Simulated Long-term Effects of the MOFEP Cutting Treatments

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Abstract.—Changes in average basal area and volume per acre were simulated for a 35-year period using the treatments designated for sites 4, 5, and 6 of the Missouri Ozark Forest Ecosystem Project. A traditional growth and yield model (Central States TWIGS variant of the Forest Vegetation Simulator) was used with Landscape Management System Software to simulate and display changes over time. Both the even-aged and uneven-aged treatments exhibited decreasing average basal area per acre and increasing average standing volume per acre over the 35-year period. The no-harvest treatment exhibited both increasing average basal area and increasing average standing volume per acre. The even-aged treatment produced the greatest average yield per acre, the uneven-aged treatment produced an intermediate average yield per acre, and the no harvest treatment produced the least average yield per acre. Tools used to visualize the model output are illustrated.

The Missouri Ozark Forest Ecosystem Project (MOFEP) was designed to investigate relations between common forest management practices and other components of the forest ecosystem (see Brookshire *et al.* 1997). Forest response to silvicultural treatment at Missouri Ozark Forest Ecosystem Project can be predicted in many ways. In this paper I used a traditional growth model to simulate growth response of MOFEP sites to uneven-aged, even-aged, and no-harvest treatments. I graphically displayed simulation output using recently developed stand and landscape visualization software, and I compared the outputs to illustrate differences in mean response of the MOFEP sites. This methodology has general applicability for simulating forest change under a wide variety of scenarios and is complimentary with other landscape scale disturbance models being applied in the Ozarks (e.g., Shifley *et al.* 1997).

The software used for the projections presented in this paper are bundled in the Landscape Management System (LMS)[2] (McCarter *et al.* 1996), a generalized software system for the display and manipulation of spatial data on a landscape scale. This software provides an interface to the Forest Vegetation Simulator (FVS) Central States variant (Bush 1995), and the Stand Visualization System (SVS) (McGoughy and McCarter 1995) and Landscape viewer (UVIEW) (McGoughy 1996). These tools were used to simulate MOFEP stand development for a 35-year period and visualize stand and landscape structure.

LANDSCAPE MANAGEMENT SYSTEM

Landscape Management System (LMS) is a computer program which integrates landscape-level spatial information, stand-level inventory data, and distance-independent individual-tree growth models to project changes through time. A long-standing problem with software developed for specific tasks is the difficulty of interfacing one program's output to another program's input. LMS is a flexible, extensible system for connecting growth models with analysis, and visualization tools. LMS follows the philosophy that many good tools exist, but they are difficult to use together. The Landscape Management System provides a collection of translation tools that allow the movement of data from one program to another and provides an interface through a Microsoft Windows® environment.

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[2] This software was developed by Dr. Chadwick D. Oliver, Jim B. McCarter and the silviculture group at the University of Washington.

The configuration of LMS used in this analysis included the LMS 1.5, Central States variant of the Forest Vegetation Simulator (FVS), Stand Visualization System (SVS), and the UVIEW Landscape visualization system. Additionally, links and macros are provided to process model output with EXCEL® spreadsheet and ACCESS® database system, which are part of the Microsoft Office® package. The three major component programs (FVS, SVS, and UVIEW) used in this analysis are discussed below.

FOREST VEGETATION SIMULATOR

The Forest Vegetation Simulator (FVS) framework is now the dominant forest modeling tool used by the Forest Service. It started as the Prognosis stand growth model developed by the Forest Service Intermountain Forest Experiment Station (Wykoff *et al.* 1982). This model was built as a distance-independent individual-tree growth model for Idaho, western Montana, eastern Washington, and eastern Oregon. The software developed for the model is of late 1970's vintage, retaining the concept of card image files and specific column input. Despite the age of the Prognosis program, it is very flexible and allows local calibration, and complicated management regimes, and it provides a facility to submit large batch runs. Because of these features and the flexibility of the distance-independent individual tree growth model, the Forest Service began making variants of the model by modifying the internal equations for other geographic regions. The user interface has also been expanded and improved.

There are now 22 variants of the model, which span geographically from Alaska to California and east to the Rocky Mountains. Recently, the equations developed for the TWIGS (Miner *et al.* 1988) growth model were incorporated into the FVS framework, extending the FVS variant coverage east to include the Lake States, Central States, and the Northeast USA. The specific equations used in each variant are described in documents available with the software (Bush 1995).

STAND VISUALIZATION SYSTEM

The Stand Visualization System (SVS) is a program developed by the Cooperative for Forest Systems Engineering, a group that includes both Forest Service and university scientists working on a number of forest systems engineering problems. SVS is a DOS program that reads a flat ASCII file containing tree records and draws these trees on a representative acre (McGoughy and McCarter 1995). Trees can be displayed in three basic configurations: map, profile, and three-dimensional views. Additionally, each view can be drawn in wire frame, solid, and realistic tree images. The program also allows viewing the stand structure with two-dimensional graphs that illustrate diameter, height, crown-ratio, and species classes.

SVS contains a "tree designer" that allows the program to be used in regions other than the one for which the program was originally designed. A complete set of tree images was designed for Missouri species in the FVS Central States TWIGS variant.

UVIEW

UVIEW is a forest landscape visualization tool also developed by the Cooperative for Forest Systems Engineering. This program uses a digital elevation model (DEM), a stand map, and the stand inventory to produce a three-dimensional image of the management area landscape (McGoughy 1996). As forest conditions change, trees of the appropriate size are drawn within each stand boundary but at a lower resolution than the SVS viewer. The user can move the viewing position or the point of focus within the image as desired. This tool is effective for evaluating the aesthetic aspects of a particular forest management treatment.

METHODS

Software Data Structure

The software used for analysis was built on the premise that foresters are managing a collection or portfolio of stands on a landscape. A variety of data are needed to describe the management units.

- Stand data including stand identifiers, site index, age, ecological land type, aspect, slope percentage, elevation.
- A stand inventory made up of individual tree records describing species, diameter, height, crown ratio, and the number of trees per acre each sample tree represents.
- A digital elevation model (DEM), which is a standard method of describing the surface of a particular part of the Earth through a grid of elevation values.

- A stand map, which allows the connection of specific forest characteristics to specific locations on the landscape.

MOFEP Data

During the initial phase of MOFEP, stands were laid out with methods typically used by Missouri Department of Conservation foresters based on slope, aspect, and operability by logging equipment. MOFEP stands were approximately 10 acres in size resulting in between 70 and 73 stands per site. Plot-level data were used to describe stand conditions within each MOFEP site. Plots falling on or adjacent to stand boundaries were rejected. For stands that did not include an inventory plot, a plot from a similar stand was chosen to represent initial stand conditions.

Data from the 1992 inventory were used to define initial stand conditions for all trees ≥ 4.5 in. d.b.h. Variables included species, diameter at breast height, and expansion factor (trees per acre represented by the sample tree). Tree height and crown ratio, measured on a subset of trees, were used where available and estimated from crown ratio equations for the remaining trees.

Analysis

To initialize the analysis, the 1992 MOFEP stand conditions were entered into the LMS program. For this analysis, three sites were chosen to illustrate the treatment classes found in the MOFEP study: site 4 (an uneven-aged management unit), site 5 (an even-aged management unit), and site 6 (a no-harvest unit) (see figs. 1 and 2 in Brookshire *et al.* 1997). The FVS growth model predicts in 5-year time steps, and treatments cannot be conveniently implemented midcycle within the model. Consequently the treatments implemented in the field during the summer of 1996 were applied by the model in year 1997 of the simulation. The first simulated treatments were applied to individual stands as specified in the cutting information provided at the 1995 MOFEP investigators meeting. Distance-independent individual tree growth models do not allow clustered stand treatments, so the uneven-aged management was simulated as 70 percent retention removed proportionally (equal thinning in all diameter classes), with 60 trees per acre (TPA) regeneration. Even-aged management was implemented as either harvest with 300 TPA regeneration or thinning from below to 100 TPA without regeneration.

All stands in the three sites were grown to the year 2027 (35 years). In years 2007 and 2017, stands were treated in a manner similar to the 1997 treatment subject to the following constraints: previously untreated stands are treated first, riparian exclusion stands are not treated, and harvests in the even-aged management unit are dispersed as much as possible. Changes in stands for each site was predicted and the projected basal area and volume were summarized by species over time. Additionally, yield (cut volume plus standing volume) was calculated for each compartment.

RESULTS

A series of computer-generated figures are used to illustrate the possible outputs from the LMS program. Figure 1 illustrates a three-dimensional view of site 4, stand 14 in year 2027. Figure 2 shows the profile of the same stand, and figure 3 illustrates the two-dimensional graphical abilities of the SVS program. Figure 4 illustrates output from the UVIEW program, a landscape view of site 4 in year 2027.

The two treated sites exhibited similar basal area per acre and board foot volume profiles over time. Both treatments slightly reduced residual basal area and increased standing volume over time (figs. 5 and 6).

In the uneven-aged treatment site (4), basal area by species tended to remain relatively constant while faster growing species such as black oak (*Quercus, velutina* Lam.), scarlet oak (*Quercus coccinea* Muenchh.), shortleaf pine (*Pinus echantia* Mill.), and white oak (*Quercus alba* L.) increased in volume (fig. 5A). In this site, the uneven-aged treatment favored scarlet oak in volume increment.

In the even-aged treatment site (5), basal area and volume by species remained relatively constant. White oak volume was favored slightly by this treatment method (figs. 5B and 6B).

The no-harvest treatment site (6) initially had the greatest basal area and volume per acre (figs. 5C and 6C). Both values continued to

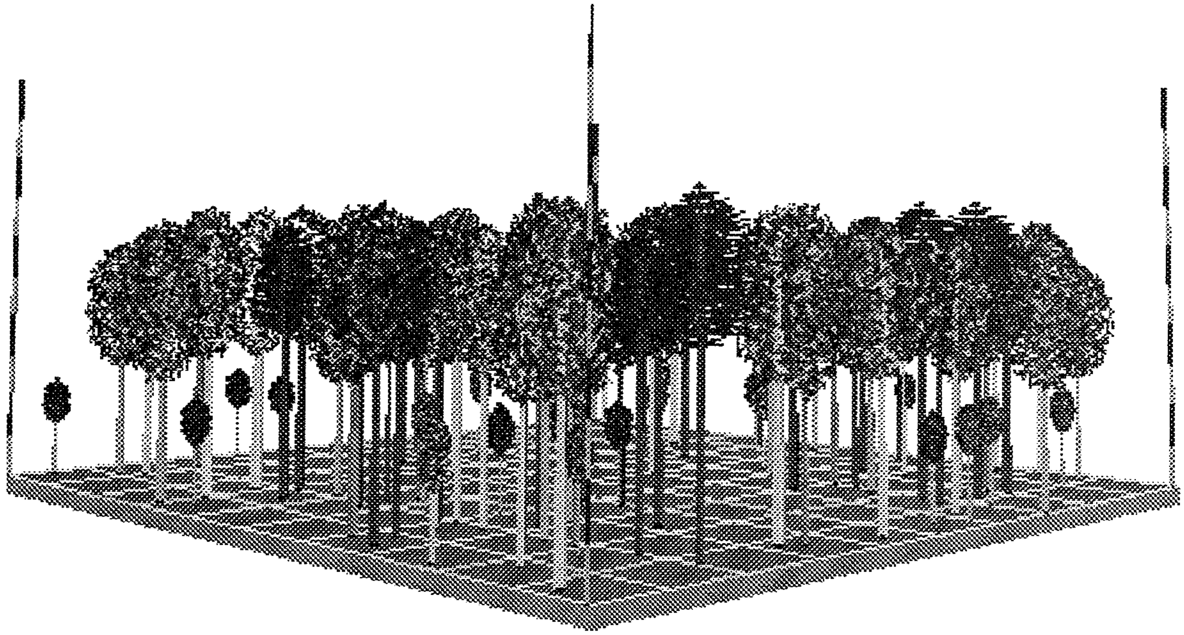


Figure 1.—*Example of output from the Stand Visualization System (SVS) program showing a three-dimensional view of site 4, stand 14, in 2027.*

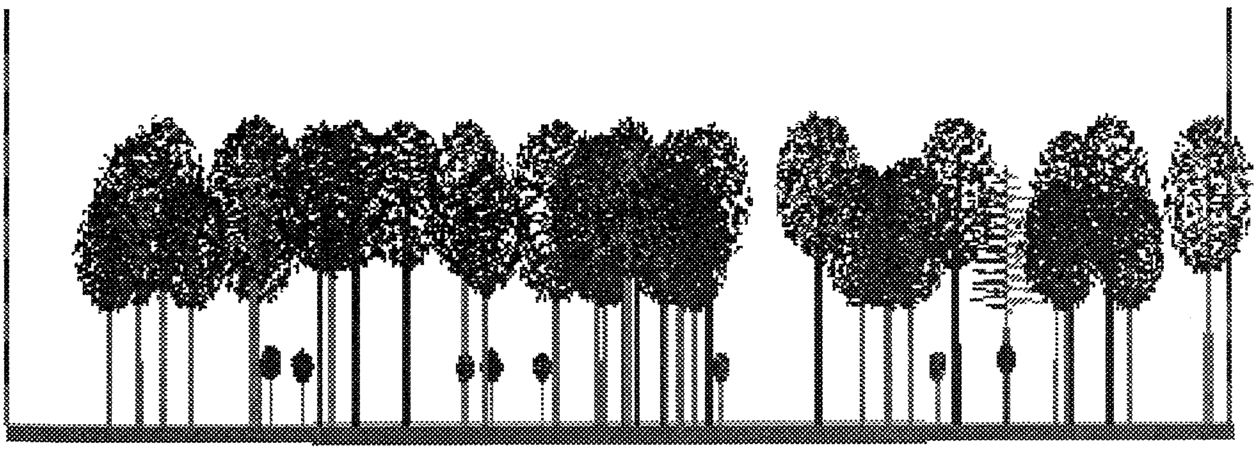


Figure 2.—*Example of profile output for site 4, stand 14, in year 2027 from the SVS program.*

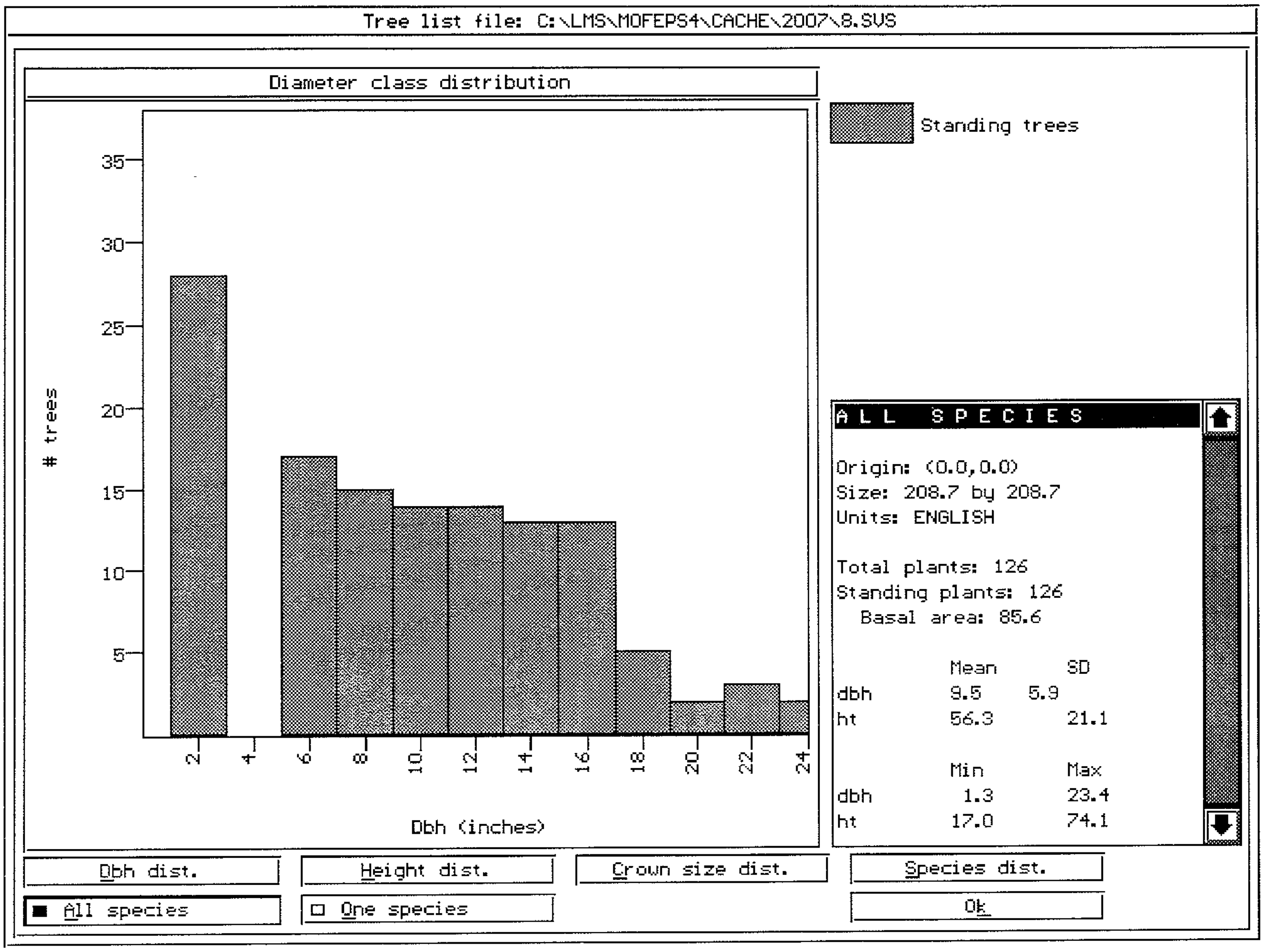


Figure 3.—*Graph of the diameter distribution for site 4, stand 14, in year 2027.*

Figure 4.—*Example of landscape output from UVIEW for site 4 in year 2027.*

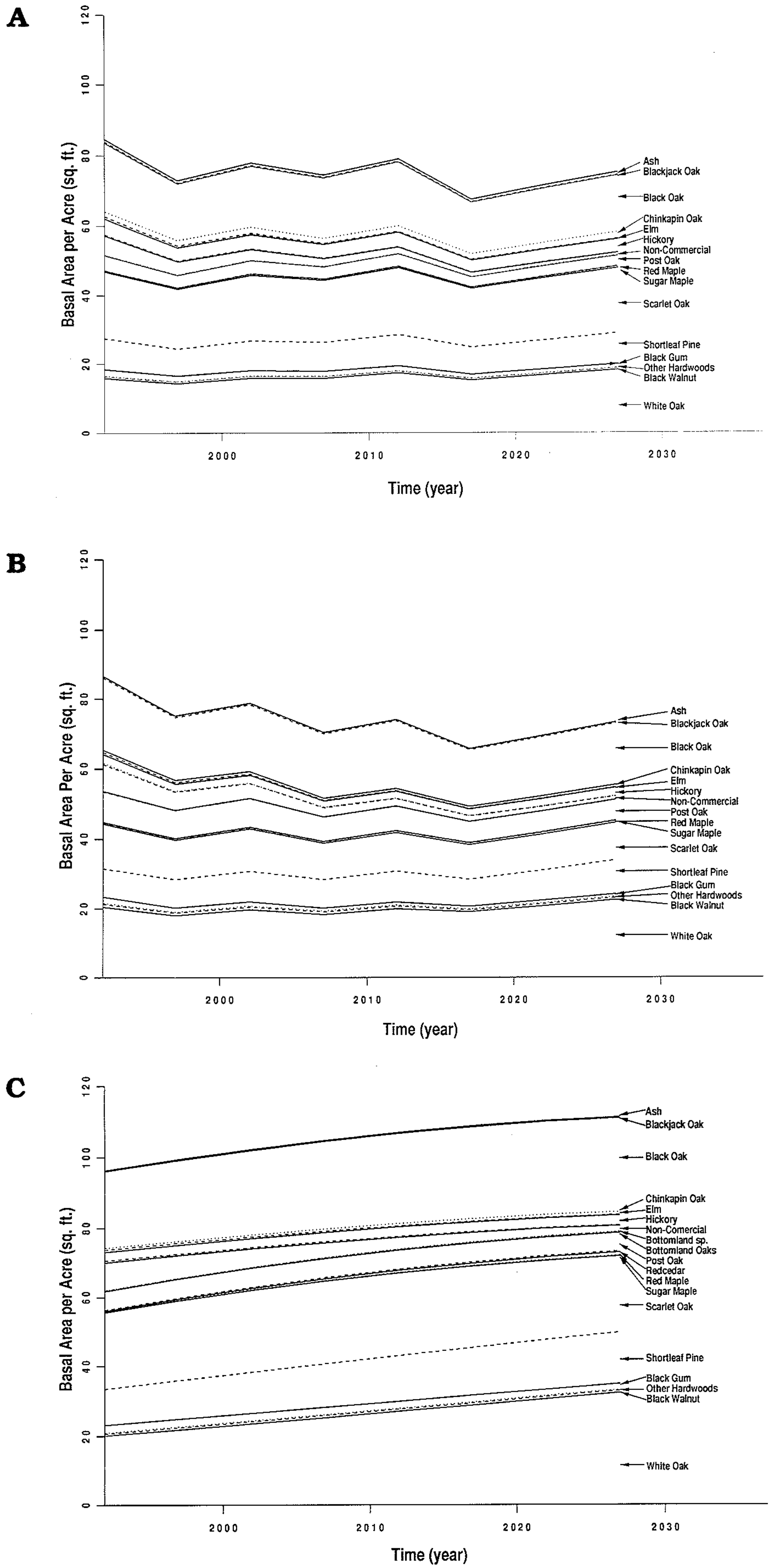
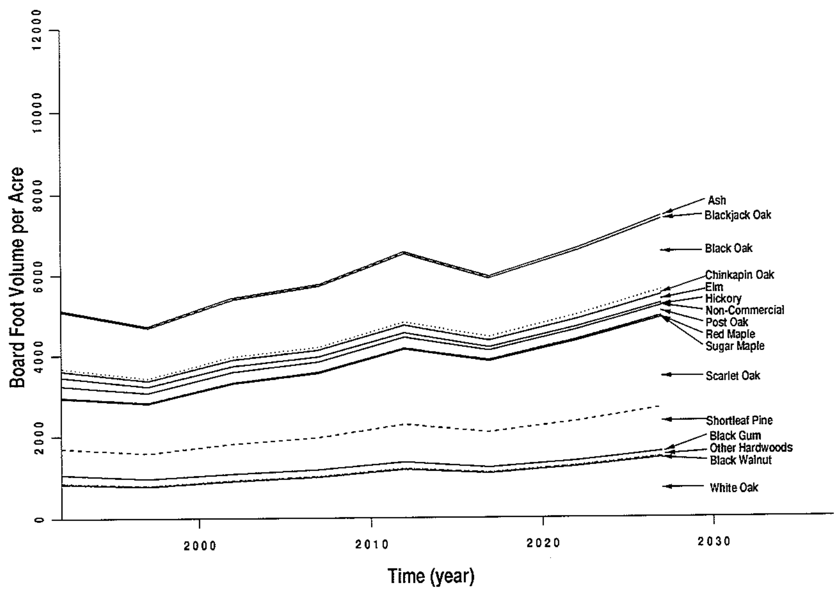


Figure 5.—*(A) Average basal area per acre for site 4 over time. The graph is a cumulative graph; the top line is the total average basal area per acre at each time. The difference between two adjacent lines is the basal area contribution of the species indicated on the upper line.*

(B) Average basal area per acre for site 5 over time.

(C) Average basal area per acre for site 6 over time.

A



B

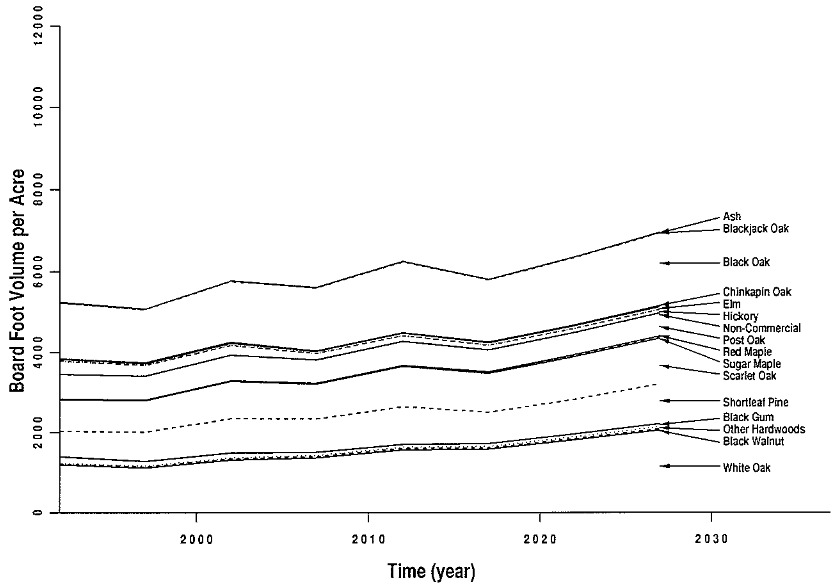
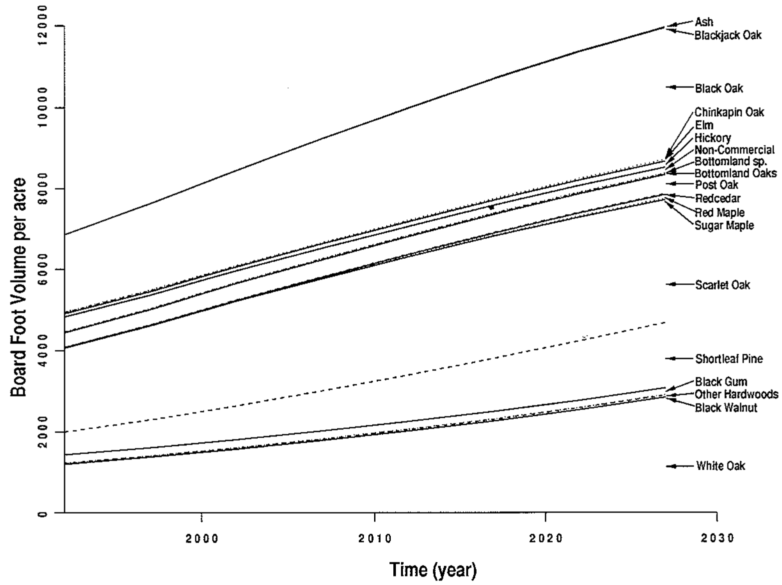


Figure 6.—*(A) Average volume per acre for site 4 over time. The graph was constructed like the basal area graph and can be interpreted in a similar way.*

(B) Average volume per acre for site 5 over time.

(C) Average volume per acre for site 6 over time.

C



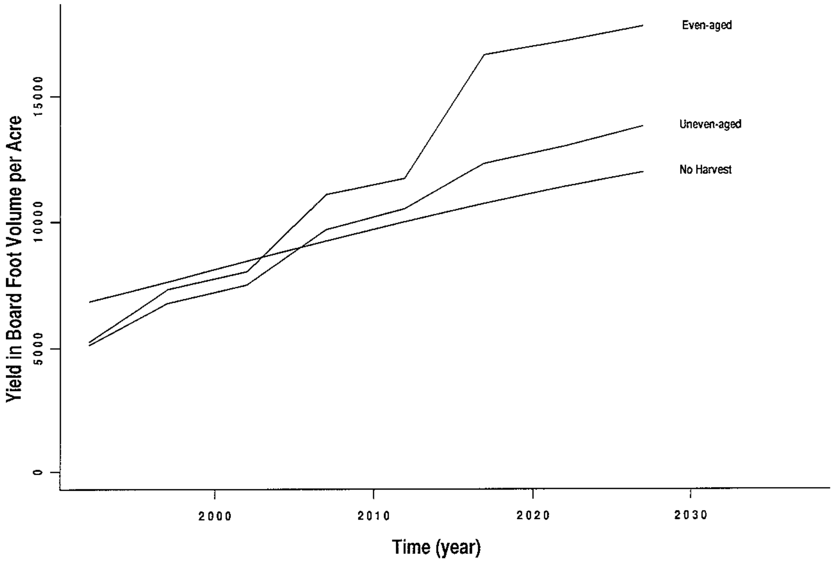


Figure 7.—*Average yield per acre for each site. Yield is standing volume plus cut volume.*

increase during the growth simulation period. The greater stand densities resulting from no thinning tended to favor basal area increases in black oak and white oak and to disfavor non-commercial species. Black oak, scarlet oak, shortleaf pine, and white oak increased in volume relative to other species. This treatment resulted in the greatest standing volume at the end of the projection period.

To evaluate the volume production by site and treatment, total volume yield was calculated for the 35-year simulation period (fig. 7). Total yield for each site includes cut volume plus the current standing volume. Figure 7 illustrates that the no-harvest treatment produced the least total yield over the 35-year simulation. The uneven-aged treatment produced intermediate yields and the even-aged treatment produced the greatest yield per acre over time.

DISCUSSION AND CONCLUSION

Assuming that the representations of the treatments and the projections in this analysis are reasonably accurate, uneven-aged and even-aged management produced equivalent average basal area and average standing volume per acre. The no-harvest treatment produced the largest average standing volume. In terms of average yield per acre, the even-aged treatment produced the greatest yield over time, the uneven-aged treatment produced an intermediate yield, and the no-harvest treatment produced the lowest average yield per acre over the simulation period.

Although projections of forest change are seldom precise they are useful for comparing the anticipated outcomes of alternative management practices. As with all predictions, the variance of the estimates increases exponentially with the length of prediction time. However, this applies to all the predictions equally. These projections are reasonable estimates of the average outcome of stands like these over the next 35 years. They serve to illustrate the likely changes in tree growth due to stand density over that period.

This paper also illustrates several of the currently available tools for projecting forest growth for the Missouri Ozarks and some of the ways this information can be used. These tools provide a framework for both growth and yield estimates as well as a way to visualize the changes in forest structure on the landscape due to silvicultural treatments. Growth analysis of the MOFEP treatment indicate the both even-aged and uneven-aged treatment will maintain equivalent basal area and volume per acre averages. The no-harvest treatment will maintain the largest standing volume but the least total yield over time.

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