The ecosystem indicators in studies of ecological recovery for plant cover in arid environment

G. A. Heshmati

Fac. of Rangeland & Watershed Manage., Gorgan Univ., Iran.

Abstract

Plant cover in arid environment shift across dynamic thresholds between different ecological states in response to natural or human-induced factors. The notion of a single 'pristine' final state is only conceptual in nature, and because of this, dynamic thresholds and the effects of various processes on ecosystem structure and function must be incorporated in decision-making. The different states are results of interactions among climate, soils, grazing history, and management practices. Rangeland managers should have a working knowledge of the key ecological processes in each state, the processes that drive a system across a dynamic threshold from one state to another, which they need indicators for critical decision-making points. It is essential to identify the thresholds of an ecological transition state and ecological indicators of these states. The criteria of these ecological indicators might be measurable, sensitive to stress on the system, have a known response to disturbance and easy to measure. The state and transition approach may offer an appropriate framework as an aid for decision making and can be used to highlight 'management windows' where opportunities can be seized and hazards avoided.
Keywords: Ecosystem indicators, Threshold, Vegetation dynamic, state and transition model

Introduction

Dynamic thresholds and the effects of nonlinear processes on ecosystem structure and function are rarely considered sufficiently and to date their incorporation in decision-making is inadequate (Eiswerth and Haney, 2001). Natural ecosystems shift between different ecological states through ecological transition zones (Anand and Li, 2001) in response to natural or human-induced factors rather than follow a prescribed successional path (Friedel, 1991). There is a general recognition that 'pristine' states are only conceptual in nature and that multiple stable states exist as a result of interactions among climate, soils, grazing history, and management practices (Westoby *et al.* 1989) which rangeland managers need a workable framework. The state and transition approach of Westoby *et al.* (1989) may offer an appropriate framework as an aid for decision making and can be used to highlight ‘management windows’ where opportunities can be seized and hazards avoided. Natural managers should have a working knowledge of key ecological processes in each state, but they need indicators for critical decision-making points to serve as the basis for developing and interpreting natural ecosystems.

Rangeland ecosystems shift across dynamic thresholds between different ecological states in response to natural or human-induced factors. These different states are stable and each state is a result of interactions among climate, soils, grazing history, and management practices (Westoby *et al.* 1989). The notion of a single ‘pristine’ final state is only conceptual in nature, and because of this, dynamic thresholds and the effects of various processes on ecosystem structure and function must be incorporated in decision-making (Eiswerth and Haney, 2001).

The question of what constitutes an indicator of threshold, and how to measure it, is important for ecosystem management. What attributes are to be measured, how are they to be measured, and how are the measurements to be interpreted, are the subject of continuing debate (Andreasen *et al.* 2001). Rangeland ecologists need to be able to explore spatial relationships of many species over many environmental features in relation to grazing effect. Whilst the measurement of vegetation composition is important in the assessment of vegetation condition, other attributes are required in order to understand better vegetation dynamics. If only vegetation is monitored, it will not be clear whether any changes in composition are due to interactions between gazing and vegetation alone, or whether the soil, as a habitat for native plants, has been degraded. Tongway, D. and Hindley, N. (2000) have suggested that attributes of the soil-surface condition (soil cover, soil texture, cryptogam cover) may be combined in various ways to provide useful indicators of landscape function such as stability, infiltration or nutrient cycling.

Rationale

If a system shifts across a dynamic threshold from a stable, productive, undisturbed (defined as “healthy”) state to a less healthy state, if would be valuable to have a set of indicators to (i) give an early warning of such change, and to (ii) facilitate the recovery of the system. The U.S. National Research Council (1994) and Andreasen *et al.* (2001) pointed out the need for an early warning phase between “healthy” and “at risk” states and the need to identify thresholds between “at risk” and “unhealthy” states. Such ecological indicators must be workable and measurable and Dale and Beyeler (2001) proposed the following criteria: easily measured, sensitive to stresses on the system, respond to stress in a predictable manner, be anticipatory, predict changes that can be averted by management actions, be integrative, have a known response to disturbances, anthropogenic stresses, and changes over time, and have low variability in response. However, caution must be exercised with indicators that are highly sensitive to change because they may also be highly sensitive to natural variability and may not be useful (Andreasen *et al.* 2001). Understanding the role of plants as indicators has important implications for sustainable rangeland management, and for the rehabilitation of areas that are already degraded (Heshmati, *et al.* 1998). The threshold concept describes unidirectional changes in ecosystem structure and ecosystem functional processes. The state-and-transition model (Westoby *et al.* 1989) implies that plant community composition makes dramatic changes only during times of unusual environmental influences. Furthermore, the species composition of differing plant communities in particular states, on a particular ecological site, fluctuate within defined limits, which can also be expressed as several domains of attraction (West and Yorks, 2002) or threshold (Friedel, 1991) or ecological transition zones (Anand and Li, 2001) depending on the degree of responses to disturbance. When these thresholds are crossed, recovery to the original ecosystem states is difficult (Friedel, 1991). Here, we will explain some concepts that are important in the structure and functioning of rangeland ecosystems

Simplified picture of the natural ecosystems process

We can begin with an initial stable state (Zone A) that is "healthy" and where light grazing has no role in development or maintenance of the status of its vegetation and the exclusion of grazing would have little impact on the dynamics of the vegetation; this could be a conserved park or a reference area (Figure 1). If grazing intensity is increased (or some other form of harvesting) we will move across a dynamic threshold (I) to Zone B in which the vigor and population density of the vegetation will be different, typically lower.

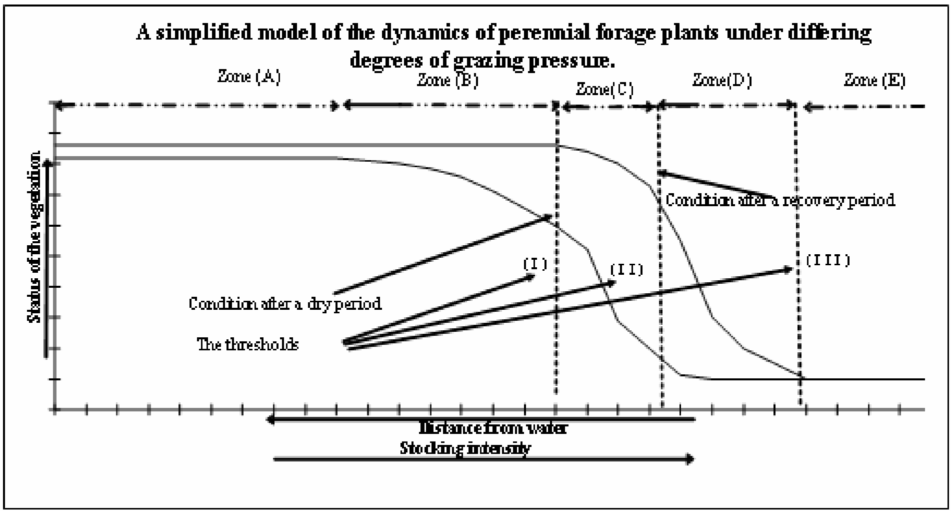

Figure 1. Simplified picture of the natural ecosystems process. Zones (A-D) are described in the text.

During this transition the desirable and /or grazing intolerant species will decline and perhaps become locally extinct. If the vegetation (Zone B) continues to exclude grazing, the second transition between states will start toward the stable state (Zone A). It is obvious that by further increasing the grazing intensity, there is a certain level beyond which the vegetation cannot sustain its stability at this state (Zone B) and will begin to decline. This is the beginning of the third transition (III) which is between second (Zone B) and the third stable states (Zone C) and it may lead into the critical stage or critical threshold.

The zone D is the further degraded zone with no or with minimum, recovery potential and protection from grazing should cause no recovery. The vegetation will move in one direction (degradational) only. The remaining vegetation and soil will continue to decline regardless of being harvested and it would proceed to an irreversible stage. The key factors in the outcome of the grazing pressure research are the transitional stages, which have more definite and evident. The grazing effect on vegetation, cross the thresholds and it could show with plant and soil indicators.

It should be stressed that the above-mentioned classification is a highly simplified picture of the processes that are occurring within rangeland ecosystems in different habitats. It is quite possible within an assemblage of many different species, while the populations of some species are at a stable state, other populations may be transitional, and this can be true all along the line of change in this model. In fact for every species a separate and different state and transition model can be drawn.

Rangeland management implications:

The role of rangeland management in either maintaining or restoring rangeland ecosystem needs to be seriously thought about. It is most likely that any form of grazing by sheep will effect a change in botanical composition. Even if thresholds could be a established and reliable indicator found, it is still not clear whether the rangeland manager can adjust stocking rates, or patterns of grazing in a way that can make any considerate difference. Another important factor is to develop a set of threshold values that will signal the onset of a major change in rangeland ecosystems before it becomes irreversible.

The state and transition approach of Westoby *et al.* (1989) may offer a more appropriate framework as an aid for decision making and can be used to highlight ‘management windows’ where opportunities can be seized and hazards avoided. Natural managers should have a working knowledge of key ecological processes in each state, but they need indicators for critical decision-making points and to serve as the basis for developing and interpreting monitoring natural ecosystems. Indicators would be useful tools as an early warning between poor and good condition (Andreasen *et al.* 2001).

From an ecological point of view we might conclude that any form of grazing used by domestic livestock is likely to cause a shift in botanical composition. The longer term benefits (and impacts) of grazing needs to be weighed against the diminution of ecological values, including biodiversity. From the review of the relevant literature we would suggest a number of propositions for consideration for implication in rangeland management. These are set out in Table 1. appropriate framework as an aid for decision making and can be used to highlight ‘management windows’ where opportunities can be seized and hazards avoided.

Table 1. Some propositions for rangeland managers to consider.

Proposition 1. Any form of grazing of rangelands by sheep will inevitably lead to shifts in botanical composition. Some of these will be benign but most will lead to serious compromise of ecosystem stability.
Proposition 2. Even careful range and livestock management will do some damage to rangelands. Therefore, the long-term impact of pastoralism must be carefully weighed against the biodiversity and other ecological values.
Proposition 3. Shifts in botanical composition *per se* do not necessarily mean reduced animal productivity but may be early warning of long-term damage.
Proposition 4. Many methods of range condition assessment do not accurately reflect the changes in animal productivity. Therefore, range monitoring techniques and procedures should be more oriented to the pastoralist’s perspective.
Proposition 5: Plant-based attributes alone cannot serve to characterize range sites and states or trends. Soil factors, including micro topography and cryptogam cover relationships should also be assessed (Tongway, 1995).

Rangeland managers should have a working knowledge of the key ecological processes in each state, the processes that drive a system across a dynamic threshold from one state to another, which they need indicators for critical decision-making points. The ecological indicators can ensure that decision maker viewpoints produce important new understanding of rangeland function for better livestock feeding. Quantifying the link between rangeland condition and livestock performance will be an important step in improving the adoption of more sustainable grazing practices in rangeland environments. The combined assessment of vegetation and soil features could provide more comprehensive understanding of disturbance affects, such as grazing, and could be a sound basis for management of a particular area. It will help to aim at sustainable utilization of the plant community with regard to full ecological understanding of vegetation condition.

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