Assessing catchment functional integrity in the Gascoyne-Murchison region of Western Australia

Hugh Pringle[1] and Ken Tinley[2],

[1] Department of Agriculture, Centre for Management of Arid Environments, P.O.Box 417 Kalgoorlie, WA 6430. [2] WA Wildlife Research Centre, Department of Conservation and Land Management, Woodvale, WA 6005.

Context

Scale and hierarchy issues are seen as critical areas for research in order to manage natural resources in more sustainable ways {Allen, O'Neill, et al. 1984 #110}. In Australian rangelands, much progress has been made in extending spatially observations made at fine (or local) fractal dimensions using remote sensing {Ludwig, Bastin, et al. 2000 #4060}{Bastin, Ludwig, et al. 2002 #4580}.

However, these approaches are essentially spatial extensions of traditional site or plant community scale observations (or finer). They do not focus on the variables of pattern and process that operate specifically at catchment scales. In this sense, the substantial progress can be said to have addressed scale issues with minimal attention to issues of ecological hierarchy {Allen & Starr 1982 #78}{Allen, O'Neill, et al. 1984 #110}{O'Neill, DeAngelis, et al. 1986 #1180}. Never-the-less, this progress will play a major role in future monitoring and managing rangelands, but perhaps could be strongly complemented by a more hierarchical conceptual framework for managing rangelands. That is, we suggest that an understanding of why fine-scale pixel values are changing is required in order to plan new trajectories or reinforce the status quo.

This article results from work through the Ecosystem Management Unit of the Gascoyne-Murchison Strategy in the arid scrublands of Western Australia {Pringle & Tinley 2001 #4340}{Tinley & Pringle 2002 #4440}. It uses the catchment as the fundamental unifying geo-ecological context {Tinley 1991 #4190} in terms of i) characteristics of healthy catchments, ii) key drivers of catchment changes, iii) symptoms of dysfunctional catchments, and iv) some approaches for restoring catchment integrity. “Integrity” (or being “intact”) is regarded here as including patterns and processes reflecting minimal alteration from pastoral and other economic developments.

Our premise is that widespread rangeland degradation needs to be understood within a broader, geomorphic context than contemporary within-landscape assessments {Pringle 1991 #770}{Ludwig & Tongway 1995 #1870}{State Of Environment Advisory Council 1997 #930}{Rapport & Whitford 1999 #1740}{Bastin, Ludwig, et al. 2002 #4580}. In this article we attempt to describe indicators of catchment functional integrity and dysfunction, in the hope that some of the narrative (indicators) will be adequately foreign to contemporary descriptions of rangeland “health” or degradation, that the need for this catchment context in its own right will be obvious.

We believe that with management of rangelands (particularly restoration activities) based on increasingly better understanding catchment-scale patterns, processes and critical control points, the cumulative assessments from remote sensing will more likely show desirable trends in space and time. Without this geo-ecological context though {Tinley 1982 #4030}, we believe much rangeland restoration will continue to be symptom's-based and frustratingly unsuccessful {Hacker 1989 #2270}.

i) Characteristics of intact catchments

1. Incision of drainage tracts restricted largely to strongly sloping erosional terrain
2. Limited net export of resources (especially sediments)
3. High rain-use efficieny; strongly contrasting values at nested scales reflecting strong ecological organisation/differentiation
4. Strongly heterogeneous pattern and processes within component land systems/terrain elements
5. Clear boundaries between terrain process elements (eg run-through pediments, run-on floodplains)
6. Retention of intact (not leaking/breached) ephemeral wetlands at terrain process element junctions
7. Unaccelerated land succession processes
8. Long residence times of floodwaters on floodplains
9. Nested series of base levels primarily set by geomorphic context, rather than by incision wrought by land use
10. Effective distributary (slowing and spreading) flow down-slope of pediments with minimal incision
11. Effective overbank flooding with moderate events, rather than just after extreme rainfalls
12. Long periods of creek and river flow due to obstruction/infiltration in the catchment area (slower, longer lasting flows)
13. Slower, finely scaled erosion cells marching up-slope, allowing effective sel-healing within landscapes
14. Longer, less "spiky" responses of primary productivity to rainfall, with strong differentiation between terrain process elements
15. Effective and persistent "greening up" of local ephemeral wetland features at terrain process element junctions in response to local rainfalls
16. Control of scrub encroachment by effective seasonal waterlogging in flooded areas in all terrain process elements (including uplands).

ii) Key drivers of catchment change in the Gascoyne-Murchison region

1. Watering places in/near drainage tracts leading to incision, headward gully retreat and land dessication; particularly near key-lines at which drainage patterns should switch from tributary to distributary process states
2. Water capture, erosion and down-slope droughting due to poorly located and constructed access routes
3. Livestock pads breaching ponding sills in wetlands, including pans, billabongs, levee banks and convergent delta plugs.

4. Livestock pads linking erosion cells and initiating rapid headward gully erosion and landscape desiccation
5. Excessive grazing pressure reducing ground cover and so obstructions to flows of wind and water, exacerbating/accelerating natural land surface succession processes such as i) sediment accumulation in pans and ii) the fragmentation and stripping of wanderrie bank sands.
6. Low ground cover and canalised drainage networks leaving interfluve areas effectively perched above most water flow, and increased sediment output (or accumulation in endoreic drainage termini)
7. Landscape excision leading to more rapid drianing/drying of floodplains, which in turn favours scrub species over previous hydrophytic floodplain grasses.

iii) Symptoms of dysfunctionaldrainage systems

1. Nested hierarchies of lowered base-levels initiating canalisation and widespread sheet erosion with resulting landscape desiccation
2. Strongly canalised drainage networks connecting watersheds to exit/sump areas with severely reduced infiltration across the catchment
3. Scrub encroachment of leaking floodplains
4. Increasingly large rainfall events required for overbank flooding in deeper and wider channels
5. Shortened periods with moist soils hence shorter-lived vegetation responses to rainfall
6. Reduced differentiation of responses to rainfall between terrain process elements
7. Breaching, erosion and desiccation of ephemeral wetlands by gullies at terrain process element junctions
8. Increased prominence of bare soil, annual plant communities and scrub in seasonally waterlogged areas
9. Decline in prominence of perennial grasslands and chenopod shrublands; bare stages colonised after time along guttered erosion by scrub
10. Increased and expanding soil erosion (coalescence of bare and scalded areas)
11. Larger and faster eroding erosion cells, loss of self-healing capacity
12. Increasing “spiky” responses to rainfall across process terrain elements subject to run-on (due to desiccation).
13. Within landscape reduction in strength of patterning and loss of radioactive nuclides (eg Pb210, Cs157) and migration downslope and lost out of exoreic (out-flowing) catchments and accumulating in endoreic basin concavities.
14. Increasing dominance of broader-scale physical geomorphic processes (e.g.landscape reversal, headward gully retreat) over finer-scale biologically-mediated processes.

iv) Some approaches for restoring catchment integrity

1. Critically, identify lowered base-levels in drainage networks and restore them as best as possible once the cause of their lowering has been addressed (e.g. reticulate water away from critical drainage pattern control points; encourage stock to travel across slope to favoured grazing areas)

2. As above for breached wetland sills (the sills are the local base levels responsible for a wetlands existence)
3. Develop grazing strategies in line with the different behaviour of terrain process elements (particulary with respect to toposequences/catena responses to rainfalls)
4. Choose type of livestock that will facilitated recovery (e.g. sheep tend to graze down to ground level, baring much soil and reducing resistance to flows; conversely, goats graze perennial grass least if they have access to browse)

The choice of techniques with which to restore ecological functioning within individual landscapes should focus on using natural processes to direct autogenic succession {Tongway & Ludwig 1993 #4}{Whisenant 1999 #4590}.

Conclusion

Contemporary documentation of rangeland degradation consists of aggregated {State Of Environment Advisory Council 1997 #930} or spatially explicit {Bastin, Ludwig, et al. 2002 #4580} accounts of within-landscape dynamics. Yet these assessments record the impacts of landscape change, not the causes. If monitoring is to be useful, it must have management context {Walters 1986 #135}. Yet assessments of degradation within-landscapes seem to have encouraged development of symptoms-focused restoration, that is; within-landscape restoration {Hacker 1989 #2270}{Tongway & Ludwig 1993 #4}. This focus on lower levels of ecological hierarchy is consistent with much contemporary ecosystem modelling {Garner & Steinberger 1989 #4640}{Milton, Dean, et al. 1994 #1200}{Chapin, Walker, et al. 1997 #4650}{Scholes & Archer 1997 #4620}{Breshears & Barnes 1999 #4660}{Whisenant 1999 #4590} (it is not a particularly Australian tendency).

Degradation in Australia’s rangelands is extensive {State Of Environment Advisory Council 1997 #930}; effective restoration of widely degraded catchments is likely to require a catchment-level approach. Once drainage patterns become slower, more spread out and sinuous, local within-landscape approaches {Tongway & Ludwig 1993 #4}{Whisenant 1999 #4590} are likely to succeed. However, until this more expansive approach is enacted, the success of local interventions is likely to be at best restricted to landscapes selected for intervention treatments, rather than addressing the full scale at which degradation has occurred.

Diagnosis and restoration of catchment integrity therefore requires far more than the collation of multiple fine-scale observations. Assessing and monitoring catchment integrity need to be based on catchment models based primarily on geomorphology {Mabbutt 1963 #2010}{Tinley 1982 #4030}, rather than patch/inter-patch landscape ecology. Importantly, approaches to repair damaged catchments (rather than their worst affected landscapes) are urgently needed. Within-landscape approaches are unlikely to result in the major shifts in process-states needed to address catchment scale dysfunction. Indeed, progress in addressing catchment-scale restoration may greatly enhance local landscape restoration {Murchison Land Conservation District Committee and the Ecosystem Management Unit. 2002 #4470}.

Importantly, grazing management such as resting strategies can only achieve so much in catchments that have large areas effectively perched above average sheetflows or subject to less frequent and less persistent flooding (Pringle and Tinley submitted). These areas are entrained in an insidious trend of increasing desiccation {Tinley 1982 #4030}{Tinley 2001 #4370}. Canalised drainage patterns need to be addressed by restoring *base levels* at major drainage confluences starting at source areas and working downwards. Wetlands and floodplains may need to have ponding sills restored and reinforced. These strategic interventions will favour a flip from increasingly canalised and erosive drainage patterns and ineffective rain use, to slower, spreading drainage patterns more likely to deposit sediment than entrain it.

Finally, we recognise that the catchment-scale strategies so critical to effect meaningfully extensive rangeland restoration {Murchison Land Conservation District Committee and the Ecosystem Management Unit. 2002 #4470} will demand many more resources than are immediately available. Thus, critical success factors will include:
1. Catchment-scale participatory planning
2. Strong community cohesion and individual self-reliance
3. Commitment to long-term management objectives
4. Achievable objectives in successively longer timeframes
5. Some early successes, starting in source areas
6. Consistent, reliable Government support.