Failures in the Assumptions of the Condition and Trend Concept for Management of Natural Ecosystems

Tony Svejcar and Joel R. Brown

Much of the emphasis in managing rangelands has been based on the concepts of range condition and trend first described by Dyksterhuis (1949). These concepts were well-founded in existing theories of structure and function in plant communities. The concepts remain appealing even 40 years later because they provide a clearly defined goal (progression toward a climax plant community), a measure of health (deviation from climax), and allow each unit of rangeland to be placed in a discrete condition class. However, the assumption that succession universally progresses toward a stable endpoint after disturbance may not be valid.

Ecological theory has progressed dramatically over the past 40 years, but few of the new concepts have been incorporated into rangeland inventory and management. Traditional climax-based theories stress succession toward a clearly defined plant community in the absence of unnatural disturbance. Current ecological theory allows for plant community changes which are not reversible, the existence of communities not in equilibrium with the current climate, and the possibility that random events may influence the course of vegetation dynamics (Westoby et al. 1989).

Central to the climax concept is the assumption of a stable climate (Clements 1936). The assumption of either long-term or short-term climatic stability may not be valid (Nielsen 1987). To paraphrase Westman (1990), "attempts to maintain parklands in their current conditions or to return them to some vignette of primitive America are inevitably frustrated both by climate change and by changing patterns of human use of fire, air, and water." Westman's conclusion pertains to parks where resource use is not a major consideration and the emphasis is placed on maintaining the natural or original ecosystem.

Range condition classification has traditionally viewed disturbance primarily in terms of livestock grazing and short-term drought. These two forms of disturbance are generally viewed as having relatively minor impacts on communities, and when suspended, allow the community to return to equilibrium. In Australia, the climax approach to range management has been abandoned because "it does not allow for multiple vectors of change (climatic variation, fire, plant introduction, as well as grazing) and because of a lack of correlation between change in vegetation composition and animal production or land stability" (Wilson 1984).

Authors are range scientist, USDA-ARS, 920 Valley Road, Reno, Nevada 89512, and state range conservationist, USDA-Soil Conservation Service, 2121 C, 2nd Street, Suite 102, Davis, Calif. 95616. Svejcar's current address is Eastern Oregon Agricultural Research Center, HC-71, 4.51 Hwy 205, Burns, Oregon 97720. The authors wish to thank Drs. T. Atwood, P. Doescher, B. Frost, M. George, R. Miller, J. Young, and an anonymous reviewer for comments on an earlier version of the manuscript.

Climatic Drift

An implicit assumption in many land management schemes is that the climate is relatively stable, at least over the short term. There is increasing evidence that subtle climatic changes can occur over periods of as little as 50 to 100 years. Although exact dates are not completely agreed upon, the "Little Ice Age" occurred between about 1600 and 1900, followed by a global warming trend (1900–1940) and a subsequent global cooling trend (1940–1970) (Neilson 1987). The trend after 1970 has been for increased temperatures, especially in the 1980's (Schneider 1989).

How might these relatively short-term changes in climate influence vegetation dynamics and potential successional pathways? A thought-provoking analysis of climate/vegetation interactions was conducted for the southwestern U.S. by Neilson (1986). Analysis of 130 years of climate data for Las Cruces, New Mexico, indicates that winters were dryer and summers wetter before 1900 than after. Precipitation during the summer favors growth and establishment of the C_4 (warm-season) grasses; whereas, winter precipitation favors C_3 (cool-season) shrubs. Neilson states that "the pristine vegetation of the northern Chihuahuan Desert, recorded 100 years ago, was a vegetation established under and adapted to 300 years of Little Ice Age and is only marginally supported under the present climate." The dominant species may be able to maintain dominance in the face of changing climate, but once displaced, they cannot reestablish.

There are direct interactions among climatic variation and success of plant species with different life-histories. Long-lived plants require a less frequent return to favorable establishment conditions than do short-lived plants. Long-lived species may maintain dominance centuries after climatic change makes local conditions unsuitable for seedling establishment (Brubaker 1986). Brubaker cites the example of 400 to 600 year-old stands of douglas-fir *(Pseudotsuga menziesii)* that show no evidence of decline, yet after cutting, new trees do not become established. Neilson and Wullstein (1986) concluded that two oak species (*Quercus* sp.) in central Utah could not be established under present climatic conditions, yet both species have persisted via asexual reproduction. If the oaks were considered desirable and a management plan was designed to favor their establishment, the goals would be unattainable unless a series of nontypical years were to occur. In cases where natural climatic drift is a factor, the traditional climax approach to range management results in strategies based on succession toward relict species and plant communities. An increase in global atmospheric CO_2 may also influence competitive relationships on rangelands. During the past 120 years, CO_2 has increased from about 270 to 350 parts per million (Johnson et al. 1990). In general, C_3 species respond more favorably to increased CO_2 concentrations than do C_4 species (Bazzaz et al. 1985). Johnson et al. (1990) suggested that elevated CO_2 levels may be a factor in the conversion of C_4 grasslands to C_3 shrublands that has occurred on arid and semiarid rangelands over much of the earth.

Determining relationships between vegetation and climate requires more than just yearly precipitation averages. Neilson (1987) points out that specific year-to-year weather patterns may persist for several decades, then shift to a different pattern. A multi-decade weather pattern may favor establishment of one vegetation type over another. In fact, mortality during drought years, or establishment during favorable years may control vegetation stability more than the events of "average" years. Nonrandom clustering of weather events (e.g., clustering of similar years) may have important consequences in the study of vegetation (p. 28, Neilson 1986 for a discussion of this subject).

Climate has changed at varying rates in the past, but what of the future? If the global climate change predictions are valid, then rapid changes may occur in the relatively near future. Schneider (1989) stated: "Changes in temperature and precipitation could threaten natural ecosystems, agricultural production, and human settlement patterns." On the other hand, Idso (1989) suggested that a "greening of the earth" may result from the increase in atmospheric CO_2 levels. The actual effects of increased CO_2 levels on climate and vegetation patterns are open to debate, but there is general agreement that changes will occur. Some areas may increase in biotic productivity while other areas decline. If climatic shifts do occur, potential vegetation may also shift.

Biological Invasions

Introductions of new species may also have dramatic impacts on vegetation dynamics. Many current land management schemes do not allow for non-native species to be considered components in stable ecosystems. In some cases such a view is not consistent with biological reality. About 16% of the flora of California consists of introduced species (Johnson 1985). The entire California annual grassland may be considered an invading ecosystem. However, invading species should not be viewed as universally bad. Westman (1990) points out that new colonizers can play important roles in stabilizing ecosystem functions. Plant community structure may be manipulated to provide desired products on a sustainable basis, even though dominated by introduced species (George et al. in press).

Non-native species can also effectively disrupt ecosystems. Billings (1990) suggested that cheatgrass *(Bromus tectorum)* has or will alter the vegetation of much of the Great Basin. The increase in fire frequency and competition for plant establishment sites in areas invaded by cheatgrass reduces the potential for many native species to reproduce. Unfortunately, the prognosis is not good for cheatgrass-dominated ecosystems. Cheatgrass is well-adapted to areas with relatively mild winters, and any increases in annual temperature (whether natural or human-induced) may increase the area dominated by cheatgrass. In addition, cheatgrass responds more favorably to elevated CO_2 levels than do some of the native desert grasses (Smith et al. 1987). Atmospheric and climatic changes may already be shifting competitive interactions.

Suggestions for the Future

What are alternatives to the classical climax-based vegetation management systems? Westoby et al. (1989) have proposed the use of "state-and-transition models" for management of rangelands. They suggest a catalogue of potential states (e.g., dominance of shrubs, dominance of grass, or a near equal mix of the two), and pathways from one state to another (transitions) for a particular type of rangeland (i.e., range site). Climate and management would be major factors influencing transitions among states. This system could accommodate climate change as a change in the probability of a particular set of climatic events. These authors also suggest that emphasis be placed on timing and flexibility of management inputs rather than fixed programs and policy decisions.

A case can be made for management based on ecosystem function rather than on groups of species believed to have existed in the pristine past. Graetz et al. (1988) suggested that emphasis be placed on guilds of species (groups that are functionally equivalent) rather than on individual species. Johnson (1985) points out that species can often be added to or deleted from an ecosystem without affecting ecosystem function, whereas a single species (such as cheatgrass) may disrupt whole ecosystems. In the past we have placed less emphasis on actual function (e.g., infiltration, cycling of nutrients, etc.) and more emphasis on species assemblages. We must also keep in mind that genetic changes have and will continue to occur in both native and introduced species (J.A. Young, personal communication).

Specific Suggestions:

1) Deal with changes that can occur under the current climatic and biological conditions. We cannot freeze time, and attempts to rate current species

assemblages against pre-settlement vegetation types may have little to do with management decisions by land users.

2) Emphasize collection and storage of vegetation, soils, and climate information. Data collection is not especially useful if the information cannot be retrieved and objectively analyzed 5, 10, or 20 years later to evaluate long-term trends. Assessment of reproduction by individual species may be useful for interpreting vegetation trends.
3) View changes in management and/or climate as alterations in the disturbance regime of a specific site. These changes should be analyzed using a systematic approach to ecosystem function.
4) Acknowledge that succession in most rangeland ecosystems is not linear and does not have a fixed end-point. Multiple states and pathways can exist. The functionality and value of each state should be identified.
5) Strive for conceptual, if not day-to-day, agreement among land management and technical assistance agencies in order to provide the best information to land users and the general public based on the above- stated principles.

Literature Cited

Bazzaz, F.A., K. Garbutt, and W.E. Williams. 1985. Effect of increased atmospheric carbon dioxide concentration on plant communities. p. 155-170 *In:* B.R. Strain and J.D. Cure (eds.), Direct effects of increasing carbon dioxide on vegetation. U.S. Dept. of Energy, DOE/ER-0238.

Billings, W.D. 1990. *Bromus tectorum,* a biotic cause of ecosystem impoverishment in the Great Basin. p. 301-322 *In:* G.M. Woodwell (ed.), The earth in transition: patterns and processes of biotic impoverishment. Cambridge Univ. Press. N.Y.

Brubaker, L.B. 1986. Responses of tree populations to climatic change. Vegetatio 67:119-130.

Clements, F.E. 1936. Nature and structure of the climax. J. Ecology 24:252-284.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. J. Range Manage. 2:104-115.

George, M.R., J.R. Brown, M. Robins, and W.J. Clawson. 1990. An evaluation of range condition assessment of California annual grassland. Cal. Dept. of Forestry and Fire Protection Report (In press).

Graetz, R.D., B.H. Walker, and P.A. Walker. 1988. The consequences of climate change for seventy percent of Australia. Natr. Environment 399-420.

Idso, S.B. 1989. Carbon dioxide and global change: earth in transition. IBR Press, Tempe, Ariz..

Johnson, H.B. 1985. Consequences of species introductions and removals on ecosystem functions-implications for applied ecology, p. 27-56. *In:* E.S. Delfasse (ed.). Proc. VI Int. Symp. Biol. Control Weeds, Vancouver, Canada.

Johnson, H.B., H.S. Mayeux, Jr., and H.W. Polley. 1990. Increasing atmospheric CO_2 concentrations and vegetation change on rangelands. Proc. Soc. Range Manage. 43rd Annual Meeting. Reno, Nev.

Neilson, R.P. 1987. Biotic regionalization and climatic controls in western North America. Vegetatio 70:135-147.

Neilson, R.P. 1986. High-resolution climatic analysis and southwestern biogeography. Science 232:27-34.

Neilson, R.P., and L.H. Wullstein. 1986. Comparative drought physiology and biogeography of *Quercus gambelii* and *Quercus turbinella.* Amer. Midl. Natr. 114:259-271.

Schneider, S.H. 1989. The changing climate. Sci. Amer. 261:70-79.

Smith, S.D., B.R. Strain, and T.D. Sharkey. 1987. Effects of CO_2 enrichment on four Great Basin grasses. Functional Ecology 1:139-143.

Westman, W.E. 1990. Managing for biodiversity. Bioscience 40:26-33.

Westoby, M., B. Walker, and I. Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. J. Range Manage. 42:266-274.

Wilson, A.D. 1984. What is range condition: development of concepts in Australia. Bull. Ecological Soc. Amer. 65:171.