil productive potential linked to plant performance had been developed to a certain stage (Tongway and Smith 1989, Ludwig and Tongway 1992), but needed the spatial and inter-regional context to become more useful to potential stakeholders. The soil condition indicators were initially developed from geomorphic processes such as erosion, crust formation, litter decomposition and correlates observed in the field. The validity of these indicators was enhanced by laboratory experiments (Műcher *et al.* 1988, Greene *et al.* 1994) and field measurements (Tongway 1993, Greene 1992). Spatial analysis of a number of landscape types (Ludwig and Tongway 1995) suggested a means by which the soil indicators could be packaged for use in different landscape types.

In 1992-1995, NSCP funding brokered by Ag WA facilitated the development of extensively applicable methods, integrating soil surface condition procedures with the emerging TTRP framework. This resulted in a nested hierarchical information system. The method was overtly linked to land system resource map bases (e.g. Mitchell *et al.* 1988; many others). Land units as sub-units within land systems were recognised, with the monitoring site located within the land unit. Australian standard methods (McDonald *et al.* 1990) were used to provide landform and slope characterisation.

THE METHOD IN OPERATION

"Landscape organisation" is the coarsest form of LFA data and is the first step in data collection. Data are collected on a line transect oriented in the direction of resource flow (usually down slope, but aeolian landscapes would use wind direction). Landscape features that interrupt, divert or absorb runnoff and transported materials are recorded according to protocols outlined in the technical methods manual (Tongway 1994, Tongway and Hindley 1995, 2000). Typically, zones of resource loss (source or runoff zones) are distinguished from zones of resource gain (sink or runon zones) and their relative sizes measured. Several indices of landscape organisation can be deduced from these data. In addition, the data provides a "map" of the transect. In the second step, each zone type, 10 soil surface variables, plus soil texture are assessed, using the methods in the manuals. These observations are both simple and quick after a little practice. Vegetation parameters (such as density, species composition, size) can also be collected from the same transect by plotless, distance measuring techniques (Bonham 1979), as well as indicators of habitat complexity for mammals and birds (Newsome and Catling 1979).

CALCULATION OF INDICES

The soil surface data are combined in different combinations to reflect three major soil habitat quality indices: stability or resistance to erosion, infiltration/water holding capacity and nutrient cycling (Figure 2). The data are presented in percentage terms.

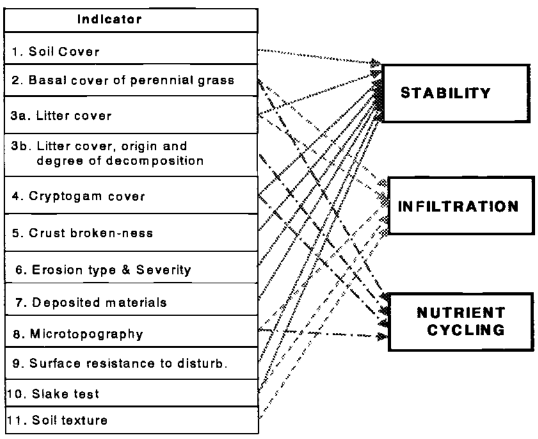


Figure 2.
The combination of Soil Condition Classes to derive indices of Stability, Infiltration and Nutrient Cycling.

INTERPRETATIONAL FRAMEWORK

The values tabulated need to be interpreted in the landscape context to make the most use of their information potential. With extensive experience, one might be able to place useful interpretations on each of the index values, but this is a haphazard process. The most recent development in LFA is the process whereby a response surface in the form of a sigmoidal curve is generated from field data (Tongway and Hindley 2000). The curve relates functional status with stress and disturbance. To fit this curve, one needs data from both extremes of the available data space as well as "typical" sites encountered in monitoring which will have intermediate values. The response surface (Figure 3) recognizes the upper asymptote as the biogeochemical potential of the site limited by climate and parent material and the lower asymptote as the lower limit of function under the existing land use stress. The slope of the line joining the asymptotes reflects the "robustness" or "fragility" of the system.

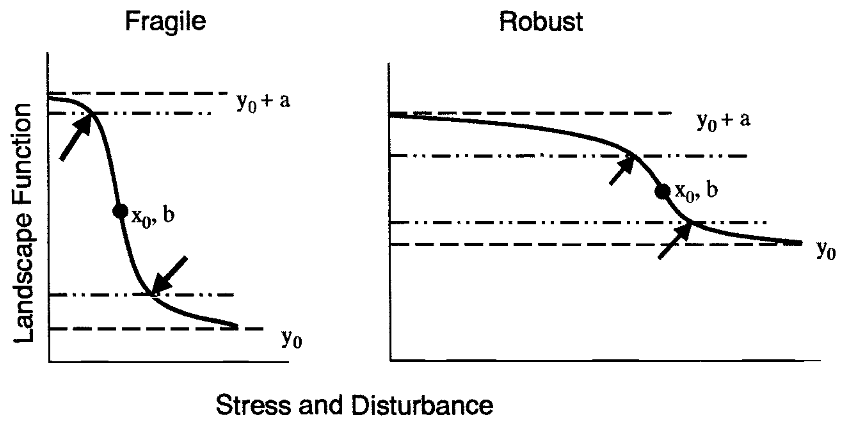


Figure 3. Examples of response curves for fragile and robust landscapes. The initial response of landscape function to stress and/or disturbance is markedly different. The fragile landscape deteriorates with low stress and has a much lower base line $\mathbf{y_0}$ then the more robust landscape. Four-parameter sigmoid curves of the form $\mathbf{y = (y_0 + a) / 1 + e^{-(x-x_0)/b}}$ provide four practical values reflecting the nature of the landscape. Critical thresholds (arrows) for each of the indices can be determined from field data.

REFERENCES

Bonham, C.D. (1989). Measurements for Terrestrial Vegetation. John Wiley and Sons, USA.

Golley, F.B. (1977). Ecological Succession. Dowden, Huthinson & Ross, Stroudsburg

Greene, R.S.B. (1992). Soil Physical properties of three geomorphic zones in a semi-arid mulga woodland. *Aust. J. Soil Res.* 30: 55-69

Greene, R.S.B., Kinnell, P.I.A. and Wood, J.T. (1994). Role of plant cover and stock trampling on runoff and soil erosion from semi-arid wooded rangelands. *Aust. J. Soil Res.* 32: 953-973.

Ludwig, J.A. and Marsden, S.G. (1995). A simulation of resource dynamics within degraded semi-arid landscapes. *Mathem.Comput. Simul.* 39: 219-24

Ludwig, J.A. and Tongway, D.J. (1992). Monitoring the condition of Australian arid lands: linked plant-soil indicators. *In* 'Ecological Indicators' (Eds D.H. McKenzie, D.E. Hyatt and V.J. McDonald). Elsevier, Essex. pp. 765-72.

Ludwig, J.A. and Tongway, D.J. (1995). Spatial organisation of landscapes and its function in semi-arid woodlands, Australia. *Lands. Ecol.* 10: 51-63.

Ludwig, J.A. and Tongway, D.J. (1997). A Landscape approach to Rangeland Ecology, *In* 'Landscape Ecology Function and Management: Principles from Australia's Rangelands.' (Eds J. Ludwig, D. Tongway, D. Freudenberger, J.C. Noble and K. Hodgkinson). CSIRO, Melbourne, pp. 1-12.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1990). *Australian Soil and Land Survey Handbook Second edition.* Inkata Press, Melbourne

Mitchell, A.A., McCarthy, R.C. and Hacker, R.B. (1988) A range inventory and condition survey of part of the Western Australian Nullarbor Plain, 1974. Technical Bulletin No.47, Western Australian Department of Agriculture.

Műcher, H.J., Chartres, C.J., Tongway, D.J. and Greene, R.S.B. (1988) Micromorphology and Significance of the Surface Crusts of Soils in Rangelands near Cobar, Australia. *Geoderma* 42: 227-244

Newsome, A.E. and Catling, P.C. (1979). Habitat preferences of mammals inhabiting heathlands of warm temperate coastal, montane and alpine regions of southeastern Australia. *In* 'Heathlands and Related Shrublands of the World' (Ed Specht, R.L.). Ecosystems of the World. Vol. 9A. Elseveir Scientific Publishing Co., Amsterdam. pp. 301-316.

Tongway, D.J. (1993). Functional analysis of degraded rangelands as a means of defining appropriate restoration techniques. *In* 'Proceedings of the Fourth International Rangeland Congress'. (Eds A. Gaston, M. Kernick and H. Le Houérou). Montpellier, pp. 166-68

Tongway, D.J. (1994). Rangeland Soil Condition Assessment Manual. CSIRO, Melbourne.

Tongway, D. and Hindley, N. (1995). Assessment of Soil Condition of Tropical Grasslands. CSIRO Division of Wild life and Ecology, Canberra.

Tongway D. and Hindley N. (2000). Assessing and monitoring desertification with soil indicators. *In* 'Rangeland Desertification.' (Eds S. Archer and O. Arnalds), Kluer, Dordrecht, The Netherlands.

Tongway, D.J. and Smith E.L. (1989). Soil surface features as indicators of rangeland site productivity. *Aust. Rangel. J.* 11: 15-20

Walker, B.H. (1996). Having or eating the rangeland cake: a developed world perspective on future options. *In* 'Rangelands in a Sustainable Biosphere' Vol. II. Proceedings of the Fifth International Rangelands Congress. (Ed. N. West) Society of Range Management, Denver. pp. 22-28.