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MANAGEMENT OF FORESTED LANDSCAPES

Simulations of three alternatives

By Stephen G. Boyce and W. Henry McNab

Left: The southern Appalachian Mountains in western North Carolina are an important source of high-quality timber. They also have great recreational value.

FORESTED LANDSCAPES CAN BE managed to support various combinations of timber, biological diversity, esthetic values, and habitats. However, al1 such management decisions are choices based on opinions about future events. Opinions underlie management decisions because there is no way to jump into the future, verify a future event, jump back to the present, and make a decision.

Research conclusions and experiences help us build mental models with which to make management decisions. However, conclusions and experiences become opinions when they are included in decisions about future events. Simulation models help managers display mental models for scrutiny, exchange ideas with others, and compare the consequences of imposing different opinions on a forested landscape. Thus they aid, but do not replace, mental models.

What are some of the consequences expected from imposing different opinions on the same forested landscape? This article compares simulated consequences of three different opinions as if each were imposed on the same forested landscape in the southern Appalachian Mountains. One set of opinions would stop al1 harvest of timber; a second set would impose traditional forestry practices; and a third set would impose landscape forestry. Outcomes from these simulations indicate that landscapes organized for old-growth, biological diversity, habitats, and esthetic values limit timber harvests and cash flows.

Three Opinions

Forest reserves is a set of opinions that would halt al1 timber harvesting. Culture is limited to maintaining access; protecting from loss by fires, insects, or diseases; limiting human impact (from hiking, hunting, fishing, and camping); and monitoring the changes. The intent is to allow natural processes to occur without interference from humans (Mann and Plummer 1993).

Traditional forestry contains a set of opinions about structuring stands and scheduling harvests to sustain flows of timber and cash (Spurr 1979, Smith 1986). Stands are scheduled for harvest according to silvicultura1 systems—cutting patterns designed to structure stands for optimal timber or cash flow and to ensure regeneration of harvested areas. Trees are regenerated, released from competition, thinned, pruned, fertilized, and genetically improved to speed the growth of crop trees. The emphasis is on structuring stands to maintain a balance of age classes within a range of optimum timber harvest (Davis and Johnson 1987).

Landscape forestry is a set of opinions about organizing forested landscapes to produce combinations of benefits that require two or more kinds of stands ordered over space and time. Rates of harvest, kinds of regeneration encouraged, and sizes of canopy openings are scheduled to distribute stands across a landscape in a variety of type, age, and area classes. Age classes extend from regeneration to old-growth stands. Endemic forest types are favored by natural regeneration. Size of

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canopy openings are scheduled to enhance biological diversity. This system emphasizes joint production of many benefits (Boyce 1985).

The concept of "stand" is the common denominator for all three sets of opinions. Stands, sometimes called communities and ecosystems, are units common to silviculturists, ecologists, landscape designers, forest managers, wildlife biologists, hydrologists, and other resource managers. Under forest reserves, new stands occur as a result of canopy gaps, fires, storms, and other causes of tree mortality. New stands under traditional forestry are begun with scheduled harvests near the age for culmination of Aows of timber and cash. A scheduled harvest to produce the desired combination of biological diversity, esthetic values, habitats, timber, and cash flows begins new stands for landscape forestry.

Al1 three approaches produce combinations of benefits, but the combinations are different for each method. They relate to differences in type, age, and area of stands distributed over time and space. As stands change over time and space, habitats for some species are enhanced and habitats for other species are limited. Patterns of shadows, colors, and other elements of scenic views also change. The proximity of different kinds of stands influence opportunities for different kinds of animals to travel, find food, escape predators, and migrate. Proximity also influences dispersion and germination of seed. Biological diversity is a function of changing dispersions of stands classified by forest type, age, and area classes. The following sections discuss the results of simulating a few of these relationships and the changes over time for a single forested landscape. Thus they present a comparison of some consequences of imposing on the same landscape concepts of management for forest reserves, traditional forestry, and landscape forestry.

The Forested Landscape

Craggy Landscape, selected for the simulations, is defined by compartments 1-24 of the Toecane Ranger District, Pisgah National Forest, in Buncomb County, north of Asheville, North Carolina-about 15,541 acres of mostly hardwood stands on the western slope of Craggy Mountains. These stands have been measured, mapped, and classified as upland hardwoods, cove hardwoods, and northern hardwoods by the USDA Forest Service (1992).

The upland hardwood stands are dominated by various combinations of chestnut oak, scarlet oak, white oak, black oak, hickories, and red maple. Yellow-poplar, beech, and buckeye may occur as minor components. Stands occupy well-drained soils on dry slopes and ridges below 4,000 feet elevation.

Cove hardwoods consist of various combinations of yellow-poplar, northern red oak, white oak, hickories, and red maple. Sugar maple, beech, buckeye, and ash may occur as minor components. Stands occupy moist slopes and coves with soils deeper than in the upland hardwoods. Most cove hardwood stands are below 4,000 feet elevation.

Northern hardwoods are dominated by various combinations of sugar maple, beech, northern red oak, basswood, buckeye, ash, hickories, and red maple. Many other species occur as minor components. Stands are frequent at elevations of 4,000 to 5,000 feet.

Table 1. 1992 inventory for stands by forest types and age classes in Craggy Landscape, Toecane Ranger District, Pisgah National Forest, North Carolina.

Stand age class		Forest type (acres)		
Code	Years	Upland hardwoods	Cove hardwoods	Northern hardwoods
R	0–1	40	44	57
A	1–10	361	394	509
AA	11–20	401	438	566
B	21–30	0	304	476
BB	31–40	7	0	532
C	41–50	17	515	95
CC	51–60	339	2,005	325
D	61–70	570	1,792	681
DD	71–80	263	283	224
E	81–90	320	688	654
EE	91–100	271	281	256
F	101–110	240	273	379
FF	111–120	36	76	272
G	121–130	51	12	0
H	131–140	22	42	179
I	141–150	0	0	198
O	151–300	0	0	53
Total		2,938	7,147	5,456

Source: USDA Forest Service 1992.

Simulation Models

The simulation models in this study displayed changes in small steps of time (every three months). Each step began with preceding states and changed age and area classes and forest types according to rules derived from research conclusions and experience. In mental models, the rules are adapted to each imposed method (such as differences in harvest schedules). Al1 models were run for 500 years of simulated time to ascertain that chaotic events did not affect outcomes and that simulated futures agreed with mental models. It is important to note that since all simulations of future events are based on rules derived from mental models, simulated outcomes have value as relative relationships, not predictions.

Simulation models were designed for each set of opinions using the Dynamic Analytic Systems Technique or DYNAST (Boyce 1985, Richardson and Pugh 1981). For these models, 4 iterations per year are found to give curved relationships that are not statistically different from 10 iterations. Each model produced values for hundreds of plots and tables; only a few examples are included in this article.

Since future events cannot be exact predictions, relative differences between normalized indices are used to compare changes in net present values, timber production, habitats, and cash flows. Outcomes are displayed for normalized values from -1 to +1.

Change in Age Classes

The initial state of Craggy Landscape is described with 17 age classes in three forest types *(table 1).* Regeneration age class R has a one-year delay. The oldest age class 0 has a 15 1- to 300-year delay. All other age classes have a 10-year delay range. Four age classes were chosen to illustrate changes over 200 years of simulated time: ages l-10 (code A for the three types); 61-70 (code D); 91-100 (code EE); and ages 121-300 (codes G, H, 1, and 0). The areas of land in each age class were normalized by dividing each one by the total area, 15,541 acres.

Figure 1 illustrates simulations under the forest reserves opinions. Changes in age classes are determined by initial inventory and an assumed 10% mortality rate for dominant and codominant trees older than 121 years (Runkle 1982, Martin et al. 1993). After 75 years, old-growth stands increase to about 36% of the area. The initial inventory, and increased rates of mortality as age increases, maintain oscillations in areas of old-growth beyond 200 years. Uncertain events (ice storms, landslides, fires, insects, diseases) start new waves of oscillations. Such uncertain events are excluded from these simulations.

For traditional forestry *(fig. 2),* changes related to harvest schedules bring about a balance of age classes within the range of optimum timber harvest for sawtimber. Rotation ages approximate those used by the National Forest System during the last 21 years *(table 1).* For upland hardwood stands, age class E is harvested at about 85 years of age. For cove hardwood stands, age class DD is harvested at about 75 years of age. For northern hardwood stands, harvest is from age class E at about 85 years of age. For this illustration, stands older than 90 years (EE through 0) are harvested over the next 10 years. After that time, the model adjusts harvest schedules to bring about a balance of age classes within the range of optimum timber harvest for sawtimber. A balanced distribution of age classes near the rotation ages is achieved in about 150 years.

Canopy openings of about 15 acres are created by timber harvest. Natural regeneration is encouraged, and no stands are intentionally converted from one to another type. After 150 years, distributions of land among age classes approach a steady state.

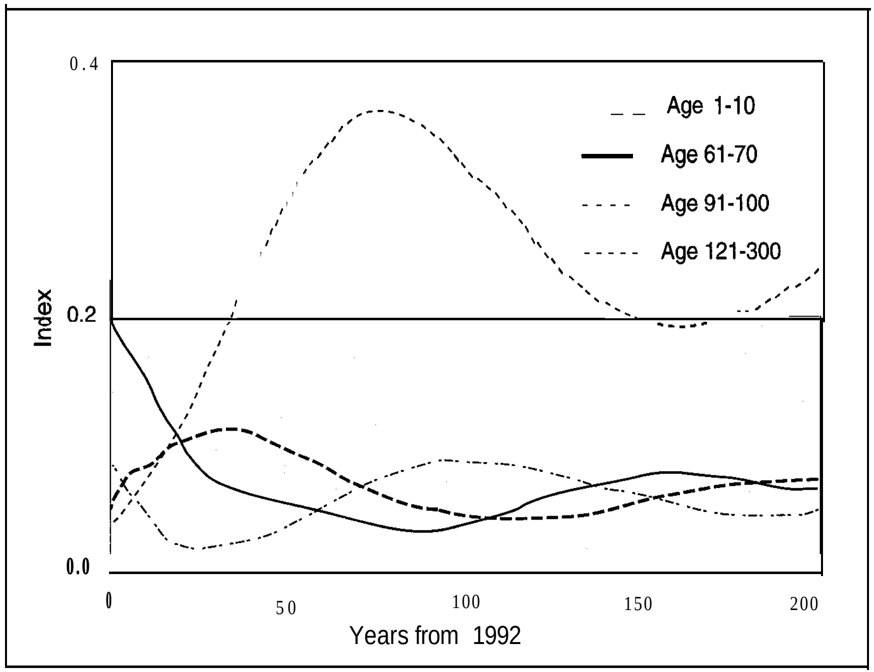

Figure 1. Distribution of land in four age classes as Craggy Landscape is turned into a forest reserve with no timber harvest. Index is urea in age class divided by total area.

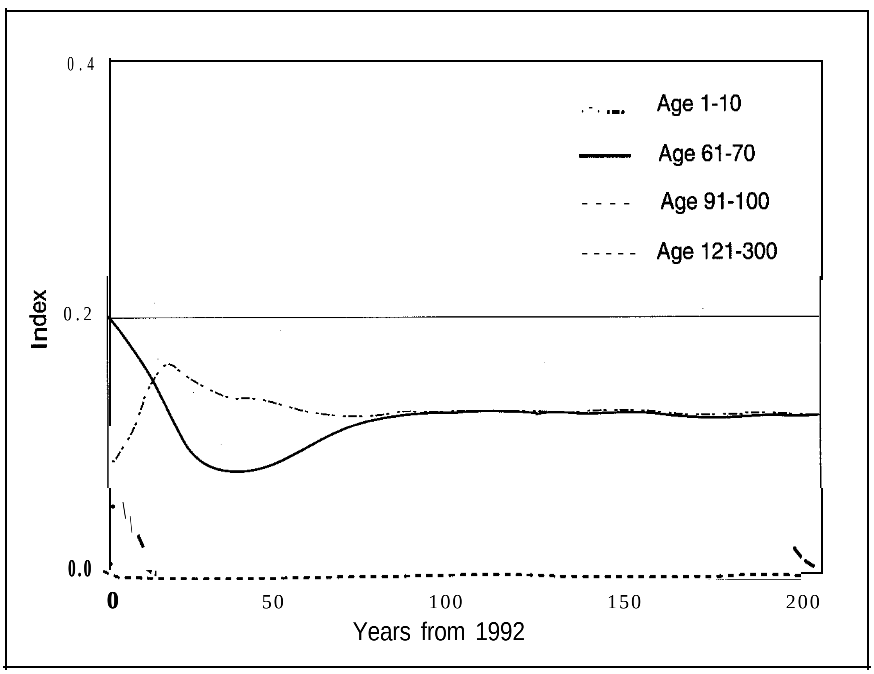

Figure 2. Distribution of land in four age classes as traditional forestry is imposed on Craggy Landscape. Index is urea in age class divided by total urea.

Landscape forestry *(fig. 3)* requires two superimposed rotation periods. Typically, a rotation age that provides a dispersion of old-growth stands in the landscape is imposed on a rotation age for optima1 timber harvest (Boyce 1985). Timber is harvested from both rotations. For this illustration, 70% of the area is rotated through the same periods as for traditional forestry. The remaining 30% has a 160-year rotation. Future revisions may include longer rotations to produce older stands of old-growth. However, the 160-year rotation is used to start the planning process. After 150 years, distributions of land among age classes approach a steady state. Old-growth stands are developed and conserved. All younger age classes are conserved but not plotted. All kinds of stands are interspersed in the landscape in

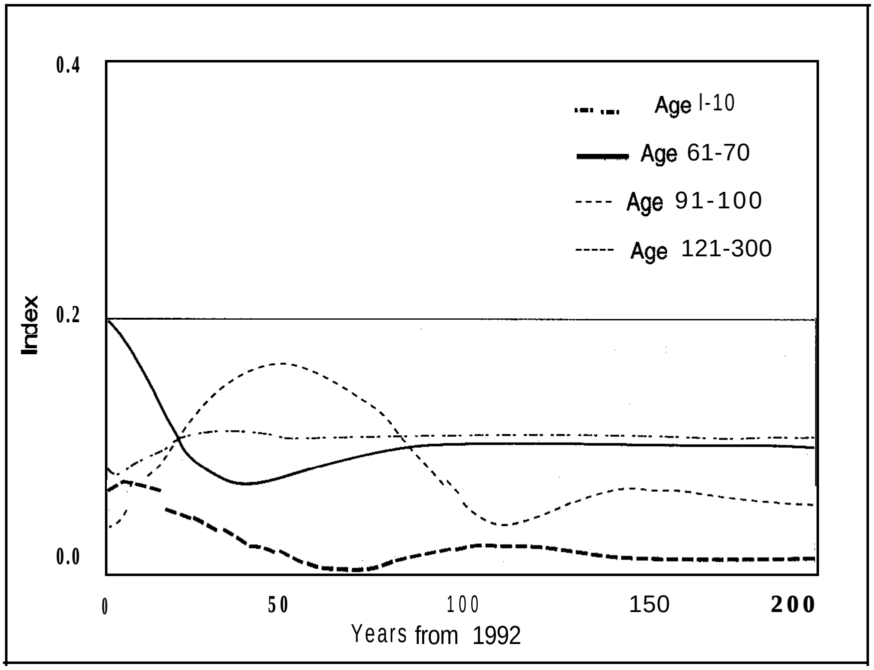

Figure 3. Distribution of land in four age classes as landscape forestry is imposed on Craggy Landscape. Index is area in age class divided by total area.

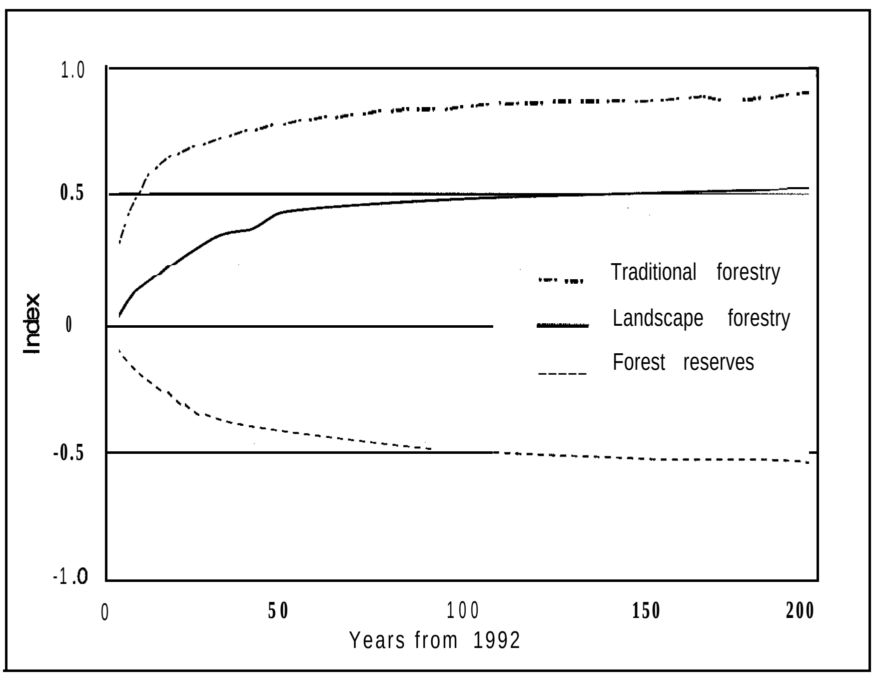

Figure 4. Comparison of net present values as three different opinions are imposed on Craggy Landscape. Index is estimate of netpresettt values divided by a base, $4 million.

relation to species adaptability to elevation, aspect, slope, land form, and soils.

Cash Flow

Every management decision involves suppositions about future cash flows. This article uses stumpage prices, continuing costs, regeneration costs, and marketing costs compiled by the Forest Farmers Association (1991), with discount and reinvestment rates of 4%, to compare net present values under the three simulations (*fig.* 4). Continuing costs are set at $5/acre/year, and neither inflation nor appreciation rates are included. Approximations of net present values are divided by $4 million to normalize indices.

Net present values under forest reserves are negative-no income is received. Net present values for traditional forestry rise rapidly during the first 10 years because all stands older than 85 years are sold. Net present values for landscape forestry are less than for traditional forestry because stands aged 91-160 years are conserved to provide old-growth, habitats, esthetic values, and other benefits. Differences in indices are related to amounts of cash flow forgone for different mixes of benefits.

Mixes of Benefits

Any habitat relationship, economic variable, scenic value, biological diversity relationship, stream flow, timber volume, or other good or service that can be normalized with a -1 to +1 index can be plotted to display productions of goods, services, and effects in the aggregate (Boyce 1985). Four benefits are selected here to illustrate different mixes of consequences, as simulated for the three policies.

Habitat indices for pileated woodpeckers are derived from a number of sources (Conner 1980). Biological diversity of spiders is derived for 134 species (Coyle 1981). An algorithm for turkey habitat is from various sources. Habitat indices do not predict numbers of animals and do not ensure the presence of an indicated plant or animal in a habitat. Rather, they display relative differences as derived from past research and experience. Displays from simulations are valuable to managers as relative differences, not predictions.

Indices for timber are based on estimated volumes of sawtimber harvested using empirical yield tables from McClure and Knight (1984). Simulated volumes are divided by 4,000 mbf to normalize indices. The largest volumes are harvested during the first 10 years under traditional forestry.

Forest reserves favor pileated woodpecker habitats (*fig.* 5). Biological diversity of spiders is low in forest reserves; habitats for guilds that favor recently harvested areas are limited by relatively small gaps in old-growth stands. Turkey habitat is low in forest reserves because small gaps in old-growth stands do not provide as many insects, seeds, berries, and ground cover as canopy openings of 15 acres or larger.

Turkeys and spiders fare better under traditional forestry (*fig.* 6). Canopy openings of about 15 acres and relatively large areas in stands 1-10 years old provide insects, seeds, fruits, and dense cover for turkeys and for many other animals. Many kinds of spiders also use these large openings (Coyle 1981). Stands in the 40- to 80-year age classes provide hard mast for turkeys and other animals. Biological diversity for spiders is greater than for forest reserves because of the diversity of habitats less than 85 years old-al1 old-growth is harvested. Pileated woodpecker habitat is constantly low because old-growth is absent *(fig. 6)*. However, the index is not zero because pileated woodpeckers feed on the ground and nest in snags in harvested areas (Conner 1980).

Landscape forestry conserves a minimum amount of old-growth and creates a diversity of habitats from 1 to 160 years old *(fig.* 7). This diversity of habitats provides livelihood for many kinds of plants and animals. Indices are relatively high for spider diversity, turkeys, and pileated woodpeckers. Volumes of timber harvested approximate those for traditional forestry because old-growth stands are conserved and harvested. However, net present values are lower than for traditional forestry because of long periods for discounting investments.

Landscapes are organized to fulfill ecological and social demands that cannot be produced in single stands. Landscape forestry changes the initial states of forest organization, step by step, toward states that produce greater varieties of habitats, goods, and services *(fig.* 7) than forest reserves *(fig. 5)* or traditional forestry *(fig.* 6). Landscape forestry uses superimposed rotations to direct states of organization. In this way, a large variety of habitats (forest type, age, and area classes) are included. Tradeoffs are made by changing rotation periods and fractional allocations to rotations.

Forested landscapes organized for biological diversity, esthetic values, and old-growth require stand distributions considerably older than those for optima1 cash flow. Landscapes organized for values that have no markets limit timber harvest and cash flows.

Conclusions

Any intervention-including restricting all human use-changes the states of forest organization and the availability of goods, services, and effects. Forest reserves provide little support for humans or for many other organisms. Traditional forestry sustains flows of timber and cash-with unplanned but possibly desirable baskets of benefits. Landscape forestry uses superimposed rotations to produce a variety of benefits.

The simulations discussed in this article display relative differences for a few consequences expected from imposing three opinions on a forested landscape. Simulated consequences are not predictions, yet *figures 1–7* reflect distinguishing differences for managers. Choices are

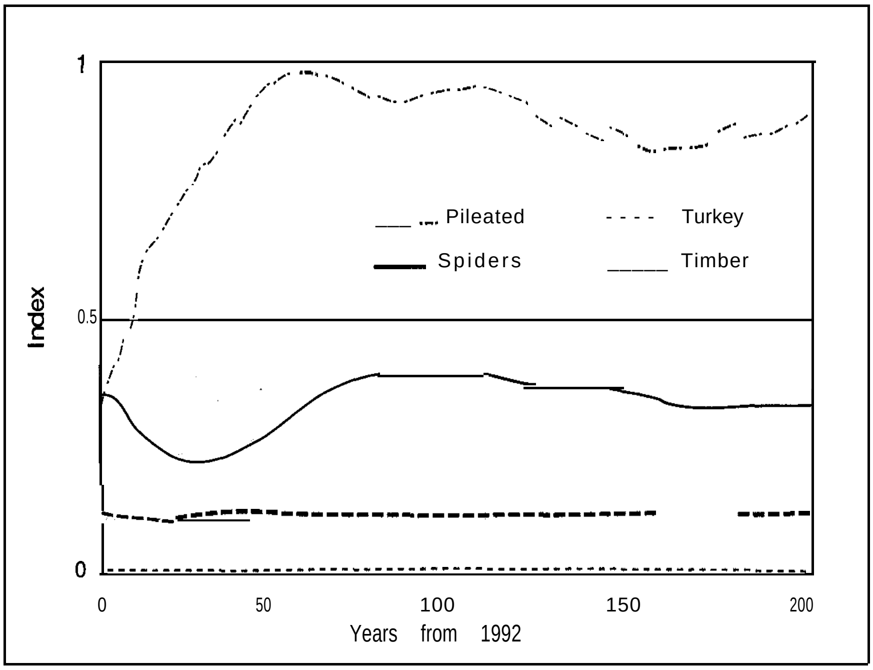

Figure 5. Relative amounts of timber harvested and three habitats as Craggy Landscape is turned into a forest reserve (no timber harvest).

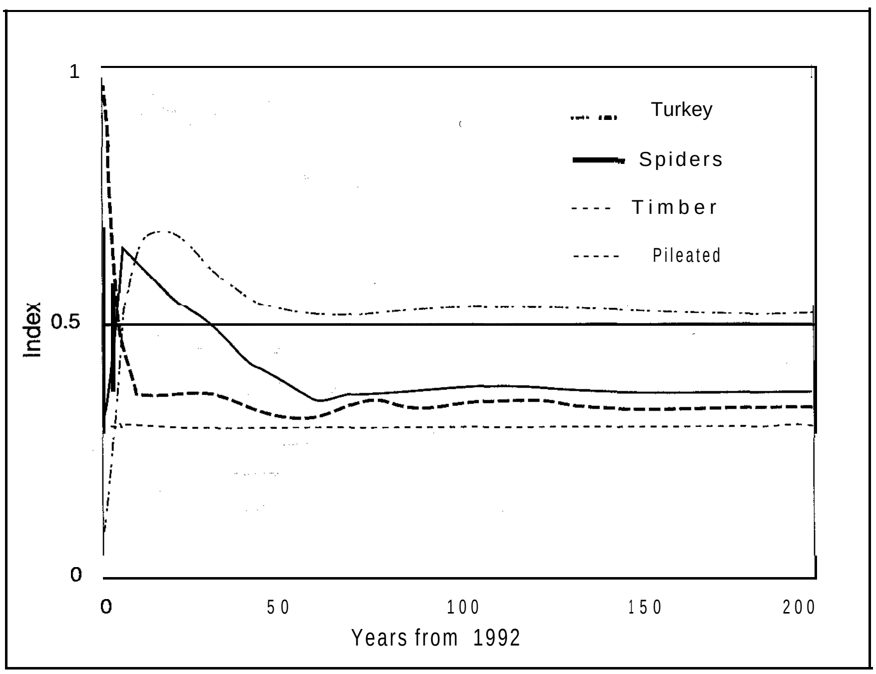

Figure 6. Relative amounts of timber harvested and three habitats as traditional forestry is imposed on Craggy Landscape.

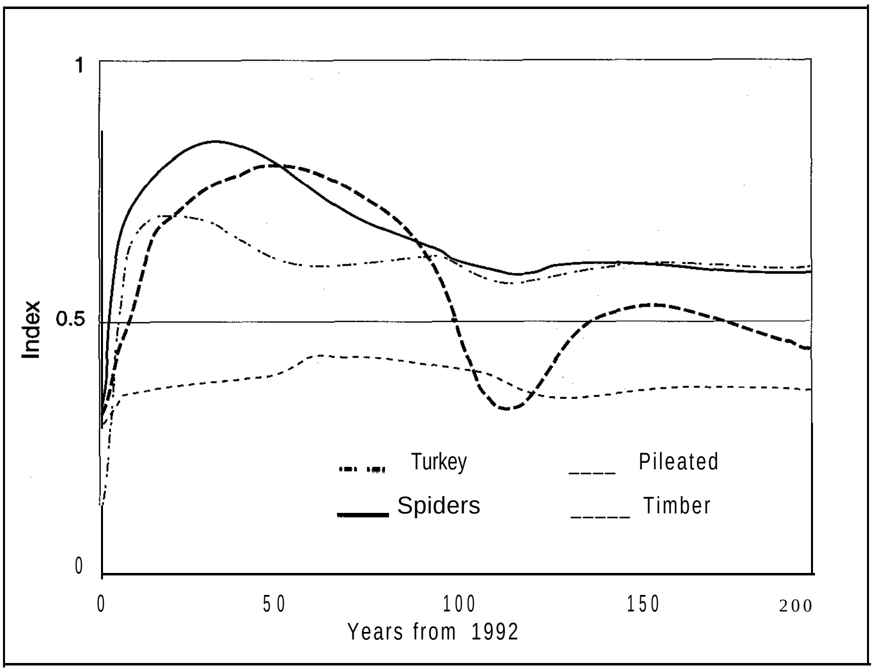

Figure 7. Relative amounts of timber harvested and three habitats as landscape forestry is imposed on Craggy Landscape.

made with mental models and incorporate insights from these displays. Simulating the consequences of imposing different opinions on a single landscape expands the base of information for managerial decisions. JOF

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