Improving the Monitoring of Rangelands

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Monitoring the "health" of rangelands is a "hot" topic both within the rangeland and environmental communities. We will consider why this is so and provide some suggestions of how the profession should participate in resolving the concerns being expressed.

Early Monitoring

During earlier decades in the history of rangeland management, monitoring of rangeland conditions was informal. On private lands, the rancher visually assessed the total amount of available forage and perhaps the balance between growth forms within the vegetation, particularly if "weeds" were increasing, but put more attention on the performance of his/her livestock. In the U.S., the rancher could get technical assistance from the Soil Conservation Service (now the Natural Resource Conservation Service) or the local extension agent, but seldom made written or photographic records. On public lands, grazing permits were administered and the range conservationist made some written and photo records from a few small plots on "key areas" located within each pasture. A map showing utilization may have been made by riding over the pasture shortly after the livestock were removed. If the range conservationist concluded, during consultation with local administrators, that conditions were unacceptable, more intensive monitoring would be done to see if conditions stabilized or improved. If not, use was adjusted (in terms of numbers and kind of livestock and/or season of use) until trend was determined to be stable or upward. Only occasionally did the permitee and government officials disagree strongly enough such that the issue had to be settled judicially.

Recent Monitoring

During recent decades a much wider set of interest groups has emerged, especially in regard to publicly-owned rangelands. These various interest groups focus on rangeland "health" at many different scales in space and time (Fig. 1). If conditions are deemed unacceptable by any interest group and the agency doesn't reduce livestock use, the issue can easily end up in court. Various interest groups are also lobbying Congress and federal agencies for better regional and national accounting of rangeland "health." This broadened interest is causing agencies historically not associated with rangeland issues to launch new initiatives [e.g., the Environmental Protection Agency's attempts at developing an Environmental Monitoring and Assessment Program (EMAP)]. The agencies who have been monitoring for decades are also trying to react to national level critiques of past rangeland monitoring practices, e.g., the National Research Council (1994). The Society for Range Management (1995) is also pressing for uniform national standards of reporting rangeland condition and trend.

In addition to changes in socio-economic context, scientific advancements and technological progress have modified the ways in which we view the dynamics of ecosystems. Societal influences, scientific advances, and technological progress act in concert (Fig. 2), along with current fiscal constraints, to alter the ways we will have to deal with rangeland monitoring in the coming century. Since the influences of socio-economic trends have been well covered here before (e.g., Kennedy et al. 1995), we will turn to how scientific advancements and technological progress already have and probably will continue to modify the ways we go about monitoring rangeland "health," functioning or integrity.

New Sci-tech Influences

The scientific and technical communities have provided both new concepts and new instruments to help obtain, organize, analyze, summarize, and present data. Most of the advances that now alter our options for

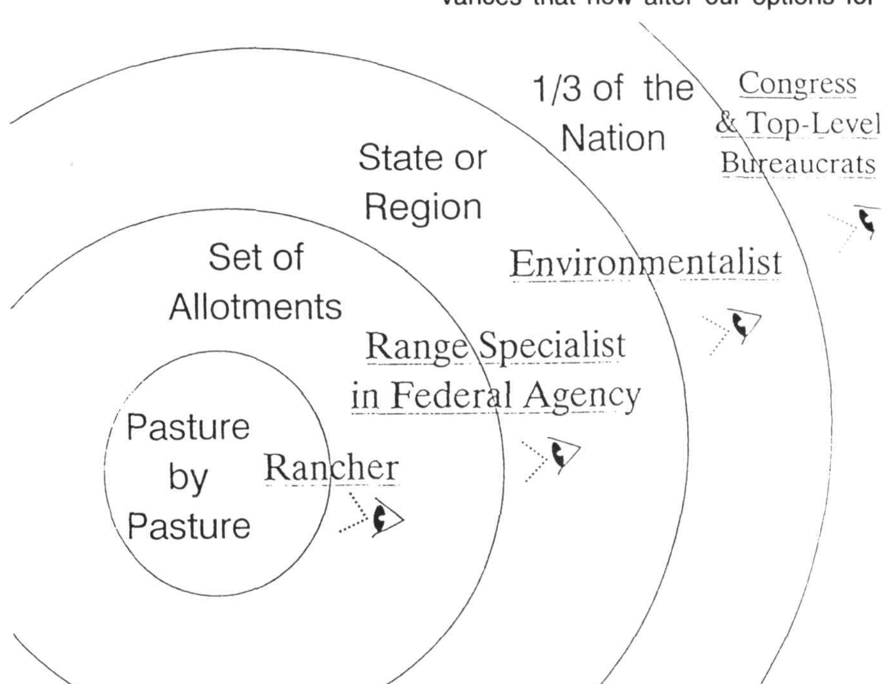

Fig. 1.

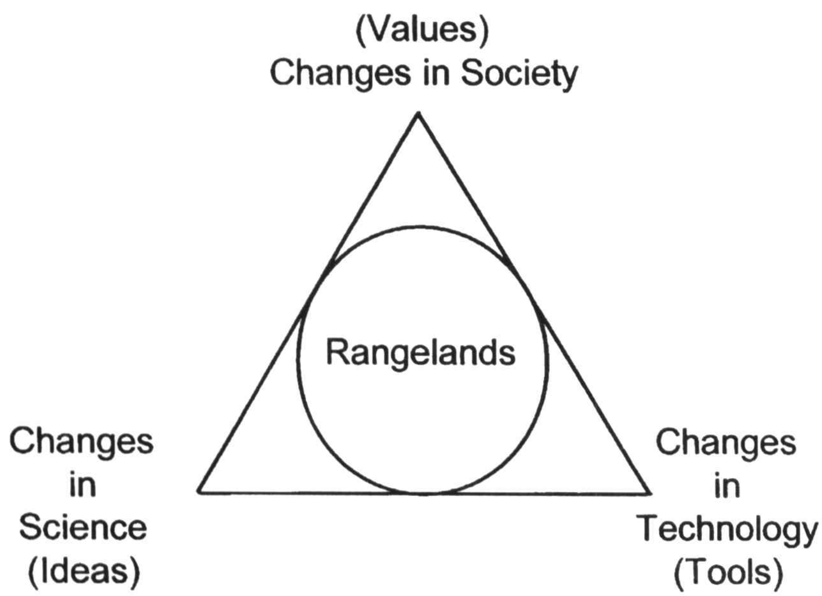

Fig. 2.

rangeland monitoring have come from the Cold War-era, security-related investments in education and research on a wide front, little of which has been directly related to rangeland management. Examples of relevant technology are computers, satellites (remote sensing, RS) and their many new kinds of sensors, global positioning systems (GPS), and geographic information systems (GIS).

Some relevant advances involve completely new ideas. For instance, research in fluid dynamics and climatology led to the quantification of chaos, a concept now beginning to be applied to describe the dynamics of some rangeland ecosystems (e.g., Lockwood and Lockwood 1993). The mathematicians' contribution of catastrophe theory is also now being used to explain rangeland development (e.g., Rietkerk et al. 1996). Geomorphologists (e.g., Renwick 1992) have shown us how different positions on a landscape show variation in inherent stability or instability to soil erosion that vegetation can only temporarily alter. Paleoecologists have shown us how flora and fauna have changed enormously over time, even before humans arrived on the scene (e.g., Tausch et al. 1993). Anthropologists (e.g., Kohler 1992) and historians (e.g., Denevan 1992) have demonstrated how the western rangelands encountered by the first Europeans were far from stable, pristine systems. Even philosophers, mainly through their expansion of hierarchy theory (e.g., Ahl and Allen 1996), have provided us with more useful ways to view the dynamic interactions within ecosystems.

All of these advances in thinking are leading us away from earlier assumptions of equilibrium and balance, which were machine-like models that prevailed during the Industrial Age. These earlier views ignored the historical and chance elements in ecological systems that we are now beginning to acknowledge.

Changing Views of Ecological Succession

Ecology probably provides the most important scientific underpinning of rangeland management. Enormous changes have occurred recently in our ecological understanding. We will briefly review but one particularly relevant ecological phenomenon—succession of plant communities.

Nearly all plant ecologists once believed in a slow, gradual, linear, deterministic, and reversible progression toward a single, self-regenerating endpoint (climax). The mechanism by which this was universally thought to occur was called facilitation; the modification of microclimate and soils through replacement by different plant species favored by these changing microenvironments over successional time. The range profession developed condition classes based on departures from the one presumed climax for each ecological site. Data were collected and interpreted by range conservationists for decades based on this Clementsian model. Few within the range profession noticed that academic ecologists had begun to abandon Clement's model in the late 1950's. The new models replacing the gradual, linear, deterministic successional trajectories instead display nongradual starts, jumps forward, reversals, crossing of thresholds and passing into new domains or alternate seemingly stable states (Laycock 1995).

Using the New Ecology

The new notions of successional patterns require some practical developments before we can apply them to land management. For instance, rather than using the one presumed climax as the reference point, many now advocate use of the desired plant community (Laycock et al. 1995). That is, we can now choose one of the possible vegetation configurations that is projected to be sustainably maintained through management. This vegetation still has to be sufficiently protective of the soil such that accelerated soil erosion will not occur (SRM 1995). Conceivably, a lightly to moderately grazed portion of a pasture could serve as a benchmark, if it were judged to be under a sustainable level of management (West 1991, West et al. 1994).

Using the above new approaches will involve developing consensus answers to six important questions during public land management. These questions are: 1) What is ecologically possible? 2) What is economically and logistically feasible? 3) What collection of successional states across a management unit will optimize the value of rangeland resources? 4) Whose values among the stakeholders around the current table will be accommodated and in what order? 5) How will that compromise affect other potential rangeland users (including those off-site, not now at the table, and in the future)? 6) Is that collection of states arrived at following a few decades of management sustainable? Monitoring is absolutely required to address the last question.

Collision with Other Interest Groups?

We do not foresee the desired plant community or sustainably grazed benchmark concepts as being easily accepted for public rangelands by conservation biologists (e.g., Noss and Cooperrider 1994). Desired plant communities are frequently early seral stages where more productive herbaceous plants, including some exotics, thrive. Conservation biologists, exemplified by Noss and Cooperrider (1994), will accept no exotics in management objectives. Furthermore, their view of acceptable conditions excludes human influences as much as possible. Most of their "umbrella" or "flagship" species whose abundance are used as indicators of overall environmental "health" functioning or integrity are those favored by "climax" conditions. Only data on populations of these selected species will satisfy their monitoring demands (Table 1, Column 4). Other interest groups that are watch dogs of particular selected variables (e.g., air quality, water quality, scenic quality, etc.) will also probably not be satisfied with monitoring data on only vegetation and soils within a few selected plots.

A possible strategy to avoid some of the anticipated disagreement is to follow the implications of hierarchy theory. Allen and Hoekstra (1992) point out that the scale of any data-gathering must be matched closely with the relevant scale of the question(s) being asked. Basic ecologists have already begun to follow this logic. Some rangeland professionals, however, continue to use methods mismatched to the often unstated major question; what is the condition of this entire pasture or allotment? In the case of monitoring, rangeland professionals have usually measured change in plant species composition in a few small plots located on subjectively chosen "key areas" and assumed that information applied to entire pastures. Attributes that are best monitored on small plots are plant population and patch dynamics, not changes in vegetation or soils within a mosaic of ecological sites scattered over an entire pasture. We now have better alternatives to the limited practicalities and traditions of the past.

We cannot simply aggregate detailed plot data upward to represent conditions over pastures, allotments, ranger districts or regions, without some means to convert the local data

Table 1. Monitoring and assessment under five generalized styles of environmental management (from Shear 1996).

	FRONTIER ECONOMICS	RESOURCE MANAGEMENT	SUSTAINABLE DEVELOPMENT	SELECTIVE ENVIRON-MENTALISM	DEEP ENVIRON-MENTALISM
Motivation	what is there?	what is there? what is changing?	what is there? what is changing? why is it changing?	what is there? what is changing?	what is there?
	facilitate resource exploitation	conserve renewable resources	ensure ecological security	protect environment	curiosity discovery
	single purpose	single or multi-purpose	multipurpose	single or multi-purpose	single purpose
Scope	resource-based	resource-based	systems-oriented	nature-based	nature-based
	narrowly focused	multidisciplinary	fully integrated	multidisciplinary	narrowly focused
	selected variable(s)	selected variable(s)	multivariate	selected variable(s)	selected variable(s)
	single medium	selected media	multimedia	selected media	single medium
Partnerships	none or few	limited	all relevant interests	limited	none or few
Methodology	inventories, surveys concerned with 'how much,' monetary potential	compliance and regulatory monitoring	comprehensive, integrated monitoring	effects monitoring	natural histories, inventories, rankings, classifications
		case studies on resource use or development	comprehensive ecosystem assessments	case studies on specific environmental concerns	
Time Frame	short-term	short-term	long-term	short-term	short-term

into summarizable information for larger expanses. The method suggested by the NRC (1994) involves assigning, plot by plot, the categories of "healthy," "at risk," or "unhealthy" as means of data reduction. We don't, however, foresee ever having enough budget or personnel to do the very large, frequent, random-point sampling that would lead to statistically adequate answers that way, except for the nationwide to state scales, as proposed by the National Resource Inventory. This leaves us with the task of developing an affordable yet statistically reliable means to measure rangeland "health" at pasture to allotment scales. We also need to avoid gridlock with conservation biologists and other special interest groups, if possible. Fortunately, new scientific ideas and technologies are now giving us some alternatives.

Potential Contributions of Landscape Ecology

Landscape ecology is a revitalized branch of ecology that deals with patterns of form and function that occur across large areas (Formann 1995). Formerly, we could only deal with such notions intuitively. Now through frequent imagery from earth orbiting satellites, organized via geographic information systems and spatial statistical analyses through greatly enhanced computer power, we can finally quantitatively compare patterns over huge areas in their entirety (Turner and Gardner 1990). These synoptic metrics (simultaneous and instantaneous measurements of entire areas) finally allow us to go beyond having only small plots (usually measured at different times) on the ground. Australian rangeland professionals (e.g., Pickup 1996) are far ahead of Americans in making these new technologies practical.

Of course, we will need to validate our interpretations of remotely-sensed imagery at well-known places on the ground. This is called ground-truthing. Global positioning systems allow us to find, mark, and relocate those crucial spots much more easily now. The discipline of spatial statistics is continually developing new approaches for us to quantitatively express the major patterns that can be discovered. These usually involve the determination of true means of population statistics, not the estimated means with their wide margins of error in the more familiar sub-sampling statistics. There can, however, be inherent biases and misclassifications that must be checked by ground-truthing. Some rangeland ecologists are already providing examples of how these metrics can be obtained (Munguia et al. 1997, Wu et al. 1997). Much more testing of them in a variety of contexts will hopefully be coming shortly.

> We should be honest and open in specifying where science and values merge in our decision making.

One major misunderstanding, perpetuated by the National Research Council's 1994 report is that there are objective ways to characterize rangeland "health." Unfortunately, it is impossible to develop and use monitoring techniques that don't involve some degree of human value judgement (Burnside and Rasmussen 1997). The choices of which variables to assess, where and when to assess them, and what benchmarks to employ, are all value laden. Determination of "health," condition, functioning or integrity is an interpretation affected by the data collected, judged against management objectives and the benchmarks chosen (West et al. 1994). Choice of benchmarks depends on our expectations of the land to meet human objectives, as well as many technical considerations (West 1991, Tausch 1996). We should be honest and open in specifying where science and values merge in our decision making.

Participate or Become Marginalized

We are all involved in an ideological battle. Most, particularly younger Americans, are aligning themselves with the notion of sustainable development. When this group comes to dominate politically, any user of the land is likely to be asked to prove that his or her actions do not endanger ecological security (Table 1, Column 3). If that can't be shown, the views of selective environmentalism (Table 1, Column 4) or even deep environmentalism (Table 1, Column 5) have greater chances of prevailing. Most conservation biologists are selective environmentalists. One of their major beliefs is that native species should have precedence over the introduced ones (including in some cases, humans). However, designation of what is "native" involves arbitrary choices of when immigration took place.

Conservation biologists are very active in national efforts to devise new means of monitoring the nation's environmental "health" (e.g., Bravo 1996). They are pushing for adoption of monitoring methods that favor their selective world view. Unless the range profession becomes more involved in developing new means to monitor rangelands, at all scales of interest, it will become increasingly left out in setting land use policy for rangelands.

We agree with Gillespie (1996) that new means of ecosystem monitoring will involve multiple perspectives and scales simultaneously (Fig. 1). Multidisciplinarity, ecosystem management, and Coordinated Resource Management Planning (CRMP) are becoming the prevailing modes of operation in resource management. One implication of ecosystem management is that ownership boundaries become less important and thus monitoring has to be similar on lands of equivalent potential under all ownerships if data are to be shared and compared. This doesn't mean throwing away the point-based data we already have, or even adopting yet more complete point-based approaches (e.g., Herrick et al. 1996) for some circumstances. We don't, however, expect to have either the personnel or budgets to be able to apply such intensive approaches at more than a few areas involving particularly intense debate about alternative land uses.

We don't expect discovery by an individual or even a small group, of a "silver bullet" (an easily measured variable that all will readily accept) which will quantify condition and trend for all kinds of rangeland at all scales in space and time. Instead, we foresee rangeland managers and scientists having to participate in many meetings, workshops and field trials with other professionals and interest group representatives until a hierarchically designed and mutually agreeable way is provided to answer the questions agreed upon. We visualize these questions bearing on the management of a particular area to involve populations of some selected species, community attributes at selected "sentinel sites" (Pickup and Stafford Smith 1995), landscape characteristics such as fragmentation, and even social and economic characteristics of embedded humans (Blahna 1995, Harwell et al. 1996), if the area of interest is large.

The chosen indicator(s) at each scale must be quantitative, repeatable, have minimal measurement error, be easily communicated and understood, susceptible to sensitivity analysis, yet affordable. Since there are very few metrics which can be applied at scales ranging from quadrats to continents (e.g., albedo, water use efficiency, Normalized Difference Vegetation Index), we will have to devise "filters" (means of data reduction) that can take the more abundant data collected at the more detailed spatial and temporal scales and quantitatively bridge them to needs across large spans of area and time. Unless most of the viewers at all scales (Fig. 1) can find a transparent (easy to understand and repeatable) process at work, they will mistrust and thus contest the conclusions. "Deep ecologists" (Table 1, Column 5) will not likely be satisfied with any consensual solution since they are driven by moralistic assertions rather than science-based arguments. We have a lot of hard work ahead of us if we are to successfully develop such procedures for assessing rangeland "health" by the beginning of the 21st century.

The range profession took leadership in developing CRMP. Unfortunately, monitoring was not always given the attention it should have received when such planning was first put in place. Where it wasn't, we will need to reconvene and update the plan to include monitoring and encourage the process toward adaptive resource management (Kessler et al. 1992). The mix of issues, and thus the needed approaches for monitoring are probably going to vary greatly in each case. If science and management are to begin to use each case as a mutual learning experience, as the adaptive resource management model calls for (Kessler et al. 1992), then administrators need to begin changing the ways in which their institutions operate. The present financing and reward structure doesn't always encourage timely interactions of the most appropriate personnel (e.g., scientists and mangers). Continued inattention to the pivotal role of monitoring in land management will jeopardize both the health of the land and the rangeland profession.

Literature Cited

Ahl, V. and T.F.H. Allen. 1996. Hierarchy Theory: A Vision, Vocabulary, and Epistemology. Columbia Univ. Press, New York.

Allen, T.F.H. and T.W. Hoekstra. 1992. Toward a Unified Ecology. Columbia Univ. Press, New York, 384 p.

Blahna, D.J. 1995. Integrating social and biophysical factors in ecosystem management. Quest for the philosopher-king. pp. 507–512. *In*: J.L. Thompson et al. (compilers) Proc. Fourth International Outdoor Recreation and Tourism Trends Symposium. Univ. Minnesota, St. Paul, Minn.

Bravo, C.A. 1996. (ed.). North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems. USDA, Forest Service, Rocky Mountain Forest and Range Expt. Sta., Gen. Tech. Rep. RM-GTR-284, Ft. Collins, Colo.

Burnside, D. and A. Rasmussen. 1997. Ecosystem management: Can it succeed? Rangelands 19(2):20–24.

Denevan, W. 1992. The pristine myth: the landscapes of the Americas in 1492. Annals of the Association of American Geographers 82:369-385.

Formann, R.T.T. 1995. Landscape Mosaics: The Ecology of Landscapes and Regions. Cambridge Univ. Press.

Gillespie, A.J.R. 1996. Research and development needs for forest ecosystem monitoring. pp. 241–246 in C.A. Bravo (ed.). North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems. USDA, Forest Service, Rocky Mountain Forest and Range Expt. Sta., Gen. Tech. Rep. RM-GTR-284, Ft. Collins, Colo.

Harwell, M.A., J.F. Long, A.M. Bartuska, J.H. Gentile, C.C. Harwell, V. Meyers, and J.C. Ogden. 1996. Ecosystem management to achieve ecological sustainability. The test case of South Florida. Environ. Manage. 20:497–521.

Herrick, J.E., W.W. Whitford, A.G. de Soyza, and J. Van Zee. 1996. Soil and vegetation indicators for assessment of rangeland ecological condition. pp. 157–166 *In:* C. Aguirre Bravo (ed.). North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems. USDA, Forest Service, Rocky Mountain Forest and Range Expt. Sta., Gen. Tech. Rep. RM-GTR-284, Ft. Collins, Colo.

Kennedy, J.J., B.L. Fox, and T.D. Olsen. 1995. Changing social values and images of public rangeland management. Rangelands 17(4):127–132.

Kessler, W.B., H. Salwasser, C.W. Cartwright, Jr., and J.A. Caplan. 1992. New perspectives for sustainable resources management. Ecol. Applic. 2:221–225.

Kohler, T.A. 1992. Prehistoric human impact on the environment in the upland North American Southwest. Population and Environment 13:255–268.

Laycock, W.A. 1995. New perspectives on ecological condition of rangelands: can state-and-transition or other models better define condition and diversity? pp. 140–164 *In:* L. Montes and G.E. Oliva (eds.). Proc. Internat. Workshop on Plant Genetic Resources, Desertification and Sustainability. INTA-EEA, Rio Gallegos, Santa Cruz, Argentina.

Laycock, W.A. et al. 1995. Grazing on Public Lands. Council for Agricultural Science and Technology, Task Force Report No. 129, Ames, Iowa.

Lockwood, J.A. and D.R. Lockwood. 1993. Catastrophe theory: A unified paradigm for rangeland ecosystem dynamics. J. of Range Management 46:282–288.

Munguia, L.M., N.E. West, and G.A. Rasmussen. 1997. Quantification of landscape structure within the Land Condition-Trend Analysis Monitoring Program at Camp Williams, Ut. Abstracts, 50th Annual Meeting, Society for Range Management, p. 44.

National Research Council. 1994. Rangeland Health: New methods to classify, inventory and monitor rangelands. National Academy Press, Wash. D.C. 180 p.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Wash. D.C.

Pickup, G. 1996. Estimating the effects of land degradation and rainfall variation on productivity in rangelands: An approach using remote sensing and models of grazing and herbage dynamics. J. Appl. Ecol. 33:819–832.

Pickup, G. and D.M Stafford Smith. 1993. Problems, prospects, and procedures for assessing the sustainability of pastoral land management in arid Australia. J. Biogeography 20:471–487.

Renwick, W.H. 1992. Equilibrium, disequilibrium, and nonequilibrium landforms in the landscape. Geomorphology 5:265-276.

Rietkerk, M., P. Ketner, L. Stroosnyder, and H.H.T. Prins. 1996. Sahelian rangeland development; a catastrophe? J. Range Manage. 49:512–519.

Shear, H. 1996. Ecological assessment in Canada. pp. 20–30 in C.A. Aguirre (ed.). North American Workshop on Monitoring for Ecological Assessment of Terrestrial and Aquatic Ecosystems. USDA, Forest Service, Rocky Mountain Forest and Range Expt. Sta., Gen. Tech. Rep. RM-GTR-284, Ft. Collins, Colo.

Society for Range Management. 1995. New concepts for range condition assessment. Report of the Task Group on Unity in Concepts and Terminology. J. Range Manage. 48:271-282.

Tausch, R.J., P.E. Wigand, and J.W. Burkhardt. 1993. Viewpoint: plant community thresholds, multiple steady states and multiple successional pathways: legacy of the Quaternary. J. of Range Manage. 46:439–447.

Tausch, R.J. 1996. Past changes, present and future impacts, and the assessment of community or ecosystem condition. pp. 97–101 *In:* J.E. Barrow et al. (compilers). Proceedings: Shrubland Ecosystem Dynamics in a Changing Environment. USDA, Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-GTR-338, Ogden, Ut.

Turner, M.G. and R.H. Gardner (eds.). 1990. Quantitative Methods in Landscape Ecology: The Analysis and Interpretation of Landscape Heterogeneity. Springer-Verlag, New York, 536 p.

West, N.E. 1991. Benchmarks for rangeland management and environmental quality. pp. 30–43. *In*: L.F. James et al. (eds.). Proc. National Conference on Noxious Range Weeds, Westview Press, Boulder, Colo.

West, N.E., K. McDaniel, E.L. Smith, P.T. Tueller, and S. Leonard. 1994. Monitoring and interpreting ecological integrity on arid and semi-arid lands of the western U.S., Report No. 37, Rangeland Improvement Task Force, New Mexico State Univ., Las Cruces, N.M. 15 p.

Wu, J., P.T. Tueller, and W.G. Gao. 1997. Multiple-scale characteristics of the landscape pattern of the Great Basin, USA. Abstracts of the 12th annual symposium, U.S. Regional Assoc. Internat. Assoc. for Landscape Ecology, Durham, NC, p. 123.

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