Tropical Grasslands (1994) Volume 28, 241-246

State and transition models for rangelands. 6. State and transition models as aids to communication between scientists and land managers

A.C. GRICE[1] AND N.D. MACLEOD[2]
[1]*Division of Tropical Crops and Pastures, CSIRO, Townsville, and*
[2]*Brisbane, Queensland, Australia*

Abstract

State and transition models were originally proposed as tools to help producers and other land managers make decisions about managing rangelands, and research workers identify critical research questions. Both of these functions are essentially communication functions. While state and transition models have been widely discussed by rangeland scientists, they have had little application at a practical level. Existing models are simple, qualitative and descriptive rather than explanatory. These characteristics govern their use as communication tools. They may be used in general education or to present aspects of the vegetation dynamics of specific communities in a simple way. More detailed models may be appropriate as an aid to decision making at regional and property level or for finer scales. Further development of state and transition models could involve improved functional descriptions, quantification, more precise targeting of vegetation types and accommodation of spatial phenomena. It is important that any model strikes a balance in terms of degree of complexity i.e. between detail and simplicity.

Current uses of state and transition models for communication

Westoby *et al.* (1989) proposed state and transition models as aids for decision making in relation to either research directions or the actual management of rangelands. Subsequently, the potential of state and transitions models has been widely discussed in Australia (Friedel 1990; Roshier 1990; Hunt 1990, 1992; Burrows 1991; Bellamy and Lowes 1992; Whalley 1992; Danckwerts *et al.* 1993; Read 1993) and overseas (e.g. 14 papers in the *Journal of Range Management* between 1990–1993).

Many of these citations relate to general discussions of vegetation change, often in connection with range condition concepts. Most is at an "academic" rather than applied level.

Despite the interest generated by the original ideas of Westoby *et al.* (1989), there has been little active development of the state and transition concept. Such development could consist of either refinements, such as providing more effective cataloguing of states and transitions, expansion to cover additional components of the vegetation or the construction of models for systems not previously modelled. While some additional models have been proposed (e.g. Ash *et al.* 1993), few current models are more advanced than those used as examples by Westoby *et al.* (1989). For example, the cataloguing of states and transitions used in their model for the semi-arid grasslands/woodlands has not been substantially improved.

Discussion of state and transition models has mainly involved range scientists rather than range managers. Most of those directly or indirectly involved with technology transfer have had some exposure to state and transition models as have many of those involved at a policy level. Few pastoralists, however, are familiar with state and transition models and these models are not yet employed in a practical way by policy makers, pastoralists or those involved in extension. State and transition models have so far had a limited impact on the condition of the rangelands or the way they are managed.

Correspondence: Dr A.C. Grice, CSIRO Division of Tropical Crops and Pastures, Private Bag, PO Aitkenvale, Queensland 4814, Australia

Potential of current state and transition models for communication

Current state and transition models have characteristics that are relevant to their potential role as communication tools:

Simplicity

Current state and transition models consist of a few simply related elements. Typically, they involve half a dozen states and slightly more transitions between those states. The states are discretely defined. Few, if any, of the existing models cover all components of the vegetation of a particular community. Such simplicity can be advantageous in a communication tool provided the limitations of particular models are recognised.

Descriptiveness

Models tend to be descriptive rather than explanatory. The originally intended function of state and transition models was as an aid to land-management decision making and the identification of research needs. As developed to date, most emphasis has been placed on describing major changes without explaining the mechanisms of change in any detail. Such detail is a necessary part of both an understanding of rangelands and the decision making process of management. The descriptive nature of current state and transition models limits their power to communicate an understanding of particular processes.

Loose definition

The transition between states is usually loosely defined and states have received more emphasis than transitions. Available models provide reasonably detailed descriptions of states but usually indicate only those environmental parameters thought to be important in a particular transition. Critical conditions of key environmental parameters are usually unknown, again limiting the information content of the model.

Qualitativeness

Current state and transition models are qualitative rather than quantitative. There are at least 2 ways in which a state and transition model can be quantified. One is to quantify the probability of undergoing each transition or the proportion of a landscape that is in a particular state. Another is to quantify the parameters that define states or the conditions that bring about transitions. Again, in current models, the conditions bringing about transitions are presented as a list of the factors deemed to be most important. This characteristic will limit, for example, the power of a model to communicate more than basic concepts of vegetation change.

Limited spatial information

With some limited exceptions (e.g. Bellamy *et al.* 1993), current state and transition models do not effectively incorporate spatial information. Applying a purely temporal model to a practical situation would involve treating an area as uniform. This is a problem in the light of the small scale heterogeneity typical of many rangelands. Failing to incorporate spatial information also overlooks spatially dependent processes such as invasion and recolonisation and the redistribution of water and nutrients. Consideration of these processes is crucial to both research and management.

Consistent with managers' world views

Pastoralists' views of rangeland vegetation dynamics may be more consistent with the non-equilibrium model that is implicit in the state and transition presentation, than with the competing range succession model. First-hand experience gives pastoralists an appreciation of the episodic nature of climate with its major rainfall events and droughts and of how fires or large increases in rabbit and kangaroo populations and other factors bring about sudden changes in rangeland vegetation.

Use and limitations of state and transition models: a case study

The potential uses and limitations of state and transition models for communication can be

demonstrated with an example. Westoby *et al.* (1989) presented a model for the semi-arid grasslands/woodlands that are widely represented in western New South Wales and southern Queensland. The model consists of 4 states and 7 transitions (Figure 1). The following discussion centres on the transitions which we argue are most important for management and hence communication.

Transition 1

This involves emergence of "many shrub seedlings", requires "two or more very good rainfall years" and is likely to occur only 2–5 times per century (once or twice in the working life of a manager). The manager should be alerted to the possibility of shrub seedling emergence.

Transition 2

Once a cohort of shrubs was established, transition to State III would be "inevitable" apart from the possibility of fire. The manager should be aware that action will be required to prevent a production loss from increasing shrub biomass.

Transition 3

This also involves fire and depends upon fuel loads and hence rainfall. The manager could reduce stock levels to build up or retain fuel in areas where a fire was desirable.

Transition 4

Reversion from State IV to State III would be "inevitable" as shrubs resprouted after fire and new shrubs established. The manager would need to consider "follow-up" treatment to control regrowth.

Transition 5

This involves a second fire soon after Transition 3 and depends on fuel loads. "Probably less rain [is] required than for Transition 3 . . .". Grazing pressure could be adjusted to build up or retain fuel.

Transition 6

This would occur where "shrubs were fire-sensitive" and again requires adequate fuel.

Transition 7

This transition would involve a fire that killed most shrub seedlings and is fuel dependent.

Having examined the model and considered the possible states and transitions, particularly as they relate to the descriptions of vegetation change, we can examine its potential for communication. The following questions are important.

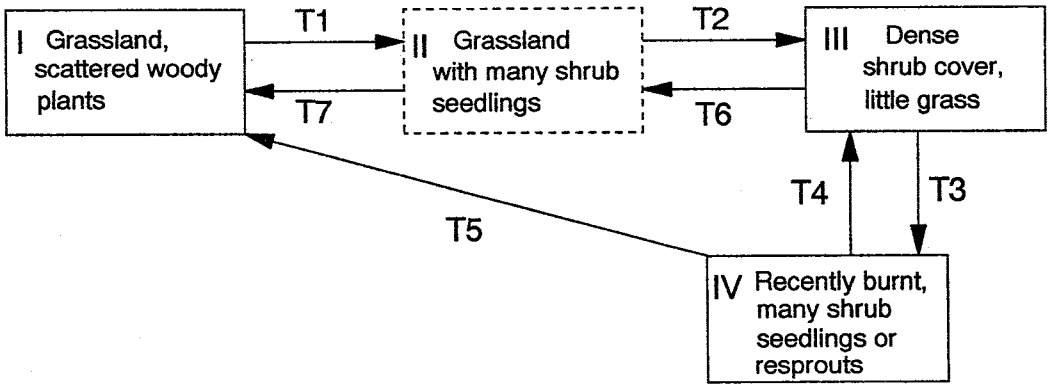

Figure 1. State and transition model for the semi-arid woodlands/grasslands of western New South Wales and southern Queensland (after Westoby *et al.* 1989; see text for explanations of transitions).

Q1. What specific assistance could this model provide to practical land managers or land administration agencies to assist with their decision making?

The model indicates to managers, albeit in relatively vague terms, when there will be opportunities to use fire in their shrub management programs.

Opportunities to burn will be determined largely by rainfall, but there is also some potential to enhance the effectiveness of this option by easing grazing pressure to build up or retain fuel loads. The consequences of the commonly adopted alternative of maintaining grazing pressure and thereby reducing the viability of a fire strategy are also made evident.

Q2. What are the limitations or weaknesses of the model?

The example model:

(i) does not quantify or describe in detail the rainfall events required to bring about specific transitions such as the rainfall required for shrub germination or establishment;

(ii) does not include quantitative information on the types of livestock manipulation that might be used to promote or retain fuel loads;

(iii) does not highlight important variations between shrub species in the ways they respond to rainfall, grazing and fire [related to (v) below];

(iv) omits significant components of the vegetation and does not address several important vegetation management issues such as the role and management of chenopods, composition of herbaceous vegetation, management of perennial grasses and invasion by alien plants;

(v) does not deal with spatial phenomena in general or even those specifically concerned with the proliferation of shrubs, which is the main theme of the model;

(vi) reflects the biases and interests of those who designed the model (principally rangeland research workers) rather than those who would use it as a management tool (managers and advisory personnel).

Q3. How could a model such as the one described for the semi-arid grasslands/woodlands be used as a communication tool?

While the real value of state and transition models as vehicles of communication is still emerging, we identify 3 possible uses:

General education. The state and transition model format can be used to highlight certain features of how many rangeland systems function. For instance, the state and transition approach emphasises the fact that, often, vegetation change is not gradual but occurs as sporadic major events whose timing is largely climatically determined. Australian pastoralists are familiar with this general feature of rangelands through direct experience. State and transition models could be used to reinforce this general awareness among pastoralists as well as to inform the general public and others with an interest in but less of a day-to-day involvement with the rangelands.

Simplifying complex relationships. State and transition models can be used as a shorthand means of describing the complex dynamics of specific rangeland ecosystems. There is a widely held view that Australian pastoralists have traditionally emphasised livestock rather than vegetation management skills (e.g. MacLeod and Taylor 1992). Simple state and transition models of specific rangeland ecosystems, through their obvious emphasis on vegetation change and what management can do about it, could be used to discuss the importance of vegetation management in sustainable pastoralism (MacLeod *et al.* 1993). They would meet the needs of those who are involved practically in managing rangelands and want a more formal structure for bringing together a knowledge of vegetation change and an understanding of the impacts that management can have. This function would need more specific and detailed models than would general education. State and transition models developed at this particular "level" could also be used by research workers to develop hypotheses about the nature and processes of vegetation change, and to build more refined models for decision making. State and transition models have also been used to explain in simple terms the structure and purpose of complex research and development (R&D) projects (MacLeod and Van Beek 1992; Vance *et al.* 1993).

In decision support. State and transition models may assist with decisions at property level and finer scales. This function would suit pastoralists and others directly concerned with the strategic management of a piece of rangeland whether it be a pastoral property, a national park or aboriginal lands. Models that could fulfil this function would have to be constructed with considerable detail and some components would have to be quantified.

Q4. How could state and transition models be developed further as aids to communication?

Current models are already useful communication tools. They can be used for general education about the way rangelands function and to describe the dynamics of specific rangeland ecosystems within the limits set by current knowledge. They can also be used to explain the structure and interrelationships of experiments within complex R&D projects.

There are key messages that current state and transition models can communicate. They effectively make the point that, often, vegetation change is not a gradual process, and also that periodically, major changes, for better or for worse, take place quickly. They indicate, in general terms, the factors and coincidences thought to be important in bringing about particular changes. Current state and transition models can provide a framework for thinking about management decisions.

To do more than this, however, requires further development of state and transition models, especially if they are to contribute in detailed ways to decision-making. Five points are relevant to the further development of state and transition models as communication tools:

Functional description and quantification. Better functional descriptions and, where appropriate, quantification of the conditions of transition are needed. Rainfall and grazing conditions are the most important factors. The "current" model for the semi-arid grasslands/woodlands (Figure 1) does not include quantitative information on the types of livestock manipulation that might be used to promote or retain fuel loads or the types of rainfall events that facilitate each transition. These are the types of quantification most likely to be of practical use in decision making.

Descriptions of the conditions leading to a particular transition should be in terms of variables that are easily understood, measured and reported. They should also use the common language of the targeted user groups and the most relevant scale. Given their extended experience of particular rangelands, pastoralists could make essential contributions to these types of refinements (Vance *et al.* 1993).

For some vegetation communities, ecological information already available could be incorporated into state and transition models. Priority should be given to filling the knowledge gaps that are important for management purposes.

Scope. Future models could either address single issues or attempt a more comprehensive coverage of the vegetation dynamics or other features (e.g. socio-economic factors) of a much wider system.

The model advanced for the semi-arid grasslands/woodlands (Figure 1) is essentially limited to the dynamics of the shrub component. Limited attention is given to grass dynamics as it relates to shrub populations. A more comprehensive system for the semi-arid grasslands/woodlands would incorporate not only manipulation of the grasses but also the roles of ephemeral forbs, chenopods and trees. Each is important and warrants consideration by management. Further subdivision may be justified in some cases, for example, resprouting shrubs versus obligate seeders, perennial versus annual/biennial grasses. In other cases, such as for policy determination, a broader scale may be warranted, taking into account such factors as cross-boundary pollution issues (dryland salinity, vermin infestation) and property size restrictions (MacLeod and Johnston 1990).

Accommodating spatial factors. Spatial phenomena are an important aspect of rangeland management. Three key considerations are: (i) the redistribution of rainfall across the landscape and the impact of this on the composition and productivity of the vegetation; (ii) the spatial heterogeneity of grazing pressure; and (iii) the spatial heterogeneity of land and vegetation resources within management units. These have themselves been the focus of modelling exercises. It is worth exploring means of integrating our understanding of spatial phenomena with state and transition models that are currently restricted to describing temporal phenomena (Hunt 1992).

Appropriate balance. As with all models intended to aid communication, state and transition models must find a balance between detail and simplicity. It is important not to "over-refine" models or let them become an entrenched view of the way that rangelands actually function. This could detract from the strengths of the state and transition approach as a communication tool, i.e. their flexibility and their potential to be used interactively. However, state and transition models could become widely used by individual policy makers, research workers, advisors, range management practitioners and their institutions, provided particular models are not institutionalised. Their principal roles may be in general education, as a shorthand way of describing and thinking about the dynamics of specific communities, and for strategic decision making rather than for "day-to-day" decision making.

Interaction between developers and end users. If state and transition models are to become effective tools of communication and management, their further development should involve both range scientists and range managers. A broader involvement is needed to decide how the models can be used in general education, to more effectively describe and discuss the dynamics of specific rangeland ecosystems, to make decisions about specific pieces of rangeland and to package and present them in the most useful way.

References

ASH, A.J., MCIVOR, J.G. and BROWN, J.R. (1993) Land condition and overgrazing: a management paradox for the savannas of northern Australia. *Proceedings of the XVII International Grassland Congress, Palmerston North, 1993.* pp. 1930–1931.

BELLAMY, J.A. and LOWES, D. (1992) The state and transition model: a conceptual framework for a decision support system for sustainable grazing. *Proceedings of the 7th Australian Rangeland Society Conference, Cobar, 1992.* pp. 388–389.

BELLAMY, J.A., LOWES, D. and MCLEOD, I.D. (1993) A spatial decision support system for assessing the state of grazing lands. *Proceedings of the Northern Australian Remote Sensing and GIS Forum, Darwin, 1993.*

BURROWS, W.H. (1991) Sustaining productive pastures in the tropics: an ecological perspective. *Tropical Grasslands,* **25,** 153–158.

DANCKWERTS, P.J., O'REAGAIN, P.J. and O'CONNOR, T.G. (1993) Range management in a changing environment: a South African perspective. *Australian Rangeland Journal,* **15,** 133–144.

FRIEDEL, M.H. (1990) Some key concepts for monitoring Australia's arid and semi-arid rangelands. *Australian Rangeland Journal,* **12,** 21–24.

HUNT, L.P. (1990) Sheep grazing intensity, drought, and the population dynamics of saltbush. *Proceedings of the 6th Australian Rangeland Society Conference, Carnarvon, 1990.* pp. 278–279.

HUNT, L.P. (1992) Piospheres and the state and transition model of vegetation change in chenopod shrublands. *Proceedings of the 7th Australian Rangeland Society Conference, Cobar, 1992.* pp. 37–45.

MACLEOD, N.D. and JOHNSTON, B.G. (1990) An economic framework for the evaluation of rangeland restoration projects. *Australian Rangeland Journal,* **12,** 40–53.

MACLEOD, N.D. and TAYLOR, J.A. (1992) Perceptions of sustainable grazing systems. *Proceedings of the 6th Agronomy Society Conference, Armidale, 1992.* pp. 169–171.

MACLEOD, N.D. and VAN BEEK, P.G.H. (1992) Rural R&D moving towards systemic approaches: the GLASS sustainable grazing project. *International Society for the Systems Sciences 37th Annual Meeting, Hawkesbury, 1992.* pp. 536–545.

MACLEOD, N.D., BROWN, J.R. and NOBLE, J.C. (1993) Ecological and economic considerations for the management of shrub encroachment in Australian Rangelands. *Proceedings of the 14th Asian-Pacific Weeds Science Society Conference, Brisbane, 1993.* (in press).

READ, J.L. (1993) Influence of habitats, climate, grazing and mining on terrestrial vertebrates at Olympic Dam, South Australia. *The Rangeland Journal,* **14,** 143–156.

ROSHIER, D.A. (1990) Stocking rates and sheep production in far western NSW. *Proceedings of the 6th Australian Rangeland Society Conference, Carnarvon, 1992.* pp. 263–264.

VANCE, P.N., MACLEOD, N.D. and VAN BEEK, P.G.H. (1993) Improving research through extension. *Australia-Pacific Extension Conference, Surfer's Paradise.* (in press).

WESTOBY, M., WALKER, B. and NOY-MEIR, I. (1989) Opportunistic management for rangelands not at equilibrium. *Journal of Range Management,* **42,** 266–274.

WHALLEY, R.D.B. (1992) The nature of vegetation changes in managed ecosystems. *Proceedings of the 7th Australian Rangeland Society Conference, Cobar, 1992.* pp. 51–55.