State and transition models for rangelands. 12. A general state and transition model for the mitchell grass, bluegrass-browntop and Queensland bluegrass pasture zones of northern Australia

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Abstract

A generalised state and transition model has been developed for the extensive grasslands on heavy cracking clays across northern Australia. This model is a simple means of getting land managers to better understand the management of native pastures if they are to move towards a more sustainable production system.

Its development, in conjunction with land managers, can be defined by looking at differences in pasture composition to give a catalogue of states. The transitions or changes between states, whilst less easily understood, are dependent on a menu of opportunities and hazards presented to the land managers.

Thresholds of hazards and opportunities between states are shown as strategic, critical and major management intervention lines, where changes that are taking place need to be addressed by appropriate decisions to reduce costs associated with increased pasture degradation.

There remains a general lack of knowledge, in some areas, of the reasons why the transitions are occurring, and further research and/or knowledge exchange with land managers, is required. This is especially so given the large and diverse nature of the specific grassland zones discussed and more specific models are therefore required. The application of state and transition models developed by land managers in conjunction with extension officers will result in improved productivity from our rangeland resources at sustainable levels.

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Introduction

The state and transition approach of Westoby *et al.* (1989) provides an opportunity to simplify understanding of native pasture management. Pasture management extension programs will benefit from this technique, especially if models are developed in conjunction with land managers. This improved understanding of pastures and their behaviour in response to management practices and to natural events will, hopefully, result in a more sustainable production system. This paper aims to present a generalised state and transition model for the mitchell grass, bluegrass-browntop and Queensland bluegrass pasture zones of Australia. The generalised model can then be used as the basis for developing more specific models for the particular grass units that make up these zones, as described by Tothill and Gillies (1992).

Pasture zone description

The zones under consideration comprise grasslands on heavy cracking clay soils. These zones extend over northern Australia from southern Queensland to the western Kimberley and Pilbara regions of Western Australia. Average annual rainfall varies between 200–650 mm and 200–800 mm on the west-east and south-north axes, respectively, with the bluegrass zones having the higher rainfall. The 3 zones cover an area of approximately 50 M ha comprising mitchell grass (81%), bluegrass-browntop (14%) and Queensland bluegrass (5%) (Orr 1975; Tothill and Gillies 1992). In their natural condition, they are virtually treeless grasslands. Land use in the Queensland bluegrass area is mixed farming, in the mitchell grass area both wool and beef production, and in the bluegrass-browntop areas cattle production.

Grasses common to the 3 zones are from the genus *Astrebla* and *Dichanthium* with various combinations of particular species being dominant or co-dominant. These native pastures are resilient to drought and grazing, having the ability to recover over a series of good seasons with suitable pasture management practices. The general nature of the soils with their accompanying high pH has resulted in little or no introductions of exotic pasture species. Unlike the practice in other pastoral areas in northern Australia, fire is rarely if ever used to manipulate pasture composition or herbage quality. Protein deficiency occurs in the dry winter season.

The treeless nature of these grasslands led to the introduction of fodder trees to provide both shade in the summer and high protein forage during the dry season. These plant introductions, together with the reluctance by pastoralists to use fire as a management tool, have resulted in exotic woody weed populations of *Acacia nilotica*, *Parkinsonia aculeata* and *Prosopis spp.* at varying densities, mainly in the central and northern parts of Queensland. Given favourable climatic events, some of these woody weeds have the potential to threaten far greater areas, as they already exist in small concentrations in southern Queensland and the Barkly Tablelands (Carter *et al.* 1990).

Pasture composition within these zones has been modified by: grazing pressure from both domestic livestock and native fauna (red and grey kangaroos); the introduction of woody weeds; use of supplements; the lack of fire management; and in some areas cropping. These modifications have resulted in an overall decline in pasture condition (Tothill and Gillies 1992), e.g. *Parthenium* infestations in northern bluegrass cropping areas; feathertop dominance over the southern rolling downs; and in the case of bluegrass-browntop, a rapid decline brought about by extensive areas of river frontage erosion (Cloonan 1992).

The state and transition model

The changes in composition of vegetation can be described using a state and transition framework. This approach has the potential to become a tool in the development of meaningful pasture management extension programs, especially if developed in conjunction with producers. The catalogue of states should be able to be defined by producers, whilst the transitions may be less easily understood due to gaps in knowledge. Given the variation both within and across zones in rainfall, exposure to weed contamination, and enterprise type, only a general state and transition model could be developed. The model is shown in Figure 1 in a manner that describes the pasture resource condition outlined by Tothill and Gillies (1992). Also included are the thresholds of hazards and opportunities shown as the strategic, critical and major management intervention lines. These lines represent the times where producers need to make decisions on moving between states. The strategic intervention line requires only low managerial input to return to a better pasture condition state and to do this, opportunities are high and hazards low. The critical intervention line, however, represents a point in time in a deteriorating pasture where decisions are critical to prevent the pasture from proceeding into a more degraded state or to return it to the more sustainable state. This critical intervention point may be within a shorter or longer time frame depending on the factors causing the transition and plant species involved. As this line moves closer to the major intervention line, the hazards increase and opportunities decrease with associated increase in risk. The states and transitions are described in Tables 1 and 2.

Hazards and opportunities

The hazards associated with transitions across the strategic intervention line are both the under- and over-utilisation of the pasture over time and the introduction of woody or herbaceous weed seed. Under-utilisation allows the introduction of undesirable perennial grasses such as feathertop grass in the central–west of Queensland, a grass that impacts on wool production. Over-utilisation and/or prolonged drought can lead to reduced tussock size of desirable species with increased risk of loss from the pasture. Opportunities include the use of fire to control both undesirable grasses and woody weeds and potential recruitment of *Astrebla* spp. as the seed bank is little affected by level of utilisation.

Hazards associated with transitions across the critical intervention line relate to the interaction of rainfall events and *Astrebla* spp. seed bank levels. Seed reserves from the last known seeding last a maximum of 2 years and false starts to seasons can cause their earlier depletion. Overgrazing and competition hazards from annuals can kill newly recruited seedlings and maintain small diameter tussocks, readily killed during drought. Other hazards include the introduction of both woody weed and undesirable herbaceous seed. These hazards make it a critical risk area with the potential to move over the major intervention line in as little as 1 year for herbaceous weeds, 2 years for *Astrebla*, and time to first seeding for woody weeds. The opportunities for a shift back to State 1 are fire management, strategic spelling, and integrated weed control strategies to both limit seeding of existing plants and prevent spread to new areas.

Providing land managers with the tools to monitor and interpret pasture condition (Phelps *et al.* 1992; Forge 1993), so that deleterious changes are detected early, provides the best opportunity for preventing the transitions across the major intervention line. Another opportunity is that, in the bluegrass zone, *Dichanthium* will reappear in the pasture if stock are removed. Obviously, the main hazard is the often uneconomical cost and time involved in returning the land to a productive state through both reseeding with mitchell grass and weed control.

General knowledge gaps

As mentioned, the transitions between states are less easily understood than the states themselves and it is in this area that the major knowledge gaps exist. From the producers' point of view, there is still the problem of them being unable to identify key species, although this is being addressed through recent publications and field days. Specific knowledge gaps seem to include:

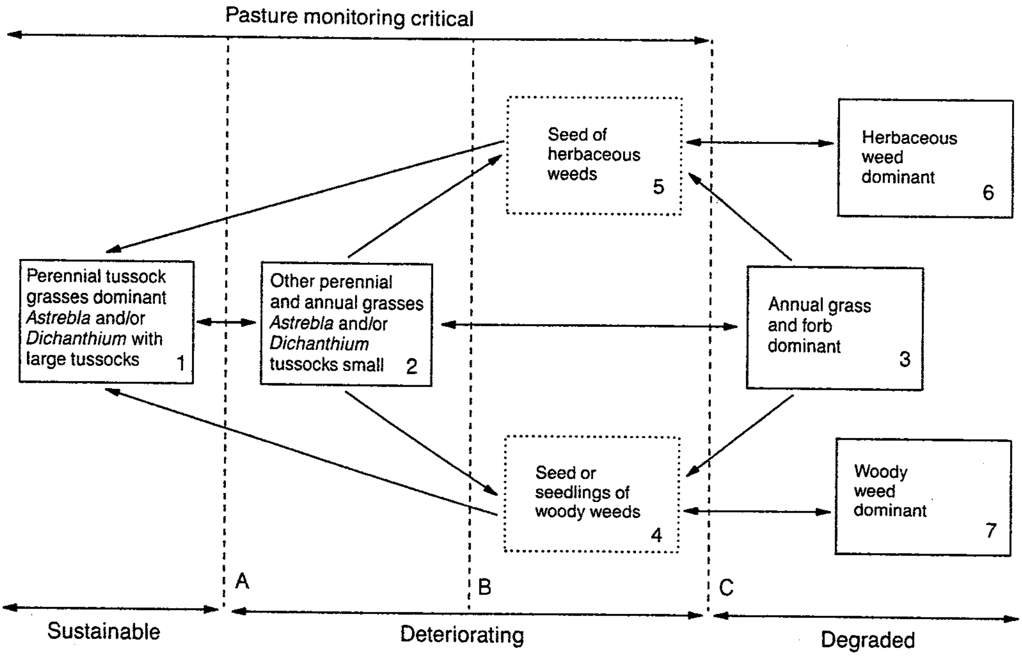

Figure 1. A state and transition model for mitchell grass, bluegrass-browntop and Queensand bluegrass pasture zones, showing strategic (A), critical (B) and major (C) management intervention lines.

Table 1. Definition of important vegetation states occurring in (A) mitchell grass, (B) bluegrass-browntop, and (C) Queensland bluegrass pasture communities.

State 1. Perennial tussock grasses
Vegetation dominated by desirable native, perennial tussock grasses having large tussocks.
Typical species: (A) *Astrebla spp., Dichanthium spp., Bothriochloa spp.*
(B) *Dichanthium spp., Astrebla spp., Sorghum spp.*
(C) *Dichanthium sericeum, Astrebla spp., Bothriochloa spp.*

State 2. Perennial-annual grasses
Vegetation dominated by a mixture of less desirable perennial grasses and desirable tussock perennials having small tussock size together with annuals and forbs as in State 3.
Typical species: (A)(B)(C) *Aristida latifolia, Panicum spp., Iseilema spp., Salsola kali, Brachyachne convergence.*

State 3. Annual grasses and forbs
Vegetation dominated by annual grasses and forbs with only undesirable perennials remaining.
Typical species: (A) *Dactyloctenium radulans, Panicum spp., Portulaca oleracea, Aristida spp.*
(B) *Cyperus bifax, Pennisetum basedowii, Sporobolus spp.*
(C) *Chloris spp., Sporobolus spp., Eragrostis spp., Aristida spp.*

State 4. Woody weed seed and seedlings yet to set seed
Can occur in vegetation States 1, 2 and 3 depending on rainfall events and level of seed introduction.

State 5. Introduction of herbaceous weed seed
Can occur from infested sites into states that have been degraded or cropped.

State 6. Herbaceous weed-dominant
Vegetation dominated by herbaceous weeds requiring major interventions to recover.
Typical species: (C) *Parthenium spp.*

State 7. Woody weed-dominant
Vegetation dominated by woody weeds requiring major interventions to remove.
Typical species: (A) Northern rolling downs — *Acacia nilotica, Prosopis* spp.
(B) *Prosopis spp., Parkinsonia aculeata.*

Table 2. Transitions between vegetation states as defined in Table 1 for (A) mitchell grass, (B) bluegrass-browntop, (C) Queensland bluegrass zones and the probability of occurrence through these factors.

T_{12} **Cause:** hot fires, prolonged drought, over-utilisation, flood and insect damage.
Probability: high.

T_{21} **Cause:** adequate rainfall event for germination, establishment and survival with reduced stocking rates and strategic spelling.
Probability: low depending on suitable rainfall event.

T_{14} **Cause:** spread of woody weed seeds by wind, water, animals and mechanical means together with suitable establishment
T_{24} conditions. Lack of fire.
T_{34} **Probability:** low but depending on location of seed source in catchment area and animal quarantine from infested areas.

T_{41} **Cause:** depletion of germinating seed reserves through biological, mechanical, and/or chemical means.
Probability: medium given a high level of commitment over time.

T_{23} **Cause:** hot fires, prolonged drought, overgrazing, flood and insect damage.
Probability: medium.

T_{32} **Cause:** reseeding with mitchell grasses with adequate establishment rains, and natural introduction of *Dichanthium* over time with adequate establishment rainfall and destocking.
Probability: (A) low; (C) medium.

T_{25} **Cause:** introduction of herbaceous weed seeds and suitable establishment conditions such as bare ground.
Probability: medium.

T_{51} **Cause:** depletion of germinating seed reserves through biological, mechanical and/or chemical means and improved grazing management over time.
Probability: moderate given a high level of commitment.

T_{35} **Cause:** introduction of herbaceous weed seeds.
Probability: high owing to large areas of bare ground.

T_{47} **Cause:** mass recruitment of woody weeds given a run of good seasons.
Probability: high–medium depending on woody weed type.

T_{74} **Cause:** biological/mechanical/chemical means or combination to reduce seed set. (A) Seeding and establishment with *Astrebla* spp. given adequate rainfall events; and (C) natural introduction of *Dichanthium* with destocking.
Probability: low–medium.

T_{56} **Cause:** mass establishment of herbaceous weeds.
Probability: high.

T_{65} **Cause:** biological/mechanical/chemical means or combination to reduce seed set. Natural establishment of *Dichanthium* through destocking given adequate rainfall events.
Probability: high–medium given a high level of producer commitment over time.

- accurate probabilities of shifts in botanical composition occurring, given a known set of management practices;
- the reseeding and establishment of mitchell grass;
- the role of fire and its effect on processes;
- the impact of insects in the system;
- animal production within each state;
- soil changes associated with different grazing management practices; and
- patch grazing.

Some of the above may require further research within the different zones. However, it could be that some of this knowledge is already held by producers and that interactive producer workshops within specific grass units of the zones under discussion need to be conducted to identify the real knowledge gaps.

Conclusions

The general state and transition model for grasslands on heavy cracking clays developed in this paper is a means of simplifying the understanding of changes in pasture composition and condition. More specific models will be required, developed in conjunction with producers, to make it a tool more applicable to their specific needs, given the large and diverse nature of the zones.

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