TECHNIQUES FOR ASSESSING RELATIVE VALUES FOR MULTIPLE OBJECTIVE MANAGEMENT ON PRIVATE FORESTS

Donald F. Dennis[1], Thomas H. Stevens[2], David B. Kittredge[2], and Mark G. Rickenbach[3]

[1]Northeastern Research Station, P.O. Box 968, Burlington, VT 05402, USA [2]University of Massachusetts, Amherst, MA 01003, USA [3]Oregon State Univ., Corvallis, OR 97331, USA

Abstract: Decision models for assessing multiple objective management of private lands will require estimates of the relative values of various nonmarket outputs or objectives that have become increasingly important. In this study, conjoint techniques are used to assess the relative values and acceptable trade-offs (marginal rates of substitution) among various objectives related to ecosystem management on private lands. Specific objectives that were considered include: maintaining apple trees to benefit wildlife, protecting rare ferns to enhance aesthetics and biodiversity, improving recreational trails, harvesting timber, and minimizing management costs. A mail survey sent to 1,250 forest-land owners in Franklin County, Massachusetts, provides the basis for the analyses.

1. INTRODUCTION

Privately owned forests comprise nearly three-quarters of the forest land in the United States and are expected to play an important role in meeting future needs for timber, recreation, wildlife habitats, and many other forest-related benefits (USDA Forest Service 1988, 1995). There is concern that these lands may not meet their potential in achieving objectives related to overall ecosystem health and sustainability and in providing benefits that transcend legal and political boundaries, such as biodiversity, water quality, and some wildlife habitats.

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Surveys of private forest-land owners conducted by the USDA Forest Service show that many owners hold their woodland primarily for noncommercial reasons (Birch 1996). Commonly cited reasons for owning forest land include: it is part of the farm or residence, aesthetic enjoyment, wildlife viewing, and other forms of forest-related recreation. Landowner attitudes and motivations suggest that they are favorably disposed to providing nontimber benefits and protecting the health of the forest ecosystem. However, the large number of owners, diversity of objectives, increasing fragmentation, and nonmarket nature of many benefits pose problems in estimating what can be expected from these lands and in designing policy to influence behavior (Dennis et al. 2000). A better understanding is needed regarding the relative importance that landowners place on various objectives and their willingness to incur costs associated with achieving these benefits. This information is relevant for policy formation and as an input to larger analytical models.

In this study, we use conjoint techniques to solicit landowner preferences for management involving varying levels of timber harvesting, recreational trail improvement, apple tree maintenance to benefit wildlife, protection of a rare species of fern, and cost. We explicitly explore the nonlinear nature of the relationships among the variables. An ordered probit model is used to estimate preferences. The results are used to compute marginal rates of substitution (MRS), or the tradeoffs that landowners are willing to incur to achieve changes in the levels of other objectives.

2. METHODS

The Dillman (1978) Total Design Method was used to design a survey that was mailed to 1,250 forest-land owners who own at least 10 acres of forest land in Franklin County, Massachusetts. In addition to questions on attitudes toward land management and demographics, each respondent completed a conjoint survey. The useable response rate was 61.3 percent.

Conjoint analysis is a technique for measuring psychological judgments and is frequently used in marketing research to measure consumer preferences (Green et al. 1988). Respondents make choices between alternative products or scenarios that display varying levels of selected attributes. The utility of each attribute can be inferred from the respondent's overall evaluations. These partial utilities indicate the relative importance of each attribute's contribution to overall preference or utility. They can be combined to estimate relative preferences for any combination of attribute levels. Conjoint techniques are well suited for soliciting and analyzing preferences in environmental decisions that frequently entail tradeoffs

between costs and benefits that are not represented efficiently in market transactions.

Forest-land owners in Franklin County were asked to rate four alternative management scenarios for a hypothetical forested property shown in a figure within the survey. The figure included an area of apple trees, a section of rare ferns, and a recreational trail that passed through the sample property. Each alternative was rated on a scale of 1 to 10, with 10 representing alternatives that they would definitely undertake and 1 those that they would definitely not undertake. Ratings of 2 to 9 were used to represent how likely they would be to undertake alternatives that they were not sure of. Each alternative varied by one or more of the following five attributes: the proportion of the apple trees to maintain on the hypothetical property, the proportion of rare ferns to protect, the extent of the trail network to improve, the extent of timber harvesting, and cost. An orthogonal array was used to create a succinct subset of attribute combinations that permits estimation over the entire range of attribute values ($3^5 = 243$ possible combinations). The resulting 18 alternatives were assigned to questionnaires in equal frequency. Each alternative consisted of a unique bundle that included all 5 individual attributes. Each attribute had one of the three possible levels appearing in parentheses. Alternatives appeared as follows:

- Maintain (none/half/all) of the apple trees shown on the figure that benefit wildlife.
- Protect (none/half/all) of the acres containing a rare species of fern shown on the figure by not harvesting timber in this area or otherwise disturbing the ferns.
- Improve (none/half/all) of the trail network shown on the figure. Improvements, if any, would include the cost of building a footbridge over the stream and clearing scenic vistas.
- Harvest timber from (none/half/all) of the lands shown on the figure. Any harvest would be selective, designed to remove poorly formed and leave some high-quality trees; 25 to 30 percent of all trees would be removed.
- This option would have a net cost to you of $ (50/250/500).

A secondary objective of the survey was to examine landowner attitudes about collaborative management. Landowners were partitioned into two groups. Each group received an identical questionnaire except one group was asked to imagine that they owned a portion of the hypothetical property described above and to rate their willingness to cooperate with the adjoining landowners to achieve the management objectives depicted by the alternatives. Because the objective here is to illustrate the conjoint technique

and a procedure for estimating nonlinear effects on preferences and not collaboration, responses for both groups are pooled for estimation.

A random utility model was used to explain forest-land owner preferences. When presented with a set of alternatives, individuals are assumed to make choices that maximize their utility or satisfaction. The utility that the i^{th} individual derives from the j^{th} alternative (U_{ij}) can be represented as:

$$U_{ij} = X'_{ij}\beta + e_{ij} \quad (1)$$

where X_{ij} is a vector of variables, which may include transformations of variables, that represent values for each of the five attributes of the jth alternative to the ith individual; β is a vector of unknown parameters; and e_{ij} is a random disturbance, which may reflect unobserved attributes of the alternatives, random choice behavior, or measurement error. In the empirical study under consideration, a respondent's utility level (U_{ij}) for each alternative is not observed, but a rating (r_j) is observed that is assumed to proxy for his or her underlying utility.

Following McKenzie (1990, 1993) and others, the analytical capabilities of the conjoint rating model can be illustrated by assuming that rating (r_j) can be modeled as a linear combination of the variables representing the attribute levels. Typically, only linear effects are considered but we modify the analyses to include quadratic effects in order to test for nonlinear relationships:

$$r_j = a + b_1x_{1j} + b_2x_{2j} + \ldots + b_nx_{nj} + q_1x_{1j}^2 + q_2x_{2j}^2 + \ldots + q_nx_{nj}^2 \quad (2)$$

The estimated partial utilities are the combined linear (b_n's) and quadratic (q_n's) effects of a discreet change in the level of the associated attribute on overall preference. Relative overall preference for any alternative (combination of attribute levels) can be determined by summing across Equation 2.

The MRS is the rate at which an individual is willing to trade one good for another while remaining equally well off (Nicholson 1978). The MRS or acceptable tradeoff of one attribute for another is determined by the ratio of the marginal responses. Setting the total differential of (2) to the point of indifference and solving yields the marginal rates of substitution or the acceptable tradeoffs for the respective attributes:

$$dr_j = b_1dx_{1j} + b_2dx_{2j} + \ldots + b_ndx_{nj} + 2q_1x_1dx_{1j} + 2q_2x_2dx_{2j} + \ldots + 2q_nx_ndx_{nj} = 0 \quad (3)$$

$$dx_{1j} / dx_{2j} = -(b_2 + 2q_2x_2) / (b_1 + 2q_1x_1)$$

3. RESULTS

Seventy-eight percent of Franklin County is forested, most of which is in nonindustrial private ownership. The average respondent owned 60 acres of forest land, and 70 percent of the parcels were less than 100 acres. Approximately 78 percent of the respondents lived within 5 miles of their woodland, 60 percent had owned their land more than 15 years, and one-third had a management plan. Approximately half of the owners were 55 or older, and 74 percent had completed at least 1 year of college.

The model was estimated using a polychotomous probit technique developed by McKelvey and Zavoina (1975) to analyze ordinal level dependent variables. The dependent variable (r_j) is the rating for each alternative scenario and was coded from 0 to 9. The explanatory variables (attributes) were coded 0.0, 0.5, and 1.0 to account for the proportions of apple trees to maintain, trail improvements, fern protection, and extent of timber harvesting. Cost was coded in units of $100 (0.5, 2.5, and 5.0). Each respondent rated four alternatives for a total of 2,504 rated scenarios. The results are shown in Table 1.

Table 1. Ordered probit parameters for a multi-attribute conjoint rating survey (dependent variable = rating, coded 0 to 9, N=2504)

Variable	Coefficent	Std. Error	t-ratio
Constant	-0.1785	0.0701	-2.55
Linear effects:			
Apples	1.1019	0.1955	5.64
Ferns	1.3040	0.1871	6.97
Timber	0.2142	0.0521	4.11
Trails	0.8580	0.1863	4.61
Cost	-0.0415	0.0116	-3.57
Quadratic effects:			
$(\text{Apples})^2$	-0.5264	0.1836	-2.87
$(\text{Ferns})^2$	-0.6996	0.1784	-3.92
$(\text{Trails})^2$	-0.6570	0.1841	-3.57

All variables were significant at the 1% level.

Log-likelihood = -5179.1

The estimated signs and relative magnitudes of the coefficients provide information on the respondents preferences. As expected, increased levels for each of the attributes except cost had a positive effect on ratings. The magnitude of the positive effects of maintaining apple trees to benefit wildlife and fern protection were greater than those for trail improvements and extending the area available for timber harvesting (which also may be interpreted as lower restrictions on harvesting). Landowners, therefore, generally placed higher value on the ecological aspects of the alternatives

than on the use aspects. These findings are consistent with previous studies that suggest that nonindustrial private forest-land owners place high values on wildlife and other nontimber amenities (Birch 1996, Brunson et al. 1996) and with the attitudinal aspects of this survey (Rickenbach et al. 1998).

A commonly accepted economic precept with intuitive appeal is that one's preference for more of a particular good depends on how much of the good one already has and that willingness to trade among goods depends on the quantities of each good in one's possession. Quadratic effects were examined to estimate these expected nonlinear relationships. The quadratic terms for apple tree maintenance, fern protection, and trail maintenance were all negative and statistically significant, which indicates decreasing marginal benefits for these attributes. The partial utility or the contribution of an individual attribute toward the total utility provided by an alternative is determined by combining both the linear and quadratic effects at a given attribute level. For example, the partial utilities for fern protection at levels none, half, and all are 0.0, 0.477, and 0.604, respectively (computed as $b_i x_i + q_i x_i^2$). Thus the increase in utility resulting from an increase in fern protection from none to half is 0.477, while the increase from half to all is 0.127. It appears that marginal increases in utility decreased once respondents felt that a significant portion of the ferns were protected or the apple trees maintained. Although respondents favored initial trail improvements, similar calculations indicate that maintaining all of the trail network versus just half actually decreased overall utility or preference for an alternative.

To examine the trade-offs that respondents were willing to accept among the objectives marginal rates of substitution can be computed for any two attributes at the selected levels using Equation 3. The trade-off between cost and attaining management objects is frequently useful to policy makers. The MRS between cost and the other attributes are shown in Table 2 and illustrate the notion of decreasing marginal benefits. Landowners were willing to incur less additional cost to maintain apple trees or protect ferns as the amounts of these attributes already under protection increased. For example, landowners on average were willing to incur $23 to protect an additional percentage of the ferns if only 25 percent were currently under protection but only $6 if 75 percent were being protected already.

The trade-offs that landowners are willing to accept between two attributes may be determined at any level selected for each attribute either by computing the MRS for the attributes directly using Equation 3 or by comparing the MRS between each attribute and cost. For example, if half of the apple trees are currently being maintained, Equation 3 can be used to determine the level at which landowners become indifferent between additional trail improvements and increased apple tree maintenance. The

MRS equates to one when apple tree maintenance is at 50 percent and trail improvement is at approximately 21 percent. Therefore, landowners would prefer to improve the trail network up to the 21 percent level over additional apple tree maintenance at 50 percent. At this level, landowners would be willing to incur the same additional cost to improve an additional 1 percent of the trail network or to maintain an additional one percent of the apple trees.

Table 2. Marginal rates of substitution, cost ($) per 1-percent increase in listed variable at indicated initial level.

Level	Apples	Ferns	Trails	Timber
0.00	26.54	31.40	20.66	5.16
0.25	20.20	22.98	12.51	5.16
0.50	13.86	14.56	4.36	5.16
0.75	7.52	6.13	*	5.16
1.00	1.18	*	*	5.16

* Negative

4. SUMMARY

Nonindustrial privately owned forests are expected to play an important role in meeting needs for a wide range of forest-related benefits. Estimates of the relative values that landowners place on various nonmarket benefits provided by their land and the costs they are willing to incur to achieve different levels of these benefits are useful to policy makers. The estimates can also be used as inputs for larger decision or optimization models that deal with multiple-objective management on private lands. Conjoint techniques are well suited for assessing the relative values and acceptable trade-offs (MRS) among management objectives. Including quadratic effects permits estimation of nonlinear MRS, which economic theory and these empirical results suggest are important.

Landowners in Franklin County, Massachusetts, generally placed higher values on the ecological aspects (fern protection and apple tree maintenance) of management alternatives than on use-related aspects (timber harvesting and recreational trail improvements). Both fern protection and apple tree maintenance exhibited decreasing marginal rates of substitution. Although landowners feel strongly about providing these benefits, their willingness to make trade-offs between these and other objectives or to incur additional cost depended greatly upon the current levels to which the objectives were being met.

5. LITERATURE CITED

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