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Growth projection and valuation of restoration of the shortleaf pine–bluestem grass ecosystem

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ABSTRACT

The fire-dependent shortleaf pine–bluestem grass ecosystem that existed prior to European settlement is being restored on approximately 62,700 ha in the Ouachita National Forest. The restoration effort's economic effects are not completely understood. This study will provide the Forest Service with a framework for better communicating the biological and economic impacts of future forest plans and amendments. It also seeks to provide information on how shortleaf pine responds to different management regimes and the implicit cost to maintain the endangered red cockaded woodpecker habitat, and the economic consequences of transitioning from the traditional management regime to a regime which restores the shortleaf pine–bluestem grass ecosystem. The paper suggests by adopting the new pine–bluestem management regime, timber harvests in the pine–bluestem area decline by 25% during the 100-year simulation period, which will incur an additional implicit cost of $72/ha/year to maintain the red cockaded woodpecker habitat. An implied value for each pair of woodpeckers amounts to either $10,550 per year (for the desired 400 total pairs) or $16,880 per year (for the 250 reproducing pairs). Timber sale marking costs decline, while prescribed burning costs increase. The success of the pine–bluestem restoration requires the maintenance of a burning regime that prevents competing vegetation from occupying the middle canopy layer. Maintaining the pine–bluestem ecosystem will be difficult if environmental regulations become more stringent.

1. Introduction

The Ouachita National Forest received approval in 1996 for an amendment to its Forest Plan that would allocate 10% of the Forest to long-rotation silviculture. The purpose of the new management area is to restore pre-European settlement forest conditions, and recreate habitat for the endangered red-cockaded woodpecker.

In this new management area, the fire-dependent shortleaf pine (*Pinus echinata* Mill.)–bluestem grass (*Andropogon* spp.) ecosystem that existed prior to European settlement is being restored on approximately 155,000 acres in the Ouachita National Forest. The restoration effort's economic effects are not completely understood.

The goal of this study is to answer the following questions: 1) Will the new silvicultural prescriptions imposed upon the new management area measurably alter the volume of timber available for removal? 2) To what degree will revenue and cost streams be affected? 3) What is the implied value of a breeding pair of red cockaded woodpeckers? This study will provide the Forest Service with a framework for better communicating the biological and economic impacts of future forest plans and amendments. It also seeks to provide information on how shortleaf pine trees respond to two different management regimes, and the economic consequences of transitioning from one regime to the other.

We hypothesize that by converting these stands to long-rotation (120 years) medium-density management, the Forest Service will lose some revenue, even though the stumpage harvested during the final thinning and the regeneration phase will be of higher-than-average quality and value. This hypothesis will be tested by simulating the growth and yield of stands managed under both the current and pine–bluestem systems and comparing the net present value of their respective cost and revenue streams.

This paper addresses the question of how the physical outputs from traditional even-aged and pine–bluestem management compare and if the slightly lower stocking and longer rotations of the pine–bluestem scenario will reduce volume production.

2. Previous work

Shortleaf pine (*Pinus echinata* Mill) has the widest range of southern pines which amounts to one-quarter of the southern pine volume and is second only to loblolly pine among the southern pines of the United States. It ranges from southeastern New York to eastern Texas and grows in 22 states over more than 1,139,600 km^2 (Willet, 1986). However, shortleaf pine growth and yield research has been the most neglected among the major southern pines. Several attempts have been made to analyze shortleaf pine growth and yield

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including Murphy (1982), Murphy (1986), Murphy (1986) and Lynch et al. (1999). In 1985, Murphy and Farrar (1982) developed models for predicting projected basal areas and current and projected volumes for selection-managed stands of shortleaf pine. Murphy and Baker (1991) also have reported volume growth data from three experimental watersheds in the Ouachita Mountains, Arkansas focusing on the selection management in shortleaf pine forests. Lynch et al. (1999) have developed a distance-independent individual tree growth model for naturally-occurring shortleaf pine forests. The model consists of individual tree basal area growth, survival, and dbh-height equations. In the Ouachitas and southern Ozarks, the Shortleaf Pine Stand Simulator model (Huebschmann et al., 1998) provided a tool to model the development of naturally regenerated shortleaf pine stands, whether even-aged (Lynch et al., 1999) or uneven-aged (Huebschmann et al., 2000). The model requires inputs such as stem density by diameter class. This enables users to predict growth over different time horizons for various treatment regimes of treatment. Guldin and Baker (1988) reassert the necessity to evaluate stand development alternatives under different levels of commercial thinning in a restoration prescription. Individual tree models generate stand and stock tables that contain data on diameter distributions in terms of stem density by size class. To apply growth and yield models in the context of restoration, foresters should quantify desired future conditions, and then apply the growth and yield models to analyze the degree to which different treatments might develop the target. A growth and yield model for naturally regenerated mixed shortleaf pine forests in the southern United States of America was developed by Schulte and Buongiorno (2004). Their attempt was to describe a site- and density-dependent, multi-species matrix model for predicting the development of naturally-regenerated shortleaf pine stands in the mid-south of the United States. Equations for three characteristics, tree growth, tree mortality, and recruitment were included in the model. The model structure was similar to that in Buongiorno et al. (1995). Density-dependent parameters and multiple species, as in Buongiorno et al. (1995), and site effects as in Kolbe et al. (1996) were taken into account. This model was very similar to the model for loblolly pine (*Pinus taeda* L.) in Lin et al. (1998). The major objective was to determine the form of the equations and the values of the parameters for mixed shortleaf pine forests. Schulte and Buongiorno (2004) found that the recruitment rate was related negatively to stand basal area, and positively to the number of trees of the same species group in the smallest diameter class. They compared this study with other growth models.

Shortleaf pine is one of the most important tree species in eastern Oklahoma as well as adjoining regions of Arkansas and southern Missouri. Shortleaf pine is important economically as a timber producing species. In southeast Oklahoma, sawmills use shortleaf pine to produce southern pine lumber, and shortleaf pine pulpwood is used to produce paper products. Shortleaf pine is also an important component of wildlife habitat for species such as the red cockaded woodpecker. The USDA Forest Service Ouachita National Forest is engaged on a project of restoring the shortleaf pine–bluestem grass ecosystem on a portion of its acreage. This forest type is thought to be the typical pre-settlement forest type on many acres of southeastern Oklahoma and southwestern Arkansas. These considerations underlie the importance of the study of the growth and development of shortleaf pine.

Since 1985 we have cooperated with the USDA Forest Service Southern Research Station and the Ozark and Ouachita National in Arkansas and Oklahoma to establish and maintain over 200 plots on which shortleaf pine growth data have been collected. The plots are located in Arkansas and Oklahoma on the Ozark and Ouachita National Forests. On each plot, tree measurements such as diameter and height are made on an approximately 5-year interval. Using these measurements, the growth of individual trees can be determined, as well as changes in the values of forest attributes such as green weight and number of trees per acre. These repeated tree measurements have been used to develop a computer-based simulator of the growth of shortleaf pine forests. The simulator is SLPSS or the Shortleaf Pine Stand Simulator (Huebschmann et al., 1998). The simulator can be used to predict shortleaf pine forest attributes such as green weight and number of trees per acre at future times. These attributes can be used to assess future economic values for shortleaf pine forests.

3. Methods

The economic impact of augmenting the endangered red cockaded woodpecker population by restoring the shortleaf pine–bluestem grass ecosystem on the Ouachita National Forest is explored. An individual-tree growth and yield simulation program was developed from equations for the purpose of comparing the timber harvest volumes available under the pine–bluestem management regime with those under traditional even-aged management. Data from historical timber sales on the Ouachita and Ozark National Forests were used to derive a valuation model for estimating the change in timber sale revenue resulting from the adoption of the pine–bluestem regime.

The methods for this study are developed as follows: 1) creating a system of equations that predicts how the growth and yield of shortleaf pine trees change under different conditions and management scenarios, and comparing the stumpage volume produced under pine–bluestem with that from traditional even-aged management; 2) estimating the revenue from timber harvest occurring under each management scheme; and 3) use these results to estimate the implied value of nesting pairs of red cockaded woodpeckers.

4. Growth and yield projections

Two major questions are addressed in the growth and yield projections: How do the physical outputs from traditional even-aged and pine–bluestem management compare and will the slightly lower stocking and longer rotations of the pine–bluestem scenario reduce volume production?

Traditional, even-aged natural stands on the Ouachita National Forest designated as “pine” or “pine–hardwood” typically carry over 13.8 m^2/ha of basal area (BA), with 80% of that BA in pine. Rotation lengths are set between 50 and 100 years, depending upon site quality (USDA Forest Service, 1990). The Forest Plan calls for 2.3 m^2/ha of overstory pine, and an equal amount of hardwood BA, to be carried over from one rotation into the next. The Forest Plan also stipulates that even-aged stands be burned every 4 years, except for stands in regeneration or when other extenuating circumstances exist. In the new management area, however, the Forest Service intends to replicate stand conditions similar to those pictured in Mattoon (1915) and described in accounts written by early European explorers and elsewhere (e.g., du Pratz, 1774; Lewis, 1924; Nuttall, 1980; Foti and Glenn, 1991). Specifically pine BA will usually exceed 13.8 m^2/ha. Stands left uncut for several entry periods may accumulate over 23 m^2/ha. Hardwoods comprise either 10% to 15% of a stand (in terms of stems per hectare if average diameter $<$ 12.7 cm.), or 2.3 to 3.4 m^2/ha of BA (if average diameter $\geq$ 12.7 cm.). The goal is to produce as many older ($\geq$ 50 years) stands as possible with 13.8 m^2/ha of pine BA and 2.3 m^2/ha of hardwood BA. Rotations are lengthened to 120 years. Regeneration cuts reduce pine BA to 9.2 m^2/ha, and that residual BA is carried over for an indeterminate length of time into the subsequent rotation.

In the absence of growth models specifically developed for the pine–bluestem forest type, this study combined published growth equations for even-aged, natural shortleaf pine in the Ouachita Highlands (Lynch et al., 1999) with their counterparts for hardwoods in the Ozark Mountains (Murphy and Graney, 1998) into a stand growth simulator. The basic input to the simulator consists of initial stand conditions in the form of either a stand table (number of trees by

Table 1
Initial regeneration conditions assumed to exist in 20-year-old, subsequent-generation stands, by shortleaf pine site index class. These values were used for both pine–bluestem and traditional management scenarios.

Site index class (m)	Basal area (m^2/ha)		% of hardwood BA in hard mast species
	Shortleaf	Hardwood	
15	15.0	1.1	50
18	13.8	2.3	40
21	12.6	3.4	30
24	11.5	4.6	20

diameter class and species group) or inventory data from field plots. Each tree (or group of trees in a diameter-class increment) is grown on a year-by-year basis. Because no stand tables existed for the new management area at the outset of this project, other methods were used to create the input needed for the simulator. The simulator allows considerable flexibility in the execution of thinnings. Excess trees can be removed either via "low" thinnings, or by specifying the number of stems to remove in a particular diameter class. Low thinnings were used most often in this study to favor the largest-diameter stems. Only during the first thinning in a young stand that contained residual overstory trees was the residual stand table specified.

Stand growth and yield were simulated over a 100-year period, beginning in the year 2000. One set of simulations treated the stands with a traditional even-aged prescription, while the other set of simulations assumed a pine–bluestem prescription. For both scenarios, the simulated second-generation stands were assumed to contain the regeneration conditions shown in Table 1 by age 20, in addition to the overstory left at the end of the initial rotation.

5. Growth simulation analysis

Of the 62,757 ha in the new management area, 40,246 ha will be managed as pine–bluestem stands. The remainder of the area consists of roads, riparian areas, or stands containing no shortleaf pine. Simulations were conducted on the 40,246 ha.

6. Example stand–level comparison

Table 2 displays the merchantability specifications used in this analysis. Statistically valid hardwood valuations could not be derived from the historical timber sales (see Section 3) because so few contained hardwood volumes. Although the hardwood component is important from a competition standpoint when simulating stand growth, historically it has generally contributed a negligible amount to sale revenue. Consequently, the hardwood volumes predicted by the simulator will be ignored in the economic analysis. Fig. 1 compares the growth of a stand under the traditional and pine–bluestem scenarios. Both scenarios begin in 2000 with the same stand conditions: stand age = 20 years; $SI_{pine} = 18.3$ m; approximately 1250 pine and 75 hardwood stems per hectare; and pine and hardwood BA of 13.8 and 3.4 m^2/ha, respectively. First thinning occurs in 2010 when the stands are 30 years old, reducing BA to the target residual levels.

Up until the regeneration cut, virtually all of the pine volume removed in the traditional scenario is comprised of pulpwood, as evidenced by the relatively smooth increase of the pine sawlog volume curve. Only when the regeneration cut occurs in 2050, at stand age 70 years, is the pine volume primarily sawlog size. The overstory is reduced in 2060 to 2.3 m^2/ha each of pine and hardwood, decreasing the amount of competition exerted on the seedlings/saplings (age 10 years in 2060). In 2080, when the regeneration has reached age 30, the remaining mature stems are removed, leaving the younger trees to occupy the site.

By maintaining 2.3 m^2/ha less pine BA in the pine–bluestem scenario between stand ages 40 and 60 years, sawtimber volume accumulates slightly more quickly than in the traditional scenario. This assertion is supported by observing that more sawlog volume is removed from the pine–bluestem stand during the thinning at age 50 years than from the traditional stand. The two simulations shown in Fig. 1 are quite comparable in their cumulative sawtimber volume growth. By the end of the 100-year projection period, volume production in the pine–bluestem scenario is only 15% less than the traditional scenario.

Projections begin at age 20 years, with initial shortleaf BA levels of 6.9, 13.8 or 20.7 m^2/ha. Pine SI is either 15 or 21 m (base age 50 years). After completing growth simulations for the pine–bluestem and traditional management scenarios, the volumes of intermediate and final harvest volumes were aggregated into hypothetical timber sales. Fig. 2 compares the sawtimber and pulpwood (roundwood and topwood) harvest volumes produced by the traditional management and pine–bluestem scenarios during the 100-year simulation period. Harvest volumes vary from year to year, particularly under the traditional management scenario.

Over the entire period, by converting to the pine–bluestem management regime, sawtimber harvest volume drops by 26% (about 4.0 million m^3); pulpwood harvest volume drops by 23% (about 943,000 m^3); and total (sawtimber and pulpwood) harvest volume drops by 25% (4.8 million m^3). The proportion of total volume in sawtimber remains essentially stable at about 78%.

Table 2
Merchantability specifications used in this study.

Attribute	Value	Attribute	Value
Stump height (m)		Minimum piece length (m)	
Pulpwood	0.15	Pulpwood	1.52
Sawlog	0.30	Sawlog	2.44
Top diameter limit (cm.)*		Minimum tree length (m)	
Pulpwood (o.b.)	10.2	Pulpwood	4.57
Pine sawlog (i.b.)	17.8	Pine sawlog	4.88
Hardwood sawlog (i.b.)	25.4	Hardwood sawlog	3.66

* o.b. is outside bark; i.b. is inside bark.

7. Valuation model

The simulated harvests created in the previous section and their associated volume estimates provide the basis for the comparisons of value discussed in this section. Data from 150 Ouachita and Ozark National Forest timber sales, covering the period from June 1992 to December 1998, were used to derive a model relating the revenue generated by those sales to their characteristics. The model derived to explain historical timber sale prices, and to predict future sale revenue is as follows:

$$\text{Revenue}_i = \exp\begin{pmatrix} b_0 + b_1 \ln TSV_i + b_2 \ln TPV_i + b_3 \ln SVPA_i \\ +b_4 \ln SVPT_i + b_5 \ln PPIR_i \end{pmatrix} \quad (1)$$

where

Revenue_i is revenue, in thousands of 1996 dollars, from timber sale i;
TSV_i is total pine sawtimber volume, in thousands of m^3, from timber sale i;
TPV_i is total pine pulpwood – i.e., roundwood plus topwood – volume, in thousands of m^3, from timber sale i;
$SVPA_i$ is average sawtimber volume, in m^3 per hectare, from timber sale i;
$SVPT_i$ is average sawtimber volume, in m^3 per tree, from timber sale i;
$PPIR_i$ is a ratio created by dividing the producer price index (PPI) for southern yellow pine #2 dimension lumber (average of

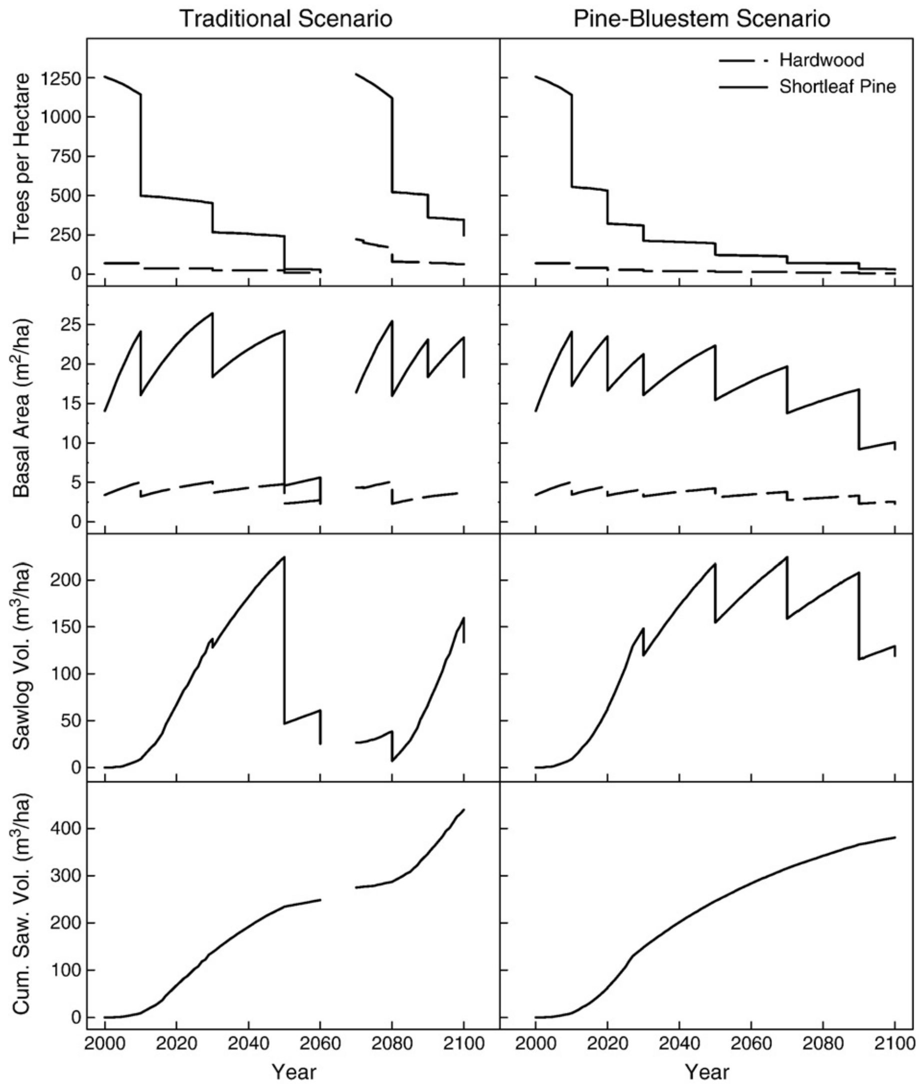

Fig. 1. Comparison of stand dynamics under traditional and pine–bluestem management of a stand with initial conditions: age 20 years, SI_{pine} 18.3 m, and 13.8 and 3.4 m^2/ha, respectively, of pine and hardwood BA.

1996 prices = 1) by the sawlog PPI (average of 1996 prices = 1) at the time sale *i* occurred;

"ln" is the natural logarithm operator; and

$b_0, b_1, \ldots, b_5$ are parameter estimates

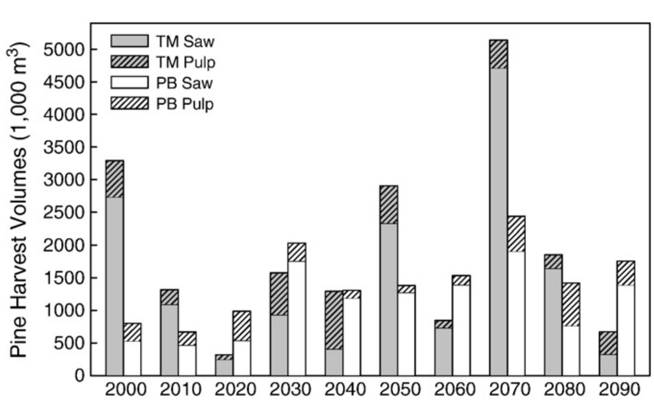

Fig. 2. Comparison of projected traditional management (TM) and pine–bluestem (PB) sawtimber (saw) and pulpwood (pulp) harvest volumes (m^3), by decade.

8. Result

The total revenue generated during each decade in the new management area under traditional and pine–bluestem management was obtained by summing the revenues from the simulated timber sales that occur in each scenario during that decade. Fig. 3 illustrates the comparison between the scenarios. For example, the pine–bluestem scenario returns in 2000 only 16% of the revenue generated by traditional management. The greatest absolute disparity occurs in 2070 when the traditional scenario produces about $170 million (undiscounted) more revenue than the pine–bluestem scenario. Traditional management does not return more revenue in every decade. However, over the entire simulation period, pine–bluestem management returns 75% of the undiscounted revenue generated by traditional management (660 versus 875 million dollars). In present-value terms, discounting the revenue streams back to 2000 at a real annual rate of 4% (USDA Forest Service, 1990), the pine–bluestem scenario returns only half of the revenue generated by traditional management (131 versus 268 million dollars). The comparatively large harvests in 2000 and 2010 give traditional management a substantial present-value "advantage." However, in most years, the revenue foregone from the new management area could be recouped by offering a few additional sales elsewhere on the National Forest.

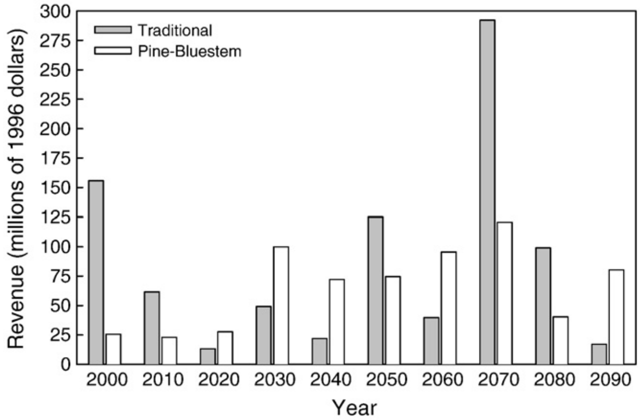

Fig. 3. Revenue generated from hypothetical timber sales in the new management area, by decade, under the traditional even-aged, and pine–bluestem management scenarios.

In the new management area, we quantified differences in cost streams resulting from the transition from traditional to pine–bluestem management. For this analysis, cost comparisons were limited to timber marking and prescribed burning. Other costs are not expected to vary enough between management scenarios to warrant study.

The Poteau District of the Ouachita National Forest follows a policy of entering each stand once per decade to determine if a timber sale is needed. The labor and materials expended to inventory and select the trees to be harvested comprise a substantial share of the cost associated with a timber sale. The new management area under the pine–bluestem management will carry somewhat fewer stems for longer periods, and will result in lower marking cost than in the traditional scenario.

Fig. 4 compares the costs, by decade, incurred for marking thinning/harvest cuts under both the traditional and pine–bluestem management scenarios. Over the entire simulation period, total undiscounted expenditures for marking pine–bluestem sales are 80% of the traditional scenario's costs (8 versus 10 million dollars). The difference in total expenditures has a present value of $1.3 million.

One of the features of pine–bluestem management is a more aggressive (3-year) burning schedule. The Poteau Ranger District has traditionally attempted to maintain a 4-year burning cycle. During years of favorable weather, the district staff estimated in 2000 that they could burn 8100 ha/year given current staffing and resources.

The area burned on an annual basis under the two management scenarios, and the present values (1996 dollars) of the burning expenditures incurred during the entire simulation period are displayed in Table 3. During the simulation period, the pine–bluestem scenario burns 35% more area and expends 43% more funds than the traditional scenario. During an average year, district staff will need to burn 50% more than their capacity in 2000.

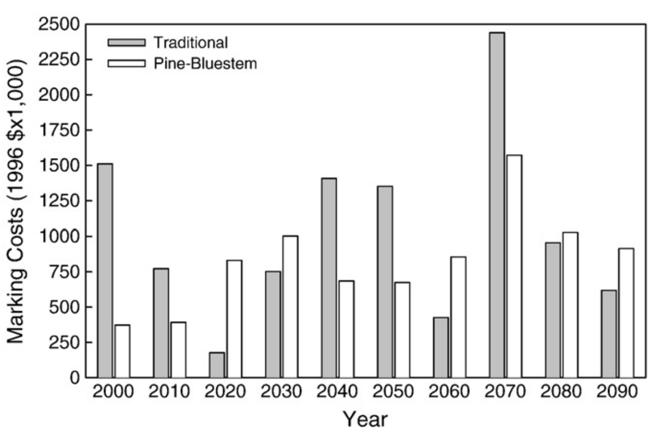

Fig. 4. Comparison of undiscounted timber sale marking costs (thousands of 1996 dollars) for harvests under the traditional and pine–bluestem management scenarios, by decade.

Table 3
Comparison of hectares prescribed burned per year, and present values (low and high estimates) of burning expenditures over the entire simulation period, by management scenario.

	Hectares burned per year				Present value of total expenditures (millions of 1996 dollars)	
Management scenario	Mean	Standard deviation	Minimum	Maximum	Low estimate	High estimate
Traditional	8962	2023	3676	10,057	1.73	6.47
Pine–bluestem	12,359	1227	9996	13,410	2.47	9.24

9. Implications for management

Because of the greater time between harvests and a more open stand structure, timber sale marking costs decline by 59% (present value terms) in the pine–bluestem scenario. However, prescribed burning expenditures will rise by 43% as a result of a shorter burning cycle. A larger budgetary commitment will be required to maintain this fire-dependent ecosystem. By adopting the new management regime, timber harvests in the pine–bluestem area decline by 25% during the 100-year simulation period. This translates into a cumulative loss of timber sale revenue in present-value (1996 dollars) terms of $137 million, or about half of what the area might have generated under traditional management.

The accumulated-volume production values demonstrate that traditional management yields the greatest overall volume. Once the new management area has been converted to the pine–bluestem forest type, it will incur an additional implicit cost of $72/ha/year (applying the Forest Service's preferred discount rate of 4%) to maintain the red cockaded woodpecker habitat. For all 40,245 ha of the new management area managed for pine–bluestem, this cost amounts to $2.9 million per year. When combined with the $137 million decline in the present value of projected timber sale revenue from the area (or $1.37 million per year), the total cost rises to $4.2 million per year. This translates into an implied value for each pair of woodpeckers of either $10,550 per year (for the desired 400 total pairs) or $16,880 per year (for the 250 reproducing pairs).

The success of the pine–bluestem restoration requires the maintenance of a burning regime that prevents competing vegetation from occupying the middle canopy layer. Despite the Ouachita National Forest's adherence to smoke management policies, the capricious behavior of weather patterns can turn an otherwise successful burn into a public relations nightmare. By adopting a more aggressive burning schedule, similar situations are more likely to occur.

The substantial hardwood fuel load present in many new management area stands complicates smoke management. Burns in these stands smolder for several days, thereby increasing the opportunity for problems. Once the hardwood fuel is reduced and herbaceous vegetation comprises the bulk of the fuel, experience in other parts of the South indicates that smoke management problems improve.

10. Conclusion

In the portion of the Ouachita National Forest where the pine–bluestem management scenario is imposed, total timber harvest volume declines by 34% (compared with the volumes available under the traditional scenario) during the 100-year-long simulation period. The longer rotations associated with the pine–bluestem scenario change the product mix, with sawtimber comprising a greater proportion of total volume. This change to a higher-valued product mix is reflected by a decline in revenue from the affected area – in undiscounted terms – of only 25%. The present value of the harvest volume declines by 38%, primarily because a large proportion of the overall pine–bluestem harvests occurs late in the simulation period. Timber sale marking costs decline, while prescribed burning costs increase dramatically.

Maintaining the pine–bluestem ecosystem will be difficult if environmental regulations become more stringent. Alternative methods of controlling competing vegetation may be used, but generally they are either less effective or more expensive than prescribed burning. It suggests that the pine bluestem management has significant economic consequences and that the plan may not be sustainable because of staffing and resource issues and other environmental issues such as smoke management.

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