Range condition assessment and the concept of thresholds: A viewpoint

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Abstract

Dissatisfaction persists with current approaches to range condition and trend assessment. Sometimes assessed condition does not truly represent the past or the potential of range. One of the likely causes is a failure to re-examine and change if necessary the theoretical basis of assessment, in line with developing understanding of ecological processes. The concept of thresholds of environmental change appears to provide a reasonable alternative in some circumstances to the concepts of gradual retrogression and secondary succession which are currently accepted. I suggest that environmental change can be discontinuous, with thresholds between alternative states. Once a threshold is crossed to a more degraded state, the former state cannot be attained without significant management effort, such as prescribed burning, ploughing, or herbicide application, rather than simple grazing control. Examination of data from extensive monitoring programs and from a study of grazing impact, as well as more general sources of information, indicates that thresholds of change may be identifiable in arid rangelands. A practical means of monitoring proximity to thresholds is available and, with the aid of multivariate analysis, the effects of spatial variability and season can be separated from those of management. The potential of this approach deserves investigation in a wider variety of environments.

Key Words: succession, site potential, ordination, classification, trend

The assessment of range condition and trend remains a source of controversy, despite years of practical experience and discussion (Lauenroth and Laycock 1989). What attributes are measured and how they are measured, and how the measurements are interpreted, are the subject of continuing debate. More importantly, perhaps, the advances in our understanding of ecological processes have not been matched by developments without significant management effort, such as prescribed burning, ploughing, or herbicide application, rather than simple grazing control. Examination of data from extensive monitoring programs and from a study of grazing impact, as well as more general sources of information, indicates that thresholds of change may be identifiable in arid rangelands. A practical means of monitoring proximity to thresholds is available and, with the aid of multivariate analysis, the effects of spatial variability and season can be separated from those of management. The potential of this approach deserves investigation in a wider variety of environments.

Current Approaches to Range Assessment

Two different philosophies have influenced assessment up to the present: the ecological approach based on comparisons with the climax state (e.g., Dyksterhuis 1949); and the site potential approach based on productive potential for a particular use (e.g., Humphrey 1949). Both focus on the forage layer. Wilson (1986) has outlined an alternative based on multivariate site potential, which combines important elements of the 2 philosophies and includes soil assessment. This approach has yet to significantly affect entrenched range monitoring systems, although it represents a philosophical advance.

The ecological or climax approach to range condition assessment has been criticized for some time (Smith 1978, 1989; Wilson 1989), but it is still in active use in a wide variety of rangelands (Tainton 1986, Pendleton 1989). The weaknesses of the approach have been summarized by Smith (1978) as: (1) climax is not always the most desirable condition; (2) pristine conditions may not be the actual climax for a site; (3) it does not allow for exotic species; and (4) it is not well suited to woodland and forested rangeland.

If one takes the approach of assessing site potential for particular uses, a single vegetation state can have a variety of potentials depending on use. Site stability or degradation cannot be inferred from the condition rating because the rating will vary with potential use. Whatever approach is taken to assessment, irreversible changes in the soil will be important indicators of site deterioration. As a consequence, range monitoring must incorporate 3 tiers of assessment—the herbaceous layer and soil, and the tree-shrub layer, where it is present.
tal information. This approach does not assume a climax, but produces classes and orders of locations which can be interpreted according to known site factors, seasonal conditions, and management history.

Foran et al. (1986) classified forage composition from 65 monitoring locations within an arid shrubby grassland range site. They concluded that, apart from differences attributable to soil type (= variable depth or minor textural differences, G.N. Bastin pers. comm.) or season of assessment, there were just 2 classes associated with management effects (Fig. 1). Those classes were identified as good and poor condition states, also distinguished by ordination on the basis of forage quality and quantity and soil stability. The same divisions into 2 classes of condition were apparent in monitoring data from 4 other range sites, each analysed independently.

The gradual deterioration implied by percentage deviation from a climax state, which the ecological approach creates, was not in evidence. Instead, a shift from 1 state or "domain" to another (Fig. 2, from Bradbury et al. 1983/4) appeared to have occurred.

In the application of the ecological or climax approach, as outlined by Dyksterhuis (1949) and Tainton et al. (1980), the seasonal fluctuations in forage composition are allowed for by comparing the monitored vegetation to an ecological benchmark which represents the vegetation climax and which is presumed to have experienced the same seasonal variations. There are many weaknesses in such a system. Benchmarks may be in atypically favoured locations, they may experience different rainfall or have a different fire history, or they may simply not exist and must be theoretically constructed. Differences due to variability within a site may be inappropriately attributed to management. Multiple benchmarks have been proposed (Wilson 1984, Bosch et al. 1987) to represent the variability within a range site or land unit.

**Changing States: Evidence of Thresholds**

The development of multivariate analysis and increasingly easy access to it suggest the next step in the assessment of condition: the comparison of each monitored location with all others, using classification and ordination of forage composition. Classification assigns locations to classes on the basis of composition, not necessarily in any hierarchical order. Ordination arranges them in a low-dimensional space so that similar locations are near each other and dissimilar locations are far apart (Gauch 1982). Ordination axes identify major elements in the distribution patterns of the locations, which can be compared with independent environment.
Two thresholds are readily recognized in arid and semiarid rangelands: one separates grassland from woodland; and the other, stable from degraded soil. The change from grass to woody vegetation can arise when the grass layer is grazed beyond its capacity to recover quickly, and fire suppression enhances the survival of woody plant seedlings. Grasses which have been grazed too heavily cannot grow fast enough to compete effectively for moisture in the topsoil. Germinating woody plants, which are not grazed, can out-compete the grasses and subsequently gain access to subsoil water as their root systems develop.

This kind of change has occurred in western New South Wales, where open eucalypt woodlands have become infested with inedible shrubs, to the detriment of grazing sheep (Harrington et al. 1984). In southern New Mexico, drought rather than grazing has enabled honey mesquite (Prosopis glandulosa Torr.) to occupy black grama (Bouteloua eriopoda (Torr.) Torr.) grassland, and to modify the site to the extent that black grama is unable to establish (Hennessey et al. 1983). Alternatively, periods of high rainfall can produce more topsoil moisture than grasses can use, even when there is no grazing, and so woody seedlings once again can reach and tap the subsoil water supply. After a series of high rainfall years in central Australia, I found no evidence that grazing by cattle had affected the massive growth of shrubs in Acacia woodlands (Friedel 1985) and attributed the cause to the absence of fire. Without fire, the conversion to shrubland was essentially permanent.

The second threshold is reached when soil erosion outstrips replenishment and soil physical and chemical properties are effectively altered irreversibly, for example when the sandy, nutrient-rich A horizon is stripped from an impoverished medium or fine-textured B horizon. Rainfall is lost in runoff and the environment becomes too xeric for the ready establishment of either grasses or woody plants. In all cases, crossing a threshold means the vegetation occupies a new domain and will not revert to its former state without considerable intervention.

Other thresholds include the change from palatable perennial species to palatable but shorter-lived species, e.g., from Atriplex spp. to grasses and Sclerolaena spp., which may not be significant in terms of animal production (Wilson 1989). Less commonly, there is a change from palatable short-lived grasses to unpalatable perennial grasses, e.g., from Enneapogon spp. to Aristida strigosa (Henr.) S.T. Blake ex J.M. Black (B.D. Foran pers. comm.). Noy-Meir and Walker (1986) have outlined models of grass/woody plant and palatable/unpalatable grass interactions in African savannas. The Themeda triandra Forsk. grasslands of Natal change to Aristida junciformis Trin. & Rupr., B with overgrazing and this may represent a change of state which is not reversible within a realistic time frame for management. A wide variety of North American examples has been provided by Laycock (1991).

Different range sites have differential susceptibilities to change. Some grasslands on heavy clay plains are unlikely to approach either threshold; species composition and productivity will simply shift about in response to grazing, fire, and season. Some savannas may develop into woodlands in the absence of deliberate intervention with fire, but may not be liable to soil erosion. Friedel (1987) found evidence for the existence of both types of threshold within a...
Fig. 4. Proposed relationship between condition index (based on forage composition) and tree density in a semiarid savanna range site, where tree equivalents are the number of trees standardised to a height of 1.5 m. A-G are sample points. Arrows indicate suggested areas for thresholds of change from (1) a grass-dominated domain to a tree-dominated domain and (2) a tree-dominated domain to an eroded domain with reduced regeneration of vegetation (from Friedel 1987). The regression applies to points from D and E to A.

South African savanna range site (Fig. 4). There, increased grazing was initially associated with greater tree density but, at an extremely overgrazed area, soil loss was considerable and tree establishment was suppressed. Both thresholds are found in some arid and semiarid Australian range sites and, almost certainly, the same is true elsewhere.

All the examples given so far refer to environmental changes away from a preferred state, that is, to range deterioration. Laycock (1989, 1991) has observed that there are "suspended" stages of succession during the recovery process in arid range, too. Despite careful grazing management, range condition does not improve. Sometimes, for example, a rare combination of environmental conditions must occur before recovery proceeds; the necessary condition could be a mean by which a threshold can be crossed.

The discontinuities in environmental change that are implied by the threshold concept can often be linked to the pulsed nature of rainfall, particularly in arid environments. Rainfall at different times of the year favours plants with different growth strategies; e.g., broad-leaved species may respond to winter rain, grasses to summer rain, while amount of rain determines whether perennial species or only ephemerals will establish (Westoby 1979/80). These shifts give rise to short-lived vegetation states. Changes from one long-lived state to another can also be driven by larger climatic events: several wet years may produce massive shrub establishment or enough fuel for major fires, or single large storms may initiate extensive erosion.

**Detecting Thresholds**

In view of the seasonal and spatial variability of vegetation in arid and semiarid rangelands, especially those rangelands that are currently dominated by short-lived species, range monitoring may be best served by a focus on the identification of thresholds. I investigated the possibility of recognizing thresholds at a single point in time, by developing relationships between the species composition of forage and the yield, the quantity of woody vegetation and the soil erosion status of sample locations, using several large data sets similar to those described by Foran et al. (1986). If the relationship between composition and yield was linear, a gradual transition from good to poor condition was indicated; that is, there was no threshold. If on the other hand there was a discontinuity in the relationship, then a threshold was possible. The final test would be to follow monitoring locations through time to determine whether the poor condition state was reversible, but assessment at a single point in time might provide a useful first indication.

For 21 relatively uniform range monitoring locations in a sparsely treed arid woodland, assessed between July and September 1986, a potential threshold was indicated in the relationship between the forage yield and composition (Fig. 5). The ordination score of species composition was obtained from ordination of the range monitoring locations, using the Bray-Curtis metric in the TAXON package, as described earlier. Other attempts to detect thresholds at a single point in time were not successful due to site variability and the influence of the tree layer on vegetation composition.

A more promising approach is to follow the trend in forage composition over time. Foran et al. (1986) followed the time trajectories of a series of monitored areas on the same range site, traced through ordination space by a procedure similar to that described above for grazing gradients (Friedel unpubl.). They found that composition on poorly managed areas fluctuated much more than that at well-managed areas, and that the 2 areas occupied different parts of the ordination space (Fig. 6). The same behaviour was observed in the grazing gradient study (Fig. 3). More importantly, they showed that location No. 245 (Fig. 6) was shifting across the ordination space from the well managed area, dominated by palatable Enneapogon spp. in summer and winter, to the poorly managed area, occupied by a fluctuating mix of short-lived species, in response to heavy grazing pressure. It was nearing or crossing a threshold and, at this point, management action was required to reverse the trend.

When quantitative methods are available for the assessment of soil condition, the status of soils may be treated similarly. Multivariate analysis has already been used to reduce complex species composition data to a few functional groups (Friedel et al. 1988a). The potential exists to characterize thresholds in terms of the relative proportions of a few groups, under specified seasonal conditions.
environments before we can be certain that it offers a real alternative to existing approaches. Its greatest relevance may be in arid rangelands. It requires much further testing in a variety of classes should be evident. The trend over time is determined by shifts in ordination space; departure from the pattern of seasonal responses shown by most monitoring locations signals the crossing of a threshold. Such a departure may be bad or good, and the management causes are worth investigating in either case.

Conclusions

There are a number of problems associated with existing methods of range condition assessment, not the least of which is an inaccurate theoretical base. As a consequence, assessments are produced that do not fit what we know to be happening in our rangelands. I have put forward the possibility of focusing on thresholds of change from one domain or state, to another. I propose that range does not necessarily deteriorate linearly as grazing pressure increases. Instead, it may retain the capacity to recover up to a critical point, beyond which it cannot readily return to its former state. Often some other factor, such as drought, fire, or torrential rain, coincides with excessive grazing to tip the balance.

Thus far, the proposition has had a preliminary testing in some arid rangelands. It requires much further testing in a variety of environments before we can be certain that it offers a real alternative to existing approaches. Its greatest relevance may be in environments like the arid rangelands which are highly variable and unpredictable.

References


Vegetation changes from 1935 to 1980 in mesquite dunelands and former grasslands of southern New Mexico. J. Range Manage. 36:370-374.

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