# The Colorado Front Range Ecosystem Management Research Project: Accomplishments to Date

**Brian Kent**
**Wayne D. Shepperd**
**Deborah J. Shields**

**Abstract**—This article briefly describes the goals and objectives for the Colorado Front Range Ecosystem Management Project (FREM). Research under this project has addressed both biophysical and human dimensions problems relating to ecosystem management in the Colorado Front Range. Results of completed work are described, and the status of the ongoing demonstration project at Manitou Experimental Forest is given.

The Colorado Front Range Ecosystem Management (FREM) project was initially funded in FY 1994 to address issues related to ecosystem management (EM) in an area (fig. 1) of rapidly growing human populations, complex and sensitive ecosystems, and diverse social and economic systems. The original proposal contained six objectives, but because of limited funding, only three were addressed:

1. Integrate social, organizational, and ecological values and issues, and improve conflict management strategies and tradeoff analysis techniques to support land management planning.
2. Improve our understanding of key biological and physical aspects of ecological systems and the interactions of humans on ecosystem structure, diversity, and productivity.
3. Initiate operation of a learning center to facilitate information sharing and to support the building of active partnerships.

The following three areas were selected for primary focus: improve understanding of a key Front Range ecosystem, develop collaboration strategies, and instigate stakeholder education. FREM team members chose a two pronged approach for ensuing work: (1) identify and collect the types of information needed about one important ecological system (ponderosa pine, *Pinus ponderosa*) and how it responds to human impacts, and (2) develop approaches to involving stakeholder groups and other interested parties in resource management decisions. Results from this work are being used to design and implement an education and demonstration study on the Manitou Experimental Forest, located in the ponderosa pine type.

In: Smith, Helen Y., ed. 2000. The Bitterroot Ecosystem Management Research Project: What we have learned—symposium proceedings; 1999 May 18-20; Missoula, MT. Proceedings RMRS-P-17. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Brian Kent is Project Leader, Wayne D. Shepperd is Research Forester, and Deborah J. Shields is Principal Minerals Economist, Rocky Mountain Research Station, Fort Collins, CO 805267, e-mail: bkent@fs.fed.us AND wshepperd@fs.fed.us AND dshields@fs.fed.us

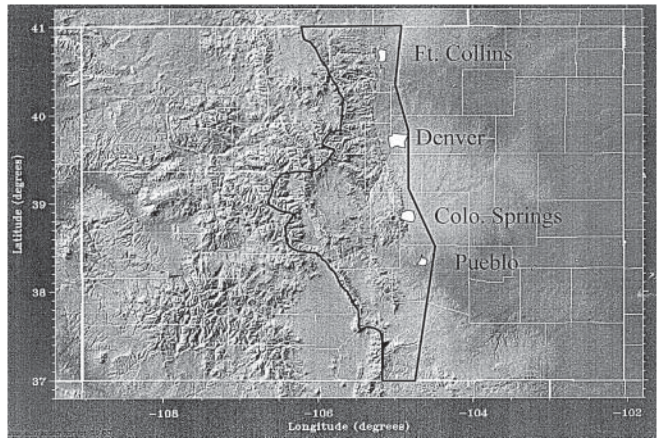


**Figure 1**—The area encompassed by the Front Range Ecosystem Management Research Project includes all mountainous lands in the South Platte and Arkansas River drainages.

## Biophysical Research

Like much of the Interior West, the Colorado Front Range has been profoundly altered by fire suppression management strategies over the past 100 years or so. Photographic records suggest this to be the case, but prior to studies undertaken in ponderosa pine stands as part of FREM, actual fire histories for sites along the Front Range had never been developed. Generally, results show that the normal pattern prior to European settlement was one of relatively frequent, usually low intensity fires, as the chronology for the Manitou Experimental Forest (MEF) (fig. 2) shows. This result, again, is consistent with findings elsewhere in the Interior West. Fire history records have also been developed for the entire Denver Water Board Cheeseman Reservoir property (Brown and others 1999), extending back into the 1200's. These data complement overstory structure and understory biodiversity data collected in other studies and are being used to help interpret how these variables and natural and human disturbances in the ponderosa pine type are interrelated. The results of these studies will lead to better assessments of the condition of human-impacted ecosystems along the Front Range and, hence, to possible restoration recommendations for these systems.

Other FREM studies have looked at patterns of cohort distribution and gap dynamics in logged and unlogged old-growth ponderosa stands in the southern Front Range. In

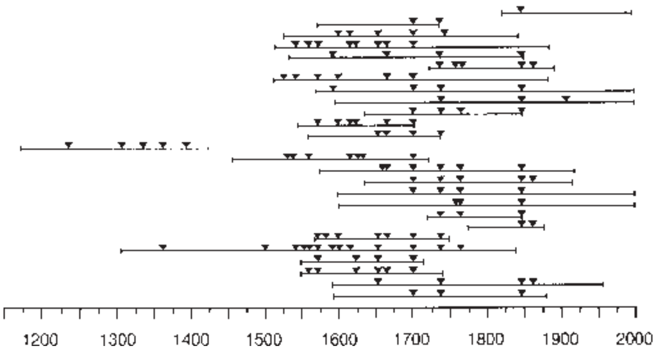


**Figure 2**—Fire chronology for Manitou Experimental Forest, Colorado. Lines are time spans of individual tree and wood samples. Inverted triangles record dates of fire scars in each ring series.

general, logged stands tended to be more homogeneous than old-growth stands, with higher tree density, fewer openings, and regeneration tending to occur more uniformly over time. The structurally more complex old-growth stands contained many trees of 400+ years of age. These results indicate that restoration of logged stands is possible by removing excess stocking, while existing old-growth stands can be maintained with prescribed fire and diverse management.

Like much of the Interior West, The Colorado Front Range contains extensive areas of urban-wildland interface, with much of this area being in the ponderosa pine type. These forests, like most of the rest of the Front Range, have developed in the absence of fire, and FREM studies have looked at how these stands have evolved by (1) accurately dating ponderosa pine seedlings and saplings of various sizes to their year of origin, (2) constructing a height growth model for ponderosa pine seedlings from seedling establishment to breast height, and (3) investigating temporal and spatial patterns of tree recruitment within and between groups of overstory trees. The results of this research are crucial to planning management activities to reduce fire and disease risks in these interface forests. These results are also being used in developing prescriptions for the cooperative demonstration project underway at MEF.

Improved knowledge about the seedling establishment of ponderosa pine is essential to developing effective prescriptions for restoring stands to more fire resistant status. Results from earlier studies suggest that seedlings are spatially distributed as a direct consequence of seed availability, or proximity to overstory trees, and of microenvironmental conditions during the summer growing season. FREM studies are testing these hypotheses, and the results are being applied to the demonstration project.

## The Hierarchical Model of Collaborative Ecosystem Management

The Hierarchical Model of Collaborative Resource Management (HM) is one of the primary products of FREM. It is a model that explicitly incorporates the interests and desires of the public in the EM decisionmaking process. In the HM, decisions about how resources are managed follow as a consequence of societal values in general and those associated with nature in particular. Societal values, and related objectives for natural resources, translate into alternative management actions. It is possible to estimate the consequences of implementing an alternative by forecasting the status of measures or indicators of current and projected environmental, social, and economic system condition. Moreover, since the measures are linked directly to the objectives, information is also available on the potential consequences of fulfilling specific objectives. Thus, the HM takes the form of a complex systems problem, i.e., one that is hierarchical and ordered and embodies control and information flows.

## The Design of the Hierarchical Model

The HM design is based on (1) the pragmatic view that resource management is, by definition, a human action, motivated by human desires, and (2) the principle that resource management goals make sense only within the context of the human social system (Cooper 1969). The philosophical perspective is anthropogenic. All values, including those dealing with the environment, are human derived (Santayana 1896); however, humans are capable of finding value in nature (Brown and Peterson 1994; Rolston 1994). Ultimately, human values drive the environmental and resource goal setting processes that inform EM decisionmaking. This perspective allows for a comprehensive conception of human well-being, one that embraces what might otherwise be thought of as irrational, e.g., non-self motivated, behaviors and choices. Thus, the survival of species and the needs of future generations, in addition to a desire for jobs, income and commodities, become legitimate concerns, and in the process influence decisions and actions.

Consistent with the above view, basic human values (sometimes called held values) are placed over the cultural, institutional, and economic framework within which societal goals and objectives are communicated, over assigned value measures, and over the actions that can impact the biophysical system (fig. 3). Typical of hierarchies, control flows from the top to the bottom; information flows in the opposite direction. Basic held values are assumed to determine the social objectives that drive land management decisions. Implementation of these decisions leads to biophysical and social impacts and, in a fully functioning application of this model, information about those impacts would be passed back up through the levels of the hierarchy.

A held value can be defined as "an enduring conception of the preferable which influences choice and action" (Brown 1984). They comprise highest-order qualities that motivate all ensuing lower-order preferences and, consequently, decisions and actions. Examples include generosity, responsibility, fairness, freedom, etc. (Brown 1984). Each person has his/her own set of held values; the sets are not necessarily identical, although they may overlap. Individuals tend to have relatively few held values (perhaps 10 or 15 at most) and also tend to order them, i.e., certain values are given precedence and emphasis over others (Boulding and Lundstedt 1988). Held values are extremely resistant to change without immense outside perturbation. In less extreme situations, existing values may be given increased or

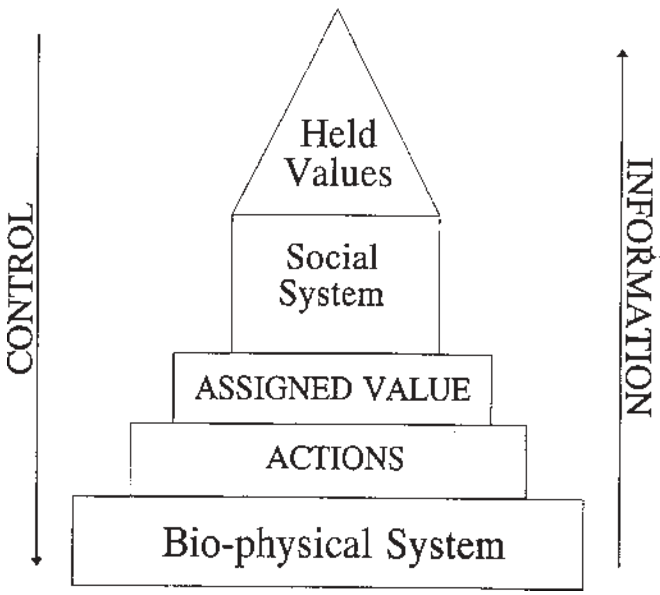


**Figure 3**—Schematic of a hierarchical model for collaborative resource management.

decreased emphasis, to be shifted to a higher or lower place in the overall value hierarchy (Rescher 1969). It is possible to identify held values through psychometric tests or carefully worded survey instruments (Hetherington and others 1994).

The social system and its related institutions evolve out of held values and are ranked below them in the HM. Social values are derived from held values; together they provide the ethical foundation for social institutions and the rationale for governmental, corporate, and individual decisions. Societies hold social values with regard to equity before the law, economic justice, and the environment, plus other values less relevant in a resource context. Environmental values are the source of the strategic objectives people hold for natural resources and so have been of particular interest to those concerned with resource management decisionmaking (Bengston 1994).

The public policy decision process is one in which held values, beliefs, and knowledge inform a cognitive valuation process that results in the assigning of relative value to alternative policies or states of the world (Stoll and Gregory 1988). In the HM, the primary connections from society to the biophysical system are through this intervening level of assigned values. Decisionmakers choose from among alternative actions, based on a comparison of their relative values. One problem has been that decision makers have historically relied too heavily on monetized values as a way to compare resource management alternatives. EM decision processes can benefit from the addition of information on how implementation of various alternatives would affect different stakeholder's perceptions of their own well-being. Assuming rationality, individuals make choices so as to maximize their well-being. Preferences, which are derived from objectives, drive the alternative comparison process. There is general agreement that people's objectives and preferences for specific resource management schemes are a function of their value sets (Steel and others 1994).

Implementation of each management action will result in a set of impacts on the social, economic and environmental systems in question. The HM accounts for the flow of information regarding the effects of alternative choices to stakeholders, be they land managers or members of the general public. Impacts can be predicted for each proposed action and changes in system condition estimated. Comparisons across alternatives can be made, and these are useful because they help both agencies and members of the public understand the short- and long-term consequences of implementing various management alternatives. In some instances, understanding the broader implications of a decision may lead to a change in the value assigned to a specific activity or situation. This in turn could lead to a reprioritization of objectives, which might imply that a different choice would be made. The ability to facilitate learning and adaptation through the upward flow of relevant information is one of the most important features of the HM, and makes it a useful construct in an adaptive management setting.

## Quantifying the Hierarchical Model

The HM is a theoretical construct that hypothesizes a relationship among values, social institutions, assigned values, personal or agency actions, and their associated environmental impacts. Although the construct is realistic, it cannot be applied directly to resource management problems in the absence of practical quantitative tools. To bridge the gap between theory and the reality of management decisionmaking, two alternative implementation approaches have been developed. The first of these, the measurement model, investigates the pathway from values to actions and behaviors. The second, the preference model, uses a decision theoretic approach to link objectives to assigned values (preferences) and thus to choices among alternative actions. The relationship between the HM and the two models is shown in figure 4.

**The Measurement Model**—The measurement model provides a means for linking values to behaviors and has been derived from the traditional values-attitudes-behaviors framework widely accepted in social psychology and consumer behavior literature (Homer and Kahle 1988). Those models omit objectives; however, most behavior is, in reality, goal directed (Huffman and Houston 1993). Thus, the framework has been modified to incorporate objectives, which have been demonstrated to mediate the relationship between values and attitudes in a FREM funded study (Martin and others 1998). This leads to a values-objectives-attitudes-behaviors (VOAB) construct.

The measurement model mirrors the HM. Thus, the uppermost level is values. The focus is on environmental values, and these are assumed to provide the motivation for objectives, attitude formation and behavior. Objectives reside at the second level of the measurement model, and they reflect, and are tempered by, the existing social, institutional, and cultural milieu within which an individual lives, in addition to being derived from the individual's value set. This model does not specifically incorporate assigned values, but rather their precursor, attitudes. Actions are represented by behaviors, which can take the form of personal

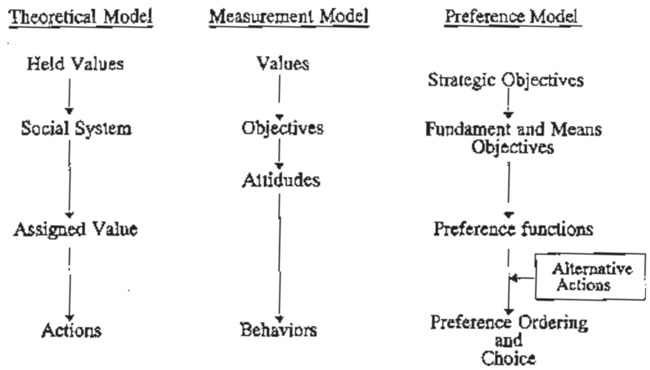


**Figure 4**—Flowchart comparing components of the measurement, and preference model alternative implementation approaches to those of the theoretical hierarchical model for collaborative resource management.

behaviors or, at the agency level, management decisions. The actions represent tangible evidence of attitudes.

As part of FREM, a survey instrument design has been developed to elicit information from individuals about their values, objectives attitudes, and behaviors with respect to natural resources (Martin and others 1998). Survey results can be explored using descriptive statistics, cluster analysis, and structural equation models (Martin and others 1997).

**The Preference Model**—The preference model provides a means for linking objectives for natural resource management to choices among potential implementation strategies. The approach is based on decision theoretic methods that are widely used to evaluate alternatives involving multiple objectives (Keeney and Raiffa 1976; von Winterfeldt and Edwards 1986). As shown in figure 4, this approach follows a path from strategic objectives to fundamental and means objectives, to preference functions, ending with preference ordering and choice.

The path parallels the measurement model, but differs from it in a number of significant ways. First, values are not explicitly addressed, but rather are assumed to be the basis for strategic objectives. Second, objectives are quantified in preference functions, which become, then, situation specific applications of values. They quantify stakeholder objectives with regard to each alternative action in terms of a relevant set of indices or measures of social, economic and ecosystem condition. Third, given that alternative actions will generate difference indicator or measure levels, it is possible to calculate a score for each action by solving the preference functions for the relevant measures data.

Because relative scores and hence, rankings, can be assigned to each alternative for each stakeholder, this information can be used to help develop consensus over which one to select. Unfortunately, no failure proof method of choosing among alternatives exists that is acceptable in democratic society. However, assuming that all relevant points of view and conflicting interests are adequately represented, a choice that provides a socially acceptable tradeoff among these interests could be considered satisfactory. To accomplish this, processes of individual and group choice can be investigated by using the scores as inputs to voting, game theoretic and equity models. Two FREM funded studies that have applied these techniques to ecosystem management problems are Shields and others (1999), using game theory, and Martin and others (1996), using voting models.

## Value-Based Decisionmaking Versus Alternative-Based Decisionmaking

Values have long been recognized as a means to better understand society and culture, based on the premise that they play an important role in human behavior. It is clear from the above description of the HM that it is a values-based construct, and as such, it is an example of what Keeney (1992) calls "value-focused thinking." However, conventional decisionmaking approaches usually revolve around the generation and evaluation of alternatives, which Keeney refers to as "alternative-focused thinking." If we view values as characterizations of what we care about in a given decision situation, they are of obvious fundamental importance, clearly more so than alternatives. In a value-focused approach, alternatives are viewed as mechanisms to achieve values. This does not mean that alternatives are not important; in fact, one of the strengths of a value-based approach is that it can facilitate the development of a richer set of alternatives by first identifying what is important (values) and then using this information to craft alternatives.

To date, most contentious resource decision situations in the Forest Service involving external stakeholders have been conducted in an environment of alternative-focused thinking. However, within FREM, three studies are underway that consider stakeholder objectives (which arise directly from values) as they apply to Forest Service decision situations on the Colorado Front Range. They focus on developing tools for eliciting information about the resource related goals and objectives of public land stakeholders and linking those goals to measurable attributes of community and ecosystem status and trend. The goals and objectives information is being considered within the context of its relationship to stakeholders' held values, their attitudes about activities taking place on public lands, and their personal behavior on these lands. The National Forests involved are the San Juan (Martin and others, in press), the Pike/San Isabel, and the Arapaho/Roosevelt.

## Values, Objectives, and Objectives Hierarchies

As noted above, values are not explicitly expressed in the measurement model and the preference model of the Hierarchical Model, but rather are assumed to be the basis for strategic objectives. This is consistent with the idea that prevailing community objectives generally make up basic conditions for achieving legitimate land use policy (Caldwell 1990). This is a primary reason why stakeholder involvement is essential to effective EM, and why both the measurement and preference models are designed to incorporate stakeholder group and individual objectives (fig. 4). An objective is a statement of what one desires to achieve and is characterized by having a context (in this instance, natural resources), an object (an action alternative) and a direction of preference (Keeney 1992). By comparing objectives (i.e., across individuals, firms, agencies), it is possible to identify those that are held in common and those that are unique to special interests. Often significant overlap among objectives sets exists, which presents opportunities for consensus building among stakeholders.

Information on objectives can be organized into an objectives hierarchy, which is a tree-like representation of an individual's or group's objectives (Caldwell 1990; Keeney and Raiffa 1976). Space does not permit a detailed description of an objectives hierarchy, but the levels are the same as shown in figure 4 for the preference model because objectives hierarchies are integral to that model. The points here are that objectives are the key component of the preference model and are an important component of the measurement model because they provide the link back to values that is necessary to make these models examples of value-focused thinking. Objectives hierarchies have been built for many public policy applications (Keeney 1988; Keeney and others 1990), and are an important component of the FREM human dimension studies mentioned above.

## The Front Range Demonstration Project

This project is a demonstration of management techniques applicable in Front Range urban-interface ponderosa pine forests, designed to bring together results from both the biophysical and human dimensions work described above. The primary objective of this project is to conduct an on-the-ground test of management techniques that can be used to improve the health of Front Range ponderosa pine forests by reducing the risks of fire and other catastrophic disturbances, such as bark beetle (*Dendroctonus* spp.) infestation, in a manner acceptable to human desires and perceptions of these ecosystems. It has been established on the Manitou Experimental Forest in cooperation with the Pike San Isabel National Forest, Region 2, the Bureau of Land Management and the Colorado State Forest Service. Other objectives include:

1. Establish a facility that can be used to interpret and contrast forest conditions and assess the benefits/tradeoffs of ecosystem management at a single, easily accessible site,
2. Provide a database and opportunity for long-term monitoring of forest health and management activities in a Front Range forest,
3. Utilize the objectives hierarchy process, and the associated survey instrument, to ascertain public perceptions about specific treatments, and
4. Perform experiments utilizing a structural equations model to determine the impact on public values-objectives-attitudes-behaviors of information presented in different formats.

### Study Description

A 25 ha forested site near the MEF headquarters was chosen for the demonstration (fig. 5). Readily accessible to the public, the site consists of a series of small drainages that are populated with a structurally diverse ponderosa pine stand that has developed after logging in the late 1800's. Small portions of the site were harvested in the late 1940's as part of the early watershed experiments at MEF, but the remainder of the site has remained undisturbed by man during the 20th century.


**Figure 5**—Aerial view of layout of the 25 ha Manitou Experimental Forest Demonstration Project. Treated areas are being harvested under an irregular uneven-aged management scheme. Post-treatment response will be compared to that of the adjoining control area.

Fire-scarred trees, stumps, and burned logs indicate a history of past fires on the site. A stand in the eastern portion of the site is heavily impacted by mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) and has suffered heavy mortality. Few dead trees or logs exist throughout the rest of the site, indicating that no other insect or disease outbreaks have occurred. A stand in the western portion of the site is more open and contains some seedlings and saplings, but little regeneration exists elsewhere.

**Site Layout/Pretreatment Data Collection**—The site will be used to compare a no treatment control against a prescribed fire treatment, an uneven-aged silvicultural treatment, and a combination of silvicultural treatment followed by fire—all designed to maintain the health and vigor of this site. Layout and pre-treatment data were completed in 1997, and the treatment sale was marked and sold in 1998. Plans are to harvest the sale in 1999 and begin subsequent monitoring following treatment.

Pre-treatment data collection include the surveying and installation of a grid of permanently marked reference points at 100 m intervals throughout the site to be used by researchers working in the area. A series of inventory plots describing the species composition, size, age, and density of the forest throughout the area were established on these grid points in 1997. Extensive tree ring data was collected to describe present and past forest structure and development. Fire scar data was collected from living trees and dead material in the area, and a complete fire history was developed for the demonstration site (fig. 2).

Preliminary focus group interviews for stakeholder groups interested in the MEF are being conducted this summer and fall. Relevant statistical analyses will be completed this winter, and the results will be used to design the VOAB survey and to develop the objectives hierarchy needed to develop the measurement and preference models needed to apply and quantify the HM to this demonstration study.

## References


Bengston, D.S. 1994. Changing forest values and ecosystem management. Society and Natural Resources. 7: 515-533.

Boulding, K.E.; Lundstedt, S.B. 1988. Value concepts and justifications. In: Peterson, G.L.; Driver, B.L.; Gregory, R., eds. Amenity resource valuation. State College, PA: Venture Publishing Company: 13-22.

Brown, P.M.; Kaufmann, M.R.; Shepperd, W.D. 1999. Long-term landscape patterns of past fire events in a montane ponderosa pine forest of central Colorado. Landscape Ecology. 14: 513-532.

Brown, T.C.; Peterson, G.L. 1994. A political-economic perspective on sustained ecosystem management. In: Debano, L.F., ed. Sustainable ecological systems: implementing an ecological approach to land management. Gen. Tech. Rep. RM-247. Fort Collins CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 228-235.

Brown, T.C. 1984. The concept of value in resource allocation. Land Economics. 60: 231-246.

Caldwell, L.K. 1990. Landscape law and public policy: conditions for an ecological perspective. Landscape Ecology. 5: 3-8.

Cooper, C.F. 1969. Ecosystem models in watershed management. In: Van Dyne, G.M., ed. The ecosystem concept in natural resource management. New York, NY: Academic Press: 309-324.

Hetherington, J.; Daniel, T.C.; Brown, T.C. 1994. Anything goes means everything stays: the perils of uncritical pluralism in the study of ecosystem values. Society and Natural Resources. 7: 535-546.

Homer, P.M.; Kahle, L.R. 1988. A structural equation test of the value-attitude-behavior Hierarchy. Journal of Personality and Social Psychology. 54: 638-646.

Huffman, C.; Houston, M. 1993. Goal-oriented experiences in the development of knowledge. Journal of Consumer Research. 20: 190-207.

Keeney, R.L. 1992. Value-focused thinking. Cambridge, MA: Harvard Univ. Press. 415 p.

Keeney, R.L.; von Winterfeldt, D.; Eppel, T. 1990. Eliciting public values for complex policy decisions. Management Science. 36: 1011-1030.

Keeney, R.L. 1988. Structuring objectives for problems of public interest. Operations Research. 36: 396-405.

Keeney, R.L.; Raiffa, H. 1976. Decisions with multiple objectives. New York, NY: Wiley and Sons. 569 p.

Martin, I.M.; Bender, H.W.; Martin, W.E.; Shields, D.J. 1997. The development of a values scale: consumption of public lands. Golden, CO: Colorado School of Mines, Division of Economics and Business. Working Paper. 29 p.

Martin, W.; Shields, D.J.; Tolwinski, B.; Kent, B. 1996. An application of social choice theory to USDA Forest Service decisionmaking. Journal of Policy Modeling. 18: 603-621.

Martin, I.M.; Bender, H.W.; Martin, W.E.; Shields, D.J. 1998. The impact of goals on the “values-attitudes-behaviors” framework. Decision Sciences Institute Proceedings. Vol. 1: 126-129.

Martin, W.E.; Shields, D.J.; Wise, H.A. [In press]. Stakeholder objectives for public lands: ranking of forest management alternatives. Journal of Environmental Management.

Rescher, N. 1969. Introduction to value theory. Englewood Cliffs, NJ: Prentice Hall. 191 p.

Rolston, H., III. 1994. Conserving natural value. New York, NY: Columbia University Press. 259 p.

Santayana, G. 1896. The sense of beauty. New York, NY: Scribner’s and Sons. 275 p.

Shields, D.J.; Tolwinski, B.; Kent, B. 1999. Models for conflict resolution in ecosystem management. Socio-Economic Planning Sciences. 33: 61-84.

Steel, B.S.; List, P.; Schindler, B. 1994. Conflicting values about federal forests: a comparison of national and Oregon publics. Society and Natural Resources. 7: 137-153.

Stoll, J. R.; Gregory, R. 1988. Overview. In: Peterson, G.L.; Driver, B.L.; Gregory, R., eds. Amenity resource valuation. State College, PA: Venture Publishing Co: 3-6.

von Winterfeldt, D.; Edwards, W. 1986. Decision analysis and behaviorial research. Cambridge, England: Cambridge University Press. 604 p.