Are we overlooking critical geomorphic determinants of landscape change in Australian rangelands?

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The contemporary paradigm of range ecology is inadequate

We believe that geomorphic factors such as landscape incision and desiccation are erroneously overlooked in assessing landscape change across Australia's rangelands. Failure to acknowledge these factors leads to mis-diagnosis of the causes and solutions for dysfunctional rangelands. A new, geo-ecological appreciation of rangelands is urgently needed if progress towards ecological sustainability is to be based on realistic models of ecosystem dynamics at all levels of organisation and scales.

Traditional rangelands ecology has viewed ecosystem dynamics almost entirely in terms of the local and reversible impacts of grazing off-take {Dyksterhuis 1958 #22}. Plant community dynamics have since been acknowledged as being far more complicated {Connell & Slatyer 1977 #1780}{Noble & Slatyer 1980 #1790}{Westoby, Walker, et al. 1989 #51}. Recent advances in the analysis of landscape function {Ludwig, Tongway, et al. 1997 #810}, remote sensing {Bastin, Ludwig, et al. 2002 #4580} and biodiversity responses along grazing gradients {Landsberg, James, et al. 2002 #4560} have improved the depth and spatial extent of our understanding in Australia. Previously less evident within-landscape patterns are now better understood, over larger areas of assessment more appropriate to scales at which rangelands are subdivided and managed.

Yet much current research has been pre-occupied with patch/inter-patch interactions in Australia {Ludwig, Tongway, et al. 1997 #810}{Bastin, Ludwig, et al. 2002 #4580}and overseas {Schlesinger & Hartley 1996 #2500}{Breshears & Barnes 1999 #4660} and has overlooked the major role of base levels in influencing landscape change at all scales. In particular, base levels affect soil moisture balances {Tinley 1982 #4030} and phases of erosion and accretion{Pickup 1985 #1460}. While influential base levels are sometimes off-site; they are readily identified if the observer knows what to look for.

Incised base levels and landscape desiccation

One example of this is the emerging pattern that we have observed and photographically recorded from ground traverses and low-level flying (about 100 to 200 metres above ground level) in many areas of Australia and Africa. This observation is of a strong pattern of increased drainage (often caused by wildlife or livestock incisions of natural levees and riparian sills) resulting in accelerated edaphic desiccation at a landscape level, which may explain much of the vegetation change evident in these areas.

In detailed studies of the Urema Lake floodplain in the Gorongoza ecosystem of Mozambique, at the southern African end of the Great Rift Valley. Tinley {Tinley 1977 #4320/d} clearly documented landscape succession brought on by drainage incision and resultant desiccation and scrub invasion of floodplain grasslands. Breaching (by hippopotami) of a valley-side tributary fan alluvial plug across the outlet of the Urema Lake and its surrounding floodplains led to insidious and progressive desiccation of the entire wetland system. Scrub invaded out from faint convexities (often associated with termite mounds) and the valley sides to predominate over large areas of floodplains.

The Australian areas in which this essentially geomorphic model of change has been observed include the chenopod shrublands of the Murchison River floodplains in Western Australia {Murchison Land Conservation District Committee and the Ecosystem Management Unit. 2002 #4470}, and grassy floodplains including the convergent delta systems of the Northwest and Kimberley regions of Western. {Pringle & Tinley 2001 #4380} {Tinley 2001 #4370}.

Clearing, fire, herbicides and rest from grazing are traditionally recommended responses to scrub encroachment {Noble 1998 #1850}{Scanlan 2002 #4600} that reflect an assumption that causal factors are largely within the landscape. Scrub encroachment is usually explained in terms of local influences such as grazing pressure or lack of fire on competitive interactions with grasses {Walker 1974 #2580}{Archer 1994 #1290}{Scholes & Archer 1997 #4620}{Scanlan 2002 #4600} and sub-shrubs {Burnside, Holm, et al. 1995 #1}, although externalities such as climate are considered {Scholes & Archer 1997 #4620}{Breshears & Barnes 1999 #4660}.

The idea that grasslands persist due to buffering that makes encroachment unlikely in certain circumstances {Jeltsch, Weber, et al. 2000 #4610}is critical, but the process-state and control points that ensure that buffering persists need to be recognised and managed. The control points (base levels) may be local, but they are just as likely to be some distance way. Landscape level desiccation of soil profiles due to drainage incision has direct bearing on the transition from treeless grassland to scrubland {Tinley 1982 #4030}{Tinley 2001 #4370} and may well drive affected savanna systems to woody dominance over grasses.

Diagnosing catchment dysfunction in arid Western Australia: a preliminary case study

Together with local pastoralists {Murchison Land Conservation District Committee and the Ecosystem Management Unit. 2002 #4470}, we have built a model of catchment dysfunction (see Figure 1 for a simplified diagrammatic representation). The model includes:

i) On valley sides:

1. Desiccation of the Murchison River valley sides driven by incision and canalised drainage patterns (often associated with stock pathways out from inappropriately sited watering points),
2. effectively perching many sheetflood areas on valley sides,
3. leading to death by droughting of mulga trees on perched interfluves.

ii) In the fllodplain:

4. Breaching of rock bars and the subsequent lowering of the channel base level between breached rock bars,
5. which drives more rapid surface drainage of floodplains as they become perched above average flood levels,
6. deeper incision of river channels also means that greater intensity (less frequent) rainfalls are required to induce the flooding necessary to water floodplains,
7. such infrequent, but vast amounts of water place extreme pressure on the subtle sills that maintain the integrity of the floodplain (like the fan sill in the Gorongoza ecosystem),
8. the intense floodwaters work efficiently in finding minor breaches and accelerating gully retreat and expansion into the floodplain,
9. ensuring that the next flood is leaked more erosively and rapidly,
10. accelerating landscape desiccation throughout much of the catchment for any particular stretch of the river's between successive rock bars.

While evidence in Australia is largely observational rather than "scientific" that scrub encroachment is related intimately with landscape desiccation consequent of incision, other effects are already likely and highly predictable. For example, sometimes the denudation of vegetation under unremitting grazing stress, compounded by a declining moisture and topsoil environment, may lead to scalding, salinisation and soil erosion {Pringle 2002 #4360}. In the Murchison River catchment we have noted typical patterns of scrub encroachment associated with gully systems off levee banks initiated by stock tracks accessing river pools, a pattern reminiscent of that occurring in the northern floodplain grasslands mentioned previously. The clue to these processes is the age/size distribution of plant functional types. When scrub species have clear patterns of topographic encroachment expressed by increasingly smaller/younger plants subtly downslope, there is strong evidence that change is being driven by biophysical interactions, rather than grazing *per se.*

We have also seen vast areas of floodplains that once supported chenopod shrublands {Curry, Payne, et al. 1994 #580} now containing extensive scalded areas interspersed with scrub-dominated sandy accumulations. Only when an incision breaches the saline scalded flats do perennial shrub species colonise, initially within the expanding tributary gully system (due to better moisture conditions and decrease of sodium).

Implications for restoring rangelands

We acknowledge that increasing resistance to flows of wind and water by maintaining ground obstruction {Tongway & Hindley 1995 #800} will retard land succession processes and aid local restoration. Local restoration in canalised catchments with nested patterns of lowered local base levels has occurred during runs of good seasons {Watson & Thomas 2002 #4510}. However we believe that the fundamental changes wrought by landscape incision prevail as an underlying influence towards increasing desiccation. We contend that effective rangeland restoration requires that base levels are restored such that the tendancy for desiccation is addressed in a step-wise fashion down the catchment. This geomorphic approach will address primary causes at multiple scales (at nested base levels) and enable effective restoration of productive bottomlands.

Our hierarchical geo-ecological approach is in strong contrast to the almost sole focus on intensive mechanical intervention at the points displaying worst symptoms, sometimes far removed from incisions causing desiccation and dysfunction {Hacker 1989 #2270}.

Ecological restoration of widely dysfunctional rangelands may need combinations of fire, herbicides and special grazing management. However, we suggest that these are secondary activities. Symptoms management will continue to be a disheartening addiction because it is in confrontation with inexorable land succession processes that increasingly change the local conditions for plant growth through positive feedback loops {Whisenant 1999 #4590}.

Through the “EMU Exercise” {Pringle & Tinley 2001 #4340}, we recommend low input approaches at strategically located points of intervention at natural drainage bottle-necks, starting from the source areas and working downwards in order to harness naturally occurring processes to drive restoration from within.

Implications to research and management

We contend that a continued failure to look (or start from) higher in the hierarchy of ecological patterns and processes {Allen, O'Neill, et al. 1984 #110} severely limits our understanding of rangeland dynamics and how to manage, monitor and restore rangeland ecosystems. We suggest that local disruption of higher level geomorphic processes at critical control points in catchments often entrain far-reaching physical land succession processes that drive transitions in vegetation. Indeed, these transitions may involve complete ecosystem replacement from grasslands to savanna or thickets and forest. Despite substantial effort, these transitions have not generally been reversed effectively by traditional agronomic approaches to management of symptoms– in our view largely because of an excessive focus on site-based problems without due regard to geomorphic and catchment context and resultant landscape processes.

For instance on Billabalong station in the Murchison River catchment, a mix of intervention strategies had all failed to restore perennial vegetation and landscape function to a flood-out plain. When a group of pastoralists and ecologists travelled up-slope, we quickly agreed that the floodplain could only be restored when the water flows onto it had been calmed. Floodplain intervention became an eventual, rather than focal objective {Murchison Land

Conservation District Committee and the Ecosystem Management Unit. 2002 #4470}.

We suggest that an hierarchical, geo-ecological approach is required in managing rangeland ecosystems. That is, rather than starting at the finest scales, and scaling upwards to explain system behaviour {Ludwig, Bastin, et al. 2000 #4060}, we suggest that the system of interest needs first to be defined within its broader context {Tinley 1991 #4190}. Then it can be assessed in terms of nested hierarchies of key components and interactions {O'Neill, DeAngelis, et al. 1986 #1180}.

We acknowledge the contrary quantitative evidence of our hypothesis of inexorable rangeland desiccation in the Gascoyne-Murchison Strategy region of Western Australia{Watson & Thomas 2002 #4510}. However we note too that the widespread recruitment of a range of plant functional types (not just scrub species) occurred in response to a succession of good seasons and the sites sampled tend to be on large areas of relatively uniform landscapes, rather than at dynaimic edges. We propose, with some support (David Tongway and John Ludwig’s personal communications), that a major research effort is required to expand our understanding beyond patch-scale dynamics within landscapes. If we are correct, the contemporary rangeland management paradigm of within-landscape management is often not sensitive to major driving influences on landscape and vegetation change and hence the fundamentals of sustainability in the arid zone which has to do with soil moisture balance.

Is a broader geo-ecological context cascading down into more intimate salience a legitimate starting point in pursuing harmony with the land {Tinley 1991 #4190}? How do we start quantifying ecosystem patterns and (more importantly) how their behaviour varies with stresses that overlap and interact at catchment scales? Is this fertile ground for research?

Acknowledgements

This work was conducted through the Gascoyne-Murchison Strategy with National Heritage Trust funding. We thank the many pastoralists who helped build the geomorphic models of land succession that we are now testing. Constructive critical comments from John Ludwig, Jill Landsberg, Ian Watson and Tein McDonald improved the manuscript considerably.