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Forest Ecology and Management 114 (1999) 329–338

Forest Ecology and Management

# Ascribing value to ecological processes: an economic view of environmental change

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**Abstract**

Decisions made by individual landowners and public land managers can have a significant impact on the rates of ecological change. Interdisciplinary cooperation is desirable if economists and ecologists are to correctly interpret the impacts of individual choices for landscape management. This paper reports results from two studies of the residents of North Carolina which contrast individual preferences for utilitarian forest benefits and financial returns with less tangible benefits of forest amenities and ecosystem stability. One study reports preliminary findings from a forest-benefit mail survey on the Nantahala and Pisgah National Forests; the second study presents an analysis of harvest decisions by private landowners. Economic methods pertinent to valuation of environmental goods are briefly considered. Individual behavior is described which suggests that segments of the public recognize welfare benefits specifically from forest amenities, and from 'natural' production of environmental goods and services. The two studies suggest how economic tools may be extended to help quantify complex social and biological values associated with ecological processes. 

*Keywords:* Environmental economics; Non-market benefits; Trade-off analysis

## 1. Introduction

Land management decisions made by individuals and by public agencies can have a significant impact on the speed and direction of ecological change. Natural systems provide a complex array of goods and services valued by humans, and it is often the case that alternative mixes of goods and services will require dissimilar management strategies. Economists are interested in the relationship between these management trade-offs and estimates of value for related environmental benefits. This paper looks at the two studies in North Carolina, one study addressing citizens' preferences for public lands management, and a second study examining decisions by private landowners. Both studies seek to explore the relationship between management strategies and the ability of the landscape to provide specific economic benefits.

The USDA Forest Service is directed by law to manage the National Forests for multiple benefits. This policy has been in place for some time, but the adoption of ecosystem management (EM) in 1992 resulted in several areas of new emphasis (Robertson, 1992; Kessler et al., 1992). The USDA Forest Service Wine Spring Creek Ecosystem Management Demonstration Project on the Wayah Ranger

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PII: S0378-1127(98)00363-6

District of the Nantahala National Forest is an interdisciplinary research project intended to address some of the complex ecosystem management issues on public lands. It has provided an opportunity for economists to work in collaboration with forest ecologists, integrating biological knowledge of the forests with a consideration of preferences for ecological benefits from public lands. The Wine Spring Creek project provides a context for our first study which reports research results on citizen preferences for benefits from the Nantahala and Pisgah National Forests in western North Carolina.

The second study examines the harvesting decisions of non-industrial private forest (NIPF) landowners as a possible means to measure the relative preferences for immediate timber revenues versus the continuing amenity values available from unharvested private stands. The preferences of private landowners are of interest in their own right. They are also of significance for public lands management, particularly in eastern National Forests which are fragmented by private inholdings, and where the decisions and preferences of private owners are of critical importance in the effective management of ecosystems across property boundaries.

There appears to be a perception among the public that non-market benefits associated with natural environments are more scarce now than they once were. Human population increase, encroaching development, species extinctions, and other factors suggest that an expanding number of individuals are competing for benefits from the forest resource. It is the perception of scarcity, and the attendant perception that trade-offs between competing resource allocations will be necessary, which is of particular interest to environmental economists.

It is well understood that the absence of well defined and enforceable property rights can result in market failures for common property goods such as benefits from public lands, and that the absence of prices and/or markets can result in significant difficulties in estimating values. However, meaningful analysis of trade-offs can be achieved without explicit markets. In this paper, we consider a number of different classes of ecological benefits. Many of these benefits are outside the scope of economic markets, but still lend themselves to trade-off analysis using economic tools which do not require monetary estimates of value. The empirical results we report in these two studies address efforts to estimate the relative importance of various classes of non-market goods, when these are compared to more traditional commodity outputs. Benefits considered include traditional market products such as timber. We also considered goods which are not traded in markets. Examples include activities such as hiking, boating, hunting and fishing. An ecosystem may provide amenity values which can make an aesthetic contribution to an activity, but need not be present for the activity to occur. The scenic beauty of a landscape is an example of such an amenity value. Additionally, we examined passively derived *service* benefits such as clean water, air, and other life-support systems, and a class of non-use benefits associated with *ecological state* (e.g., biodiversity) or *ecological functions* (e.g., hydrological or nutrient cycles) which derive from the knowledge that a species or ecosystem exists, but do not require the individual to interact with the ecosystem providing value.

In positive economic research, generally recognized empirical methods focus on understanding the actual choices made by consumers (or choices that would be made by consumers if they were confronted with a real-life choice) rather than a more normative consideration of social behavior. To understand behavior, economists have two general methodological approaches. The first of these, revealed behavior, focuses on empirical data resulting from choices made by consumers and the implicit preferences and values revealed by their behavior. The second approach elicits stated preferences from respondents. Since, individuals do not interact directly with a resource when they experience passive service benefits or existence values, only stated preference methods are suitable for exploring these types of ecological benefits. Stated preference methods are subject to the criticism that they report only hypothetical values which cannot be validated by the test of an efficient market.

## 2. Forest management on the Pisgah and Nantahala National Forests

Our first study reports the preliminary results of a mail survey conducted to determine the citizen preferences for a variety of goods and services associated with the Nantahala and Pisgah National Forests in western North Carolina. This study is of interest because it seeks to determine the relative importance of a wide range of ecological benefits including market goods (e.g., timber), non-market goods (e.g., fish and game), amenity values (e.g., scenic beauty), passive use (e.g., flood control), and existence values (e.g., preservation of species). Our desire to consider non-use benefits in this study dictated the adoption of stated preference techniques to elicit estimates of benefits.

The experiment compared the preferences of three special constituencies, a timber group, an environmental group, and a hunting and fishing group, to the preferences of a random control. The mail survey was developed using the Dillman total design method (Dillman, 1978). We pre-tested the survey on groups of university students and on a random sample of citizens of North Carolina. We distributed 1350 surveys which are given as follows: 750 to a random control of North Carolina residents, and 200 each to the three special interest groups. The names for the special interests were collected by randomly sampling the memberships of special interest organizations including the North Carolina Nature Conservancy, the Western North Carolina Alliance, a western North Carolina chapter of the Sierra Club, North Carolina members of Trout Unlimited and the Ruffed Grouse Society, North Carolina lifetime hunting and fishing license holders, members of the North Carolina Forestry Association, and members of the Southern Appalachian Multiple Use Council. The survey protocol included a reminder postcard and two replacement surveys mailed to the non-respondents.

Of the 1350 mailed surveys, 151 were returned undelivered as a result of an incorrect address, death or incapacity of the addressee. Of the remaining 1199 surveys, 818 were returned for a response rate of 68%. We report results on two subsets of this data. One subset is a stratified random sample of 290 respondents from all the four groups (three special interest and the random control) which was drawn in order to conduct this preliminary analysis. In the analysis conducted on this subset, we compare preferences across interest groups for a collection of 25 possible forest benefits, with the intention of understanding how preferences may vary across different constituencies. A second subset of 302 respondents drawn only from the random control is analyzed using the technique of conjoint analysis, with the intention of estimating marginal utilities of the citizens of North Carolina for alternative multiple-use management scenarios.

## 3. Reported personal importance values

The survey asked respondents to rate how important 25 forest benefits were to them personally, on a nine point Likert scale (0–8). The list of potential benefits was developed from a review of economic and ecological sources. The experiment included attributes considered critical by the Ecological Society of America (Christensen et al., 1995) as well as more traditional market benefits. The list of potential benefits is included in Table 1. The responses provide substantial evidence that qualitative attributes of ecological systems are very important to individuals. Three of the four interest groups reported mean values for ecological services and ecological states which were substantially higher (range: 6.99–6.14) than for any other class of benefits. No other benefits ranked as high, with the sole exception of timber harvest for the timber special interest group (mean=6.67). All four survey groups ranked *ecological process goods* (e.g., benefits resulting from services, states, or processes associated with the normal functionality of *in situ* ecosystems) quite highly in comparison to other available commodity values.

When considering all of the 25 benefits represented in Table 1, mean personal importance values reported by the timber group tended to be lower (mean=4.25) than those of other groups. Mean personal importance values for the hunting and fishing group tended to be generally higher (mean=5.58) than those of other groups. The environmental group (mean=4.75) demonstrated the greatest polarity of values, reporting 6 of the 10 highest personal importance values expressed as well as 6 of the 10 lowest values. In comparison, the mean personal importance value reported by the random control was 5.03.

A more detailed analysis of specific attributes confirms the importance of ecological process goods (EPGs). Table 2 displays the benefits from the list of 25 which received a top-five mean rating by one or

Table 1
Mean values of ecological goods, services, and processes as rated by stakeholder groups

| Special interest group: | Random | Envir. | Hunting and Fishing | Timber |
|---|---|---|---|---|
| *Ecological services*: | 6.68 | 6.85 | 6.63 | 5.39 |
| Affording opportunities for biological research | | | | |
| Absorbing or detoxifying pollutants | | | | |
| Provision of fresh, clean water | | | | |
| Contributing oxygen to the earth's atmosphere | | | | |
| *Ecological states or processes*: | 6.14 | 6.99 | 6.31 | 4.45 |
| Maintaining nutrient cycles, soils, and water cycles | | | | |
| Maintenance of biodiversity | | | | |
| Habitat for endangered species | | | | |
| Contributing to the regulation of global climate | | | | |
| *Non-consumptive goods*: | 5.31 | 5.43 | 5.53 | 3.64 |
| Swimming and boating | | | | |
| Primitive camping (no developed campsites) | | | | |
| The experience of being in a wilderness setting | | | | |
| Developed recreational camping (drive-in access) | | | | |
| Viewing or photographing forested landscapes | | | | |
| Trail use (hiking, biking, and horseback riding) | | | | |
| Wildlife viewing or photographing | | | | |
| Spiritual renewal from being in a natural setting | | | | |
| *Non-timber products*: | 4.83 | 4.31 | 3.97 | 3.45 |
| Non-timber forest products (pinestraw, mushrooms, etc.) | | | | |
| Medicines from organic compounds | | | | |
| *Timber products*: | 3.64 | 1.68 | 4.15 | 6.67 |
| Hardwood timber harvesting | | | | |
| Softwood timber harvesting | | | | |
| *Non-market consumptive goods*: | 3.02 | 1.59 | 5.43 | 3.52 |
| Warmwater recreational fishing (e.g., bass) | | | | |
| Coldwater recreational fishing (e.g., trout) | | | | |
| Hunting: Game birds (quail, grouse and turkey) | | | | |
| Hunting: Small game animals (rabbits and squirrels) | | | | |
| Hunting: Large game animals (bear and deer) | | | | |

This table displays the importance values of 25 ecological goods, services and processes which were rated on a nine point [0–8] Likert scale by three interest groups and a random control. Values reported represent means for each class of goods. (eight as most important. $n$=290).

more of the four interest groups. It is noteworthy that all the five benefits rated most highly by the random control group (clean water, contributions to global oxygen, endangered species habitat, stable forest cycles, and climate stability) are benefits we consider as EPGs. These benefits were important to three of the special interest groups as well, as each group reported at least three of these benefits among their top five. Wilderness experience and biodiversity were of moderately high importance to most respondents, but of particular importance only to specific interest groups. Use values, whether for market goods or for non-market benefits, were less important in all cases, except to participant groups.

## 4. Conjoint analysis of multiple use forest plans

The second step in our analysis was to evaluate the conjoint data responses of 302 individuals from our random sample. Each respondent provided responses to five stimuli, providing us with an aggregate sample of 1510 observations.

Conjoint analysis (CJ) was initially developed as a marketing research tool (Green and Wind, 1973, 1975) for analyzing the relative desirability of specific product attributes. The CJ method asks people to evaluate products as bundles of attributes known as 'product profiles'. The ability to vary hypothetical quantities or qualities of individual attributes makes the conjoint

Table 2
Interest group rankings of preferred goods, services and processes: five highest means for each group

| Benefit | Special interest group | | | |
|---|---|---|---|---|
| | Random ($n$=115) | Environment ($n$=59) | Hunting and Fishing ($n$=58) | Timber ($n$=58) |
| Water | 1 | 1 | 1 | 2 |
| Global oxygen | 2 | 2 | 2 | 4 |
| Endangered species | 3 | 3 | 7 | 13 |
| Stable forest cycles | 4 | 6 | 4 | 5 |
| Climate stability | 5 | 4 | 6 | 9 |
| Wilderness | 8 | 8 | 3 | 12 |
| Biodiversity | 14 | 5 | 10 | 9 |
| Trout fishing | 17 | 19 | 5 | 11 |
| Softwood timber | 20 | 21 | 24 | 3 |
| Hardwood timber | 22 | 22 | 22 | 1 |

This table displays those benefits receiving mean ratings among the top five from at least one interest group. Benefits with means ranking first through fifth are listed for each group. Numbers on the left are the rankings of the random control. The three remaining columns show the corresponding rank importance of the benefit by each of the special interest groups.

method ideally suited for evaluating the relative importance of resource attributes in multiple use forest plans. In this study we used five multiple use descriptions to characterize services and attributes provided by the Nantahala and Pisgah National Forests:

*Forest recreation* – refers to drive-in camp grounds with restrooms and showers, scenic views accessible by car, and also to wilderness trails that allow access for hiking, camping and other uses in undeveloped forest conditions.

*Hunting and fishing* – refers to hunting for birds, small and large game living in the forest, and fishing for native fish and non-native fish currently stocked in streams or lakes.

*Timber harvesting* – refers to hardwoods and softwoods, harvested by methods determined to be suitable for the terrain and sufficient for harvest volume requirements.

*Native ecosystems* – refers to forest conditions and biodiversity of plants and animals that are like they were 200 years ago. It also refers to an increase in the area of good habitat for endangered species.

*Water quality* – refers to how suitable the water is for plants, fish, and other animals, and how suitable it is for drinking, swimming and other human uses.

We further stated that each of these five multiple use attributes could be provided at three possible levels (high, medium, or low). This arrangement results in $3^5$ or 243 possible multiple use plans. We used an orthogonal fractional factorial design (Addleman, 1962) to generate a subset of 25 survey plans. A five level blocking factor was used to split the 25 plans into five random blocks. Each final survey therefore contained five plans for evaluation. We asked respondents to assign a number from 0 (very dissatisfied) to 8 (very satisfied) to each plan, indicating how satisfied they would be with a forest management plan which provided the five benefits at specified (high, medium, or low) levels. Subsequent analysis of this conjoint data allowed us to separate the effects of individual attributes, and to estimate relative marginal benefits associated with changes in the level of benefits from low to medium to high, for each attribute.

A summary of the regression results are shown in Table 3. As can be seen, the linear effects were significant at the 0.01 level for all attributes except hunting and fishing. We note that the parameter on timber was negative and significant at the 0.01 percent level. Quadratic effects were significant for recreation at the 0.01 level, and for timber at the 0.11 level.

Adding the linear and quadratic effects that are significantly different from 0 at the 0.10 level or better reveals information about the functional form of the utility functions sufficient to generate piecewise linear curves (Fig. 1). Straight line functions result for all benefits except recreation. The straight line functions with positive (negative) slope imply a constant mar-

Table 3
OLS regression results of conjoint ratings on multiple use attributes

| Variable | |
|---|---|
| Constant | (+)[a] |
| Native ecosystems | (+)[a] |
| (Native ecosystems)$^2$ | (+) |
| Timber harvesting | (–)[a] |
| (Timber harvesting)$^2$ | (–) |
| Recreation | (+)[a] |
| (Recreation)$^2$ | (–)[a] |
| Hunting and fishing | (+) |
| (Hunting and fishing)$^2$ | (–) |
| Water quality | (+)[a] |
| (Water quality)$^2$ | (–) |
| Adjusted $R^2$ | 0.184 |

This table displays the sign and significance of regressing conjoint ratings on linear and quadratic terms for multiple use attributes. Respondents are from the random control ($n$=302).
[a]: Signifies significance at the 0.01 level.
[b]: Signifies significance at the 0.05 level.
[c]: Signifies significance at the 0.10 level.

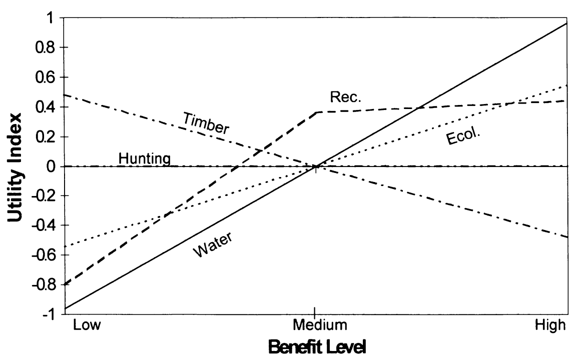


Fig. 1. Marginal utilities of multiple use attributes.

ginal rate of utility gain (loss) with increasing levels of these benefits. The straight line functions do not provide evidence of preference satiation over the range of provision. This is in contrast to the general economic expectation that as levels of benefits steadily increase, people continue to derive benefits, but at a gradually slowing rate. We did find such rates of declining marginal benefits for recreation, where individuals experience the greatest incremental gain among all benefits reported (i.e., line segment with the steepest slope) in moving from low to medium levels, but appear to be relatively satisfied with medium levels of provision and experience only limited further gains by moving to high levels of provision. For the hunting and fishing attribute, the model results were not significant at the 0.10 level, suggesting that these benefits were not of great importance to the random sample. The function associated with the timber harvest attribute is negatively sloped, suggesting that over the range of provision, greatest satisfaction occurred at low levels. Respondents reported lowest levels of utility when all benefits other than timber harvest and hunting and fishing were offered at low levels of provision, and low levels of utility when timber harvest occurred at high levels. The greatest utility gains resulted from increases in the recreation attribute from low to medium levels of provision, and from improvements to water quality at all levels.

These preliminary results suggest that a random sample of the public in North Carolina strongly prefer the production of ecological process goods and non-consumptive benefits over either priced or non-market consumptive benefits on the Nantahala and Pisgah Forests. Further, they prefer high levels of provision of service and existence-value goods such as water-quality and native ecosystems over high levels of provision of goods with utilitarian value such as recreation or hunting and fishing.

## 5. Private forest management in North Carolina

Our second study reports an analysis of harvesting decisions by non-industrial private forest (NIPF) landowners using revealed preference methods. By observing how landowners manage their forested stands, we impute values to the on-site amenities that are influenced by harvesting. This is the hedonic method, which is used to estimate the value of individual attributes of a bundled good that sells in the market for a single price (Rosen, 1974; Palmquist, 1991). For example, a house sells for a single price, but estimates of the value of house, neighborhood and environmental attributes can be obtained by regressing these characteristics on the selling price of the house. Private forest lands are analogous, in that they represent bundles of benefits including both timber revenues and amenities (e.g., non-market goods, ecological services).

The traditional forest economic viewpoint is that private landowners manage their forests for maximum monetary wealth (Faustmann, 1849; Samuelson, 1976). There is, in fact, considerable evidence from both surveys (e.g., Fecso et al., 1982) and analytical studies (e.g., Newman and Wear, 1993) that income from timber harvests is important to private landowners. However, other studies have shown that amenities also matter to these owners (e.g., Berck, 1979; Binkley, 1981; Dennis, 1989; Birch, 1996). The USDA Forest Service, Forest Inventory and Analysis conducted surveys in North Carolina in 1983 and 1990 for 2800 privately owned timberland plots using standard forest survey techniques based on variable-radius plots. After expanding the plot data to a representative acre, we tested the hypotheses that (1) timber income matters, and (2) some income will be foregone to obtain forest amenities.

Our theoretical model of private forest behavior is based on the Hartman model (Hartman, 1976) which assumes that landowners manage for both timber and amenities and assumes that amenities increase with stand age. In this paper, we consider the value of an infinite series of timber harvests, and the amenity values from the current rotation. Landowners will then harvest their stand when the marginal benefits to both timber and amenities of delaying harvest an additional year are equal to the marginal costs of waiting another year. Thus, if there are marginal amenity benefits to be derived from the standing timber, a landowner would wait longer to harvest than the traditional economic optimal rotation age. We find support for this in the NIPF plot data, which indicates that 50% of the stands are older than their financial optimum. Fig. 2 shows the stand-age profile for these plots. Evidence of amenity values can also be found by examining the characteristics of the older harvested and non-harvested plots (Fig. 3). Amenity values are generally higher on the non-harvested plots. Both findings lend support to the idea that amenities from standing timber may be significant, and may be increasing in importance. Although other conditions may delay harvesting, such as cash-flow considerations or inadequate information, these conditions are assumed to be uncorrelated with the amenity characteristics of the forest and thus will be captured in the error term without influencing the estimated coefficients.

First, to test the hypothesis that timber income matters, we estimate the probability of harvest as a function of economic, site and amenity variables. Both the marginal timber cost and marginal timber benefits,

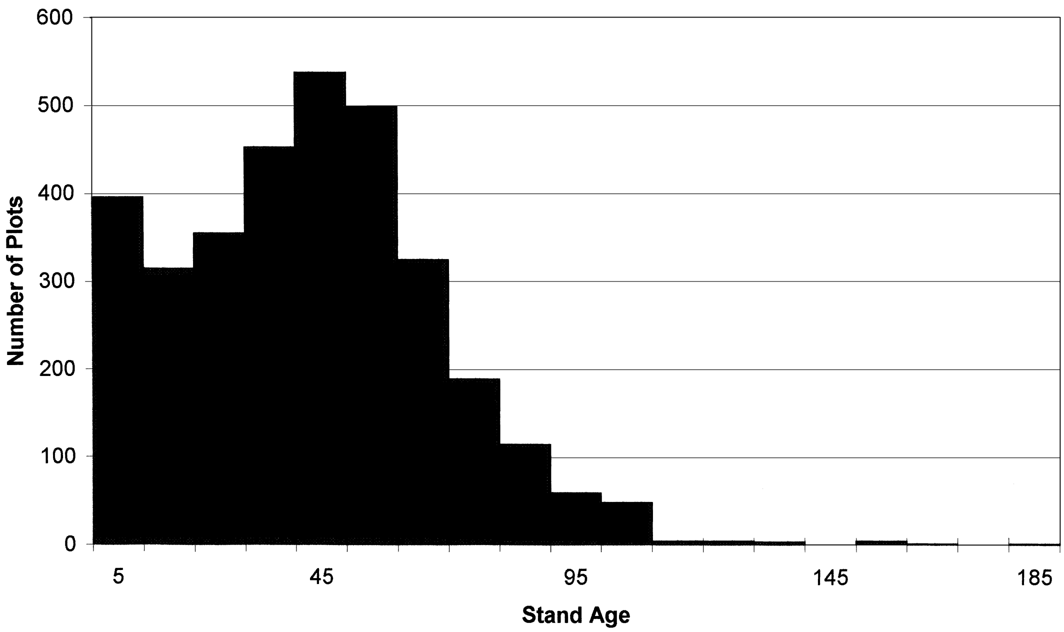


Fig. 2. Stand age distribution of NIPF plots.

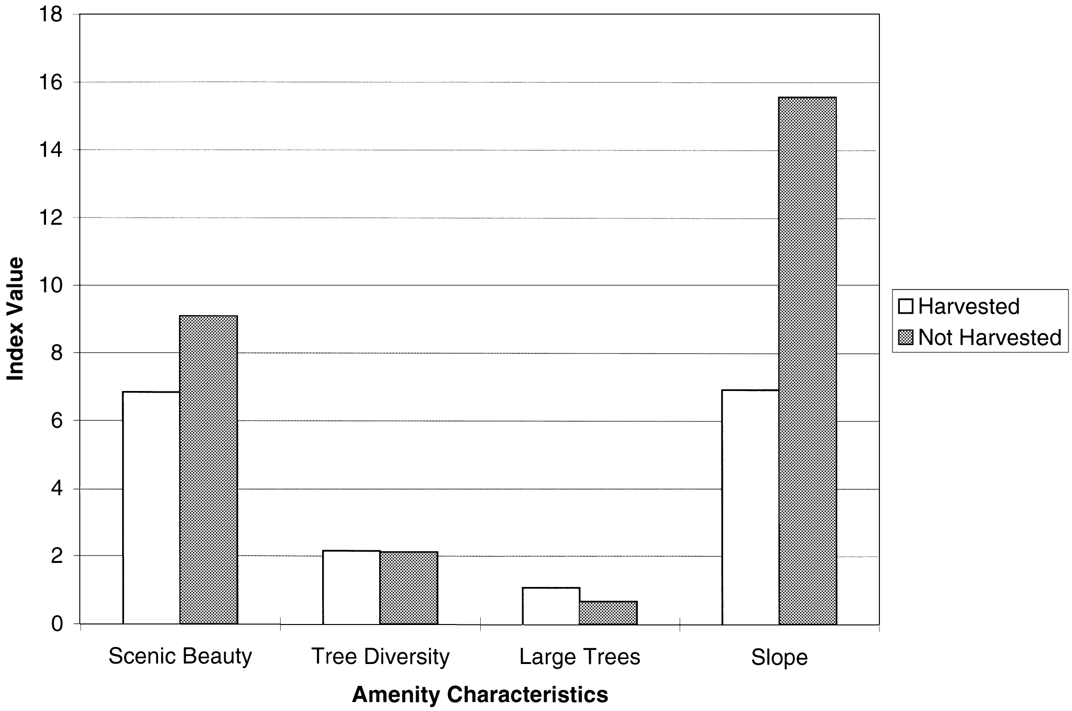


Fig. 3. Amenity characteristics of NIPF plots.

which represent the landowners opportunity costs, were significant in estimating the probability of harvest. Thus, we conclude that timber income is important in managing private forests. Another highly significant variable is the percent slope, with steeper slopes reducing the probability of harvest. This effect could be due to either harvesting costs or amenity values. As slope increases, harvesting and transportation costs increase, thus reducing the probability of harvest. However, a similar reduction will occur if increased slope represents increased amenity values (e.g., mountainous areas are more desirable for amenities). The results indicate a strong correlation between harvest and slope, but we cannot discern if the effect is monetary or amenity.

To test the hypothesis that amenities influence harvest decisions we used only harvested plots (308 of 2800 were harvested between 1983 and 1990). The opportunity cost of delaying harvest beyond the optimal rotation is used as our dependent variable and amenity characteristics are regressed on this cost to estimate hedonic values for the amenities. The model was estimated by correcting for sample selection (see Greene, 1993).

Amenity indices were developed for scenic beauty, tree diversity and wildlife habitats. The scenic beauty estimator is from Rudis et al. (1988). A tree diversity index was developed using the Shannon–Weaver formula, which is intended to account for rare species. The index used basal area by species for all the trees over 5 inches in diameter. Wildlife habitat indices were developed for several birds (Sheffield, 1981) and for white-tailed deer (Crawford and Marchington, 1989). The number of large softwood and hardwood trees was also included under the assumption that larger trees may have value beyond that measured in the scenic beauty index because the scenic beauty index only incorporates measures of diameters greater than 11 in. All of these amenity characteristics are influenced, or eliminated, by a landowner's decision to harvest.

Regressing the marginal opportunity cost on the amenity characteristics results in coefficients for the amenities that can be interpreted as hedonic prices.

One important caveat is that these indices may not accurately represent landowner preferences. With the exception of the scenic beauty estimator, none of these indices has been tested with regard to landowner preferences, thus an increase in the index may capture some preference other than the one we intend to be measuring.

The results indicate that the hedonic prices for scenic beauty, downy woodpecker habitat and large trees are positive and significant implying, as noted above, that either (1) landowners prefer these amenities, or, (2) landowners prefer other attributes correlated with these amenity indices. The hedonic price on tree diversity, however, is negative and significant at the 0.05 level. This implies that either landowners don't value tree diversity (in fact, they are willing to pay to lower tree diversity) or the Shannon–Weaver index of tree diversity is not measuring those particular aspects of biodiversity that people value.

## 6. Conclusions

In both studies we found substantial evidence that people highly value non-market benefits from forested landscapes. We would expect these preferences to have an impact on management decisions, and in turn, to affect the rates and direction of ecological change. We find some evidence of this phenomenon in the presently increasing average age of privately owned North Carolina forest stands.

We would expect both the motivations and the expectations of individuals to be different when considering public and private lands. Individuals who own forests may be presumed to strike a balance between monetary and amenity benefits. There is substantial evidence in this study and elsewhere that their decisions are influenced by financial considerations of timber harvest. Our findings show that the desire for financial gains appears to be tempered by gains from amenity values. Randomly selected citizens of North Carolina seem to have a different set of expectations for public forest lands. Low levels of timber management were strongly preferred on the Nantahala and Pisgah Forests, and citizens heavily preferred management associated with high levels of water quality and native ecosystems. We found that the highest preference values expressed were those associated with the quality of ecological process. However, given that there appears general support for public forests in which the quality and the continuity of ecological processes (e.g. hydrological cycles, nutrient cycles and nutrient retention) remain high, there remains significant disagreement about exactly what outputs might be associated with forests in which these processes are both robust and sustainable.

There is a need for further interdisciplinary work in this area. While economic tools can identify measures of trade-offs between known ecological values, it remains extremely challenging to link technical measures such as a habitat suitability index or measures of biodiversity to attributes which can be understood and perceived as valuable by untrained individuals. Development of biological measures which are both ecologically meaningful and readily understood will result in more accurate estimates of economic value, and may also result in a better informed and more supportive public. As an example, while we found support in our studies for the importance of scenic beauty, wilderness, endangered-species habitat, and stable nutrient cycling, neither study found biodiversity to be an important positive value. It may be that individuals understand biodiversity and don't care for it, but it may equally be the case that uncertainties which exist in scientific and public understanding of the causal relationship between biodiversity and ecosystem sustainability result in the biodiversity benefit being incorrectly valued as a result of insufficient information. Resolving these issues may be of importance in a policy environment which will continue to require allocations of limited environmental resources.

## Acknowledgements

Research support for this work was provided by the USDA Forest Service Southern Research Station. We thank the Research Triangle Park Economics Unit and the Coweeta Hydrological Laboratory, Wine Spring Creek Ecosystem Management Demonstration Project for their support.

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