NEW THINKING IN RANGE ECOLOGY

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Summary

Until relatively recently, range scientists based their work on the assumption that the rangelands were equilibrial systems that more closely conformed to the "Climax" vegetation concept i.e., the potential vegetation community for an ecological entity. This conceptual scheme (the *equilibrium model*) has been widely adopted by the range-management profession both in North America and, through the training received by foreigners at US universities, extended world wide. And a set of criteria has been developed to characterize range condition according to four classes – excellent, good, fair, and poor. These concepts underpinned much of range management thinking until relatively recent times. Two concepts had dominated the thinking regarding ecology and land use (i) that all rangeland ecosystems are equilibrial systems and (ii) that people are an outside source of disturbance. Now it is clear the many rangelands in drier regions are more appropriately viewed as non-equilibrial systems within which people play an integral role.

Plant cover in arid environment shifts across dynamic *thresholds* between different ecological states in response to disturbance such as grazing, drought and fire. These different states are stable and each state is a result of interactions among climate, soils, grazing history, and management practices. 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.

Natural ecosystems shift between different ecological states through ecological transition zones in response to natural or human-induced factors rather than follow a prescribed successional path. This is the *non-equilibrium model*. Range management under this model centers on carrying capacity, stocking rates and range condition assessment. In contrast, non-equilibrium rangeland systems are thought to be driven primarily by stochastic abiotic factors, notably variable rainfall, which results in highly variable and unpredictable primary production. Livestock populations are thought to have negligible feedback on the vegetation as their numbers rarely reach equilibrium with their fluctuating resource base. Multiple stable states exist as a result of interactions among climate, soils, grazing history, and management practices.

Dynamic thresholds and the effects of nonlinear processes (including chaos theory) on ecosystem structure and function are rarely considered sufficiently and to date their incorporation in decision-making is inadequate

New thinking is emerging in the area of rangeland/ people relations and the approach to changing rangeland management to maintain environmental services that rangelands can provide. The new science approaches in rangelands veer inevitably towards maintaining resource functions, diminishing the effects of marginalization, the development of adequate lifestyle and livelihood, infrastructure and redressing the inequities of poverty, education and future opportunity. The science itself must be driven by the challenge of integrating biophysical, social and economic factors and by specific issues such as future energy options, climate and atmospheric change and carbon opportunities.

Communities and individuals are increasingly developing their own visions in response to local and regional issues. Issues are usually complex, generally operate over multiple scales and are continuously changing. The challenge for the future will be to more comprehensively discuss the social and economic systems *as well as* the biophysical system in the context of the many and varied visions that rangeland people have for their futures.

1. Introduction

As an applied science, range management was developed in the western USA to address the needs of large scale commercial producers who had recently occupied perennial grasslands. The evolution of rangeland management as a separate discipline was predicated on circumstances (economic, ecological and social) so different from those that apply in most of the world's range/livestock systems (See Range and Animal Sciences and Resources Management and People In Rangelands: Their Role And Influence On Rangeland Utilization And Sustainable Development, and Range Livestock Production Systems In The Near East). This has led to a re-think about what are the important principles that operate in non-commercial range/livestock systems and shifted attention to defining new management goals and to re-examining the relevant ecological principles and processes that underpin rangeland/livestock relations.

The consideration of range management in a plant-ecological context began with the studies of F. E. Clements that were published in 1928). He emphasized vegetational changes, termed *succession*, that take place over time on bare areas when freed from disturbance. Vegetation changes from a predominance of annual, aggressive, largely herbaceous species, through stages of perennial forms, to self-sustaining, largely perennial plant communities termed *climax states*. Disturbance, including grazing, can push vegetation back down the scale, the degree of change depending on the intensity of disturbance. When disturbance is removed, the vegetation moves back up the scale.

E. J. Dyksterhuis working in the grasslands of North Texas during the 1940s, adapted the Clementsian paradigm into a formal, range-management conceptual model. His model was based on the premise that climax species were most palatable to livestock, and that palatability declined progressively down the successional. He theorized that when cattle were placed in a previously ungrazed, climax vegetation, they first grazed the climax species. These were the first to decrease, and were termed "decreasers." They were replaced by somewhat less-palatable "increaser" species (many of which are already part of the climax plant association). If grazing pressure were intense and/or continuous, the animals would turn to the increaser species, reducing their abundance, and opening the plant community to low-palatability, early-successional forms termed "invaders." How far down the scale the system is moved is considered to be a function of the intensity and duration of grazing. And the assumption is generally present for grasslands that easing or release from grazing allows the system to move back toward, or to, the climax (decreaser) stage.

The basic ecological process mediating the interaction between grazing and the vegetation composition is considered to be competition among the plant species. The climax or decreaser stage is assumed to be composed of the most competitive species which exclude the increaser and invader forms. Grazing the climax forms reduces their competitive advantage and allows intrusion of the lower-successional species. Removal of grazing restores the competitive prowess of the decreasers which then resume their dominance in the community.

Until relatively recently, North American, range scientists based their work on the "Climax" vegetation concept (i.e. the potential vegetation community for an ecological entity) relating to "vegetation series" after Clements' research and named the "*Quantitative Climax Method*" (QMC). The QMC makes little use of the soil, hence climate-vegetation relationships. It is assumed that "the climax vegetation is the most stable and productive and provides the best soil protection of the vegetation growing on the site". Unfortunately, referring to "climax" plant communities, progressive and regressive vegetation series and successions are based upon empirical-subjective opinions and does not vary with the end use of the rangeland.

This conceptual scheme (the *equilibrium model*) has been widely adopted by the range-management profession both in North America and, through the training received by foreigners at US universities, extended world wide. And a set of criteria has been developed to characterize range condition according to four classes – excellent, good, fair, poor – depending on the proportions of plant species in each of Dyksterhuis' three categories. These concepts underpinned much of range management thinking until relatively recent times.

The equilibrium model stresses the importance of biotic feedbacks such as density-dependent regulation of livestock populations and the feedback of livestock density on vegetation composition, cover and productivity. Range management under this model centers on carrying capacity, stocking rates and range condition assessment (see below).

The standard approach to range assessment based on shifts in botanical composition has little relevance to most non-commercial pastoral systems in Asia and Africa. For a start there is often no credible botanical ‘before’ on which to base a botanically-based assessment. Furthermore, it is deceptive to use the “QMC” in most arid and semi-arid regions of the world as “climax” vegetation has long since disappeared. In spite of the criticisms and shortcomings of the “climax” concept, rangeland researchers recognized that chronological successions of plant associations and range conditions changes occur over the seasons and the years. The “Climax” approach was soon modified to the successional pathways, stable states, and discontinuous transitions. New thinking gave way to new paradigms.

2. Ecosystems Dynamics and the New Paradigm

Natural ecosystems shift between different ecological states through ecological transition zones in response to natural or human-induced factors rather than follow a prescribed successional path. This is the *non-equilibrium model*. Range management under this model centers on carrying capacity, stocking rates and range condition assessment. In contrast, non-equilibrium rangeland systems are thought to be driven primarily by stochastic abiotic factors, notably variable rainfall, which result in highly variable and unpredictable primary production. Livestock populations are thought to have negligible feedback on the vegetation as their numbers rarely reach equilibrium with their fluctuating resource base. Multiple stable states exist as a result of interactions among climate, soils, grazing history, and management practices. Plant cover in arid environment shifts across dynamic *thresholds* between different ecological states in response to disturbance such as grazing, drought and fire. These different states are stable and each state is a result of interactions among climate, soils, grazing history, and management practices. 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.

Rangeland managers need a workable framework that will underpin their decision making. The effects of nonlinear processes on ecosystem structure and function and the nature of dynamic thresholds are rarely considered sufficiently and to date their incorporation in decision-making is inadequate. This is particularly so in China, Central Asia and parts of Africa where the newer thinking in ecology has not yet been widely promulgated and where assumptions based on equilibrial theories prevail. However, French phyto-sociologists did much pioneering work in North Africa *(*See Environmental Soil Management)

The *state and transition approach* (STM) of Mark Westoby and his colleagues may offer an appropriate framework and can be used to highlight ‘management windows’ where opportunities can be seized and hazards avoided. Natural resource 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.

Interpretation of assessment and monitoring data requires information about reference conditions and ecological resilience. Reference conditions used as benchmarks can be specified via potential-based land classifications (e.g., ecological sites) that describe the plant communities potentially observed in an area based on soil and climate. State-and-transition models (STMs) coupled to ecological sites can specify indicators of ecological resilience and thresholds.

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 and others 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. The following criteria have been proposed: 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.

Understanding the role of plants as indicators has important implications for sustainable rangeland management, and for the rehabilitation of areas that are already degraded. The threshold concept describes unidirectional changes in ecosystem structure and ecosystem functional processes. The state-and-transition model 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* or threshold or ecological transition zones depending on the degree of responses to disturbance. When these thresholds are crossed, recovery to the original ecosystem states is difficult.

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Biographical Sketches

Dr G. Ali Heshmati is an Iranian and a Professor in Gorgan Agricultural and Natural Resource Sciences University, Gorgan, Iran. He holds a PhD from the University of Adelaide, Australia. Dr Heshmati leads research on rangeland ecology with a focus on thresholds. He has field experience in Iran, Australia, China and Kuwait. In 2002-3 Dr Heshmati was a Visiting Fellow in the University of British Columbia, Vancouver, Canada.

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He has a background in teaching and applied research. As an educator he taught graduate and post graduate students in Australia, and conducted applied research and training programs for institutions and government agencies over the world.

Dr. Squires is an internationally well known dryland management expert. He has worked in many developing countries e.g. China, Mongolia, Thailand, Algeria, Ethiopia, Iraq, rural Australia and Italy. He has conducted many projects in multiple sectors of environment protection, natural resource and biodiversity conservation, land degradation and desertification control, livestock and rangeland management.

He is the author of over 100 scientific papers, numerous invited book chapters and several books. Dr Squires was awarded the 2008 Science and Technology Friendship Gold Medal Award by the government of China.