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Financial performance of mixed-age naturally regenerated loblolly-hardwood stands in the south central United States

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Abstract

To estimate the financial performance of a natural mixed species and mixed-age management in the loblolly-pine forest type, we examined 991 FIA plots in the south central states. The plots were of the loblolly pine forest type, mixed-age, and had been regenerated naturally. We gauged the financial performance of each plot from the equivalent annual income (EAI) produced by growth and harvest, between two successive inventories. The real price EAI (REAI) measured the financial performance based on the real price change, net of inflation, between surveys. The constant price EAI (CEAI) measured stand productivity at prices at the time of the first survey. Thus, the REAI is a measure of real economic performance, including timber growth and price changes. In contrast, the CEAI is a quantity index of timber growth, the growth of each product being weighted by its price. During the period 1977-1994, the main determinant of the REAI was the price change. Due to an overall favorable price trend, the mean REAI ($158 ha-' year-') was much greater than the mean CEAI ($24 ha-' year-'). Due to increasing prices, the best performing plots had very high stocking levels. Thus, the best financial strategy was to hold the stock, making the opportunity cost of conservation negative. Instead, CEAI tended to be lower on stands with high basal area, and higher in stands with many trees, a low share of hardwoods, and many trees near sawtimber size.

Keywords: Investment; Uneven-aged management; Price, Loblolly pine; Valuation; Growth; Productivity

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1. Introduction

The 42 million hectares of forested land in the south central United States (Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee and Texas) occupy 58% of the land area covered by the Southern Forest Inventory and Analysis (SO-FIA) work unit (Southern Forest Experiment Station, 1999). The loblolly-shortleaf pine forest type covers 26% of this forested land. Much of this loblolly pine forest is under even-aged management, but a substantial portion, 2.3 million ha, consists of mixed-age stands of loblolly pine and hardwoods.

There is a growing interest in uneven-aged silviculture in this forest type, especially among non-industrial private owners and within government agencies. Luloff et al. (1993) found that non-industrial private forest owners are well aware of the important non-timber benefits of forests, and likely to act on their concerns. Public land managers must respond to an array of pressures including a widespread distaste for clear-cutting usually associated with even-aged forestry (Hill, 1992; Guldin, 1996).

Silviculturally, uneven-aged management of loblolly-pine forests is feasible. This forest type 'lends itself, perhaps more than any other species in the world, to silvicultural flexibility' (Baker et al., 1996). And, according to Guldin (1996) uneven-aged silviculture is 'the most forgiving and most flexible among four major high-forest reproduction methods. It epitomizes a silvicultural philosophy that creates, rather than limits, future options'.

Economically, this approach has some advantages. It avoids the high cost of site preparation and planting. It produces good yields and high value trees (Williston, 1978). The cost of rehabilitating poorly stocked stands is less than conversion to even-aged stands. Thus, large areas of cutover, private, non-industrial forestlands could be restored with this system (Redmond and Greenhalgh, 1990). With the improvement of hardwood markets in the south central, hardwood trees have become valuable. This mix of species reduces financial risk to the extent that the prices of hardwoods and softwoods do not perfectly follow the same trends.

There are, however, drawbacks to uneven-aged management, including higher costs of the technical expertise (Hotvedt and Ward, 1990), more incidental damage to the growing stock during selection harvests (Stokes et al., 1993), and the difficulty of introducing genetically improved species for significantly higher production.

With the advantages of uneven-aged silviculture potentially outweighing the disadvantages in many places, the need exists for more information on its financial performance. Several studies have confirmed its economic feasibility (Chang, 1990; Guldin and Guldin, 1990; Redmond and Greenhalgh, 1990; Schulte and Buongiorno, 1998). This study uses the extensive SO-FIA database to estimate the actual financial performance of mixed-age loblolly-hardwood plots throughout the south central region, to assess the range of this performance for different owners, and to determine what factors have most affected financial performance and productivity.

Understanding the financial performance of these forests is important for all owners. In particular, institutional investment in US timberland has grown from less than $1 billion in 1989 to well over $5 billion in 1998 (Binkley, 1999). One reason for institutional investment is that timberland is viewed as a good hedge against inflation (Stolz, 1989). And, it diversifies investment portfolios, producing stable overall returns, an important goal of institutional investors (Redmond and Cubbage, 1988; DeForest et al., 1991). There is also investor satisfaction in the concreteness of land and trees. The fact that the combined loss from fire, insects and disease is less than 0.2% year^{-1} on timberland strengthens this view of forests as secure investments (Stolz, 1989). Last, real timber prices in the south have increased steadily in the last decade, generating high returns, though there is reason to believe that this trend will flatten (Binkley, 1999; Zhu et al., 1999).

New objectives of the new forest owners may drastically change the forest landscape. Will the amenity values of forests lose out under the control of firms interested in maximizing income? Or, is management of diverse, natural-looking forest ecosystems compatible with financial objectives on some lands? Does institutional investment mean an increase in forest monocultures or is it an opportunity to diversify large blocks of forest-land? To address these questions we examined the productivity of the mixed-age mixed loblolly-hardwood forest in the south. If this forest can perform well financially, perhaps we have identified an alternative for institutional and other investors to both profit from their timber investment while contributing to regional ecological richness.

2. Methods

2.1. Measure of financial performance

The equivalent annual income (EAI in $\$ha^{-1}$ year-‘) was used to measure the financial performance of a plot of land between two inventories (Buongiorno and Hseu, 1993). The EAI is based on the net present value (NPV) obtained from 1 ha of land, between the two inventories:

$$\mathrm{NPV} = \sum_{i=1}^{t-1} \frac{H_i}{(1+r)^i} + \frac{V_t}{(1+r)^t} - V_0 \quad (1)$$

where V_0 = the commercial value of the stand of trees ($\$ha^{-1}$), excluding land, at the time of the first inventory. This is what the owner would have gotten by selling the timber at that time; V_t = the commercial value of the same stand of trees ($\$ha^{-1}$), excluding land, at the time of the second inventory; H_i = the value of the harvest ($\$ha^{-1}$), i years after the initial inventory; and r = the guiding rate of interest (year-‘).

Eq. (1) is the standard investment formula for a timber stand. Given a fixed acre of land, V_0 is the initial investment necessary to get the future returns V_t and H_i. These returns occur in the future, so they must be discounted. NPV, then, is the discounted value of the future returns minus the initial investment in trees, i.e. the return to the land.

Here, the NPV is expressed by it equivalent annual income, EAI, the constant annual income that would yield the same NPV over t years (Duerr, 1960, p. 110):

$$\mathrm{EAI} = \mathrm{NPV}\frac{r(1+r)^t}{(1+r)^t - 1} \quad (2)$$

The EAI allows comparison of plots that have been measured over different time intervals, t. It can be interpreted simply as the annual rent earned by the land between two inventories. A purely financial objective would attempt to make this rent as high as possible.

Eq. (1) is sometimes used to compute the internal rate of return, i.e. the rate such that NPV = 0. However, the internal rate of return can be misleading in comparing timber investments (Hseu and Buongiorno, 1993), thus it is not pursued here.

The EAIs presented below are either at constant prices, or at real prices, net of inflation. The constant price EAI (CEAI) was computed with the prices prevailing at the time of the first SO-FIA survey (time 0). This constant price EAI is strictly a measure of timber productivity, equivalent to a quantity index, where the prices in year 0 are the weights used to aggregate the different types of timber. It also may reflect closely the actual price forecast of many managers.

The real price EAI (REAI) was computed with the real prices prevailing at time 0 and t, and at harvest time i. This real price EAI captures both timber productivity and real price changes. It is the actual financial performance experienced in the interval $(0,t)$, and under a perfectly informed rational expectations assumption, these prices are the prices used by decision makers.

REAI includes any change in the price of timber, relative to the price of other goods and services. The CEAI reflects only the growth of timber on the plot, prices being used only to aggregate different kinds of timbers. We will see that this distinction is crucial to our conclusions about the role of market conditions in financial performance.

Either measure of financial performance involves a guiding rate of interest, typically the return on some alternative investment of similar risk. Here, we used US government securities as the alternative investment. This is a fairly secure investment since the full faith and credit of the US government guarantees payment of the nominal interest and principal. The main risk with these securities, as with the timber investment, is the inflation risk. This risk is less for shorter-term bonds since new bonds can be purchased, say every 3 months, from matured 3-month bonds. The new bonds that the matured bonds are rolled into reflect changes in the market conditions, including inflation. Thus, the risk of realizing a small real rate is less than with longer-term financial instruments that are otherwise equivalent. For the real guiding rate of interest, r, we used 3% year^{-1}. This is slightly above the average real rate of 2.3-2.5% for 3–12-month treasury bonds on the secondary market during the time from which we drew our data [Board of Governors (1999) was the source for the rate of return, Bureau of Labor Statistics (1999) for the consumer price index that was used as deflator].

The CEAI or REAI is the cash flow above the cash flow that would have been realized by selling the timber stock and investing the proceeds at the guiding rate.

2.2. Stand and price data

The stand data came from the Forest Inventory and Analysis database for the south central region (SO-FIA). The selected l-acre plots were all from the loblolly pine-hardwood type, naturally regenerated, and 'mixed-age' in the sense that they had more than one age class in the dominant species at the time of the most recent survey. SO-FIA documentation applies the mixed-age classification to plots in which the difference in age between the youngest and oldest trees of the dominant species exceeds 10 years. Table 1 shows the distribution of plots throughout the south central and the survey dates. Most of the plots were located in Alabama, Louisiana, Mississippi and Texas. Time 0 and t in the EAI formula correspond to the terms 'past' and 'current' used in the SO-FIA database. The average interval $(0,t)$ was over 7 years, ranging from 6 to 11 years.

Table 1
FIA plots of naturally regenerated, mixed-age loblolly pine stands in the south central USA

	Number of plots	Survey date	
		Past	Current
Alabama			
North	114	81-82	89-90
South	178	80-82	89-90
Arkansas			
South	53	77-78	87-88
Louisiana			
North	134	83-85	91
South	109	83-85	91
Mississippi			
North	140	86-87	92-94
South	130	86-87	93-94
Oklahoma			
South	4	86	92
Tennessee			
West	1	79	88
East	1	80	89
Texas			
North	26	85	91-92
South	101	85-86	92
Total	991	77-87	87-94

In all there were 991 plots, with 40 187 sample trees. Table 2 shows the distribution of the tree species by state and for the region as a whole. Nearly half of the trees were loblolly pine, 6% were shortleaf pine, and the rest consisted of 94 other species, eight of those softwoods.

The plots were predominantly under non-industrial private ownership (Table 3), but a substantial number were in the public domain or owned by the forest products industry. The site productivity is recorded in the FIA database as a site productivity class, ranging from class 1 (greater than 15.5 m^3 ha^{-1} year-') to class 6 (less than 1.4 m^3 ha^{-1} year-'). Most of the plots were in classes 3 and 4, and site classes were distributed similarly by ownership categories (Fig. 1).

To obtain the equivalent annual income for each plot we calculated the volumes of hardwood and softwood timber suitable for use as sawtim-

Table 2
Tree species in FIA plots of naturally regenerated, mixed-age loblolly pine stands in the south central USA

Species	Number of sample trees by state							
	AL	AR	LA	MS	OK	TN	TX	Total
Loblolly pine	4579	1234	4749	5430	96	32	2951	19 071
Shortleaf pine	684	104	329	766	30	0	361	2274
Eastern red cedar	91	21	10	92	0	1	5	220
Longleaf pine	147	0	115	145	0	0	19	426
Slash pine	51	0	19	55	0	0	15	140
Virginia pine	98	0	0	0	0	2	0	100
Other softwoods	28	0	16	12	0	0	0	56
All softwoods	5678	1359	5238	6500	126	35	3351	22 287
Sweetgum	1346	309	1048	1199	14	7	481	4404
Southern red oak	394	104	347	378	16	4	248	1491
Water oak	494	55	238	405	0	0	169	1361
Red maple	457	103	282	432	0	6	36	1316
Post oak	202	85	225	251	4	0	241	1008
Blackgum	294	61	251	278	2	2	73	961
White oak	147	38	141	206	6	0	43	581
Winged elm	104	53	143	133	1	2	101	537
Hickory sp.	269	53	114	0	1	2	15	454
Black cherry	112	15	49	172	0	2	7	357
Yellow-poplar	181	0	20	90	0	3	0	294
Cherrybark oak	30	41	83	68	0	0	50	272
Willow oak	39	36	56	44	10	0	62	247
Other hardwoods	1619	217	934	1393	7	23	424	4615
All hardwoods	5688	1170	3931	5040	61	51	1950	17 898
All species	11366	2529	9169	11549	187	86	5301	40 187

ber or pulpwood, for (1) the past survey (time 0), (2) the current survey (time t), and (3) the harvests (times i). The sawtimber volume for a tree was calculated from the saw log dimensions. The pulpwood volume was the difference between the total wood volume and the volume of saw wood extractable from that tree. After expanding the sample tree data to the total volume per acre, the volume was summed with other wood in the same category. Similarly, for each harvest time i we calculated the volumes harvested from the trees per acre cut and the dimensions of the cut trees recorded by the SO-FIA survey.

The stumpage price data for the market areas in the south central region came from the Timber Mart-South (1998) database. These prices are available for hardwood and softwood as either sawtimber or pulpwood. Figs. 2-5 illustrate the time series of the average price over all of the markets for the four, stumpage product types. Prices had been somewhat depressed since the late 1970s and had improved recently. However, prices differed substantially between states and even within a state (Table 4). The value calculations used all of the price information by pricing each tree at the price prevailing for the relevant wood type at the time when and in the region where the tree was measured.

2.3. *Effects of site and stand characteristics on performance*

After obtaining the EAI with Eq. (2) and with the growth and price data described above, we assessed which site or stand characteristics affected productivity and/or financial performance the most, other things being held constant. We accomplished this by regressing the EAI on the site and stand characteristics. The estimates of the coefficients, or combinations of them, showed the partial effect of each stand characteristic (basal area, site index, number of trees, etc.) on the stand financial performance, when all of the other characteristics were held constant.

3. Results

3.1. Financial performance of forest stands

The distribution of the REAI is in Fig. 6, and the CEAI is in Fig. 7. The distributions are similar in shape, but the measures of central tendency are quite different. At constant prices, the mean CEAI was $24 ha-’ year-‘. This measures the return from the growth of timber alone. The much larger mean REAI at real prices ($158 ha-’ year-‘) represents the growth of timber, plus its price appreciation, net of inflation. For the entire set of observations, the average return due to timber growth alone was one fourth of the return due to increases in real prices.

Table 3
Ownership of FIA plots of naturally regenerated, mixed-age loblolly pine stands in the south central USA

Owner	Number of plots
Private individual	442
Farmer	107
Private corporation	82
Other private	22
Total private	653
Forest industry	227
Leased from	
Private individual	8
Private corporation	2
Farmer owned	1
Total forest industry	238
National forest	94
Other federal	4
Other public	2
Total public	100
Total in all categories	991

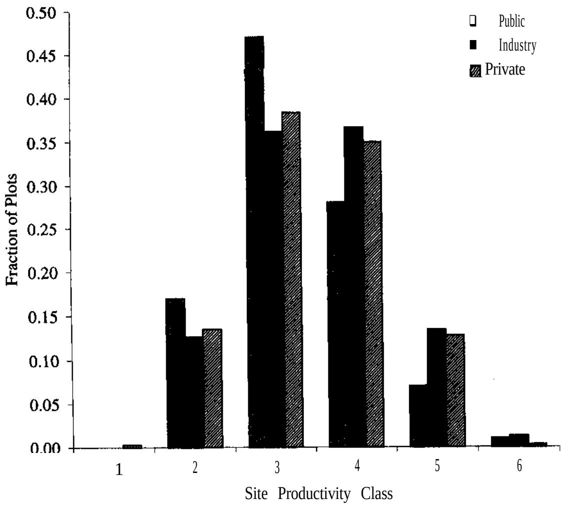

Fig. 1. Distribution of SO-FIA plots of naturally regenerated, mixed-age loblolly pine in south central USA, by owner and site productivity class.

As discussed earlier, these results are for a real guiding rate of interest of 3% year-‘. The EAIs decrease as the interest rate increases. For example, with a 6% real guiding rate the average REAI was $29 ha-’ year-’ and the average CEAI was -$21 ha-’ year-‘. These general changes in levels do not affect the conclusions of this paper.

The last two columns of Table 5 show that, although there was some positive correlation between volume growth and CEAI, it was very weak. In fact, the CEAI should be a better measure of productivity, because it takes into account the very different value of pulpwood and sawtimber. Still, Fig. 8 shows that there was little relation between the timber productivity measured by CEAI, and ultimate financial performance measured by REAI. This was due to the wide local differences in price changes between the survey dates (Table 4). The differences in prices at harvest dates also contributed to the variations in

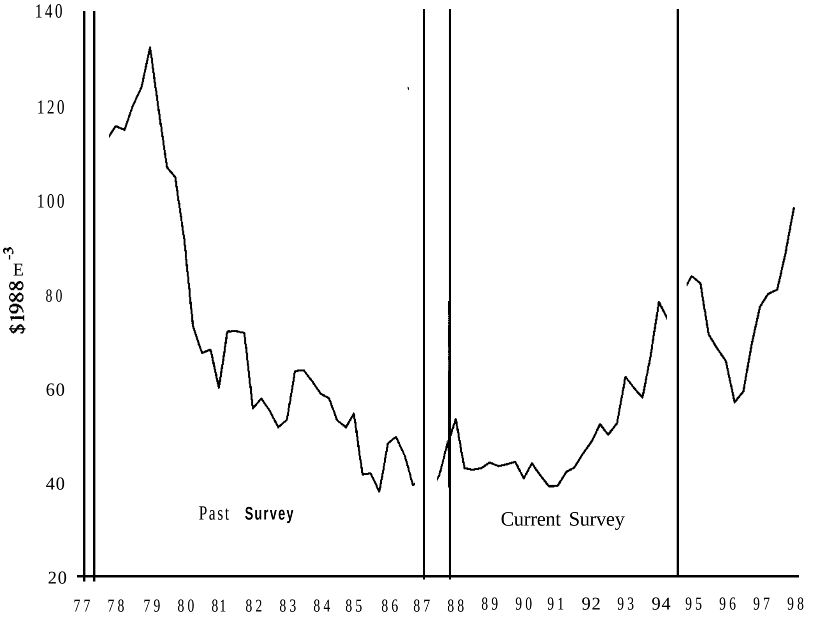

Fig. 2. Softwood sawlog average stumpage price in the south central USA (Timber Mart-South, 1998).

REAI. The financial returns in the various subregions (Table 5) follow largely the price changes in Table 4. Mississippi, with the greatest appreciation in prices between the previous two surveys,

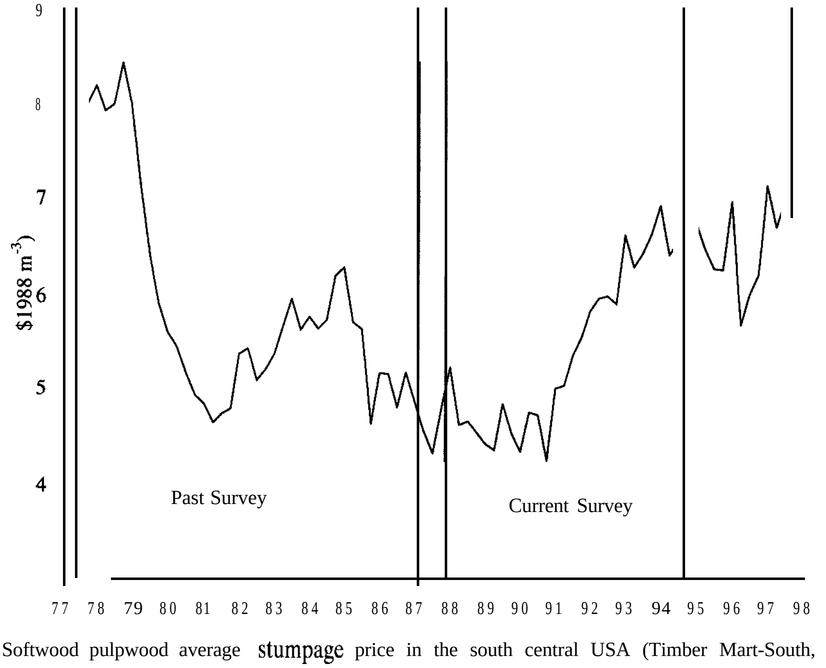

Fig. 3. Softwood pulpwood average stumpage price in the south central USA (Timber Mart-South, 1998).

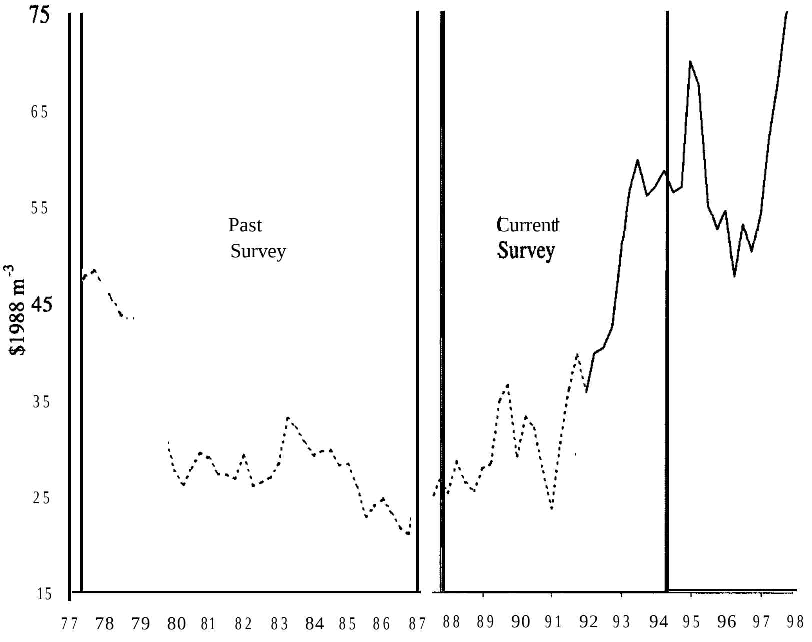

Fig. 4. Hardwood sawlog average stumpage price in the south central USA (Timber Mart-South, 1998). Missing values before 1991 were estimated from hardwood pulpwood price changes.

had an average REAI more than 10 times larger than the CEAI. In contrast, Arkansas, with the greatest price drop between surveys, had a negative REAI despite excellent timber productivity ($53 ha^{-1} $year^{-1}$ average CEAI).

Table 6 shows data for the four plots with the

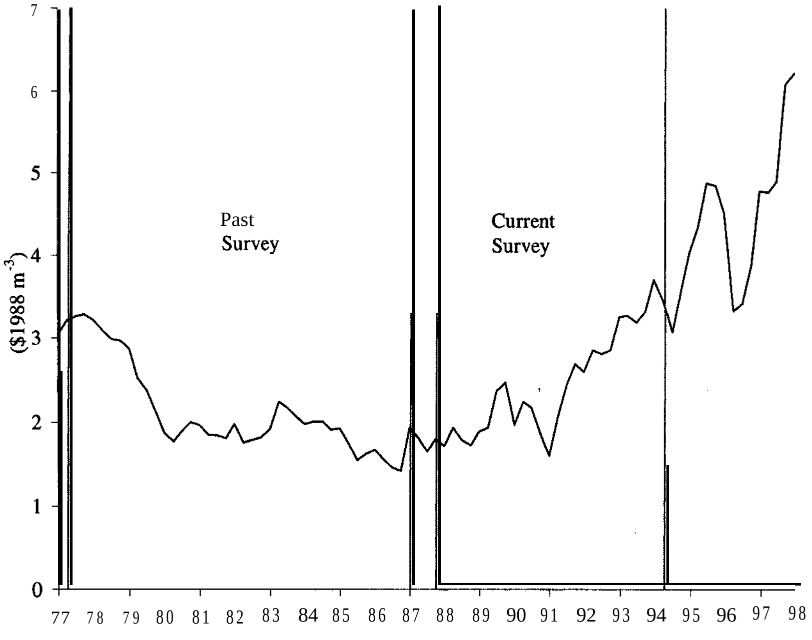

Fig. 5. Hardwood pulpwood average stumpage price in the south central USA (Timber Mart-South, 1998).

largest difference between constant price and real price EAI. They were all in Mississippi, in heavily stocked stands (five to nine times the average volume of softwood sawtimber). The plots were overstocked in the sense that the CEAI was negative in all four plots. But due to the price increase, the real price EAIs were very large, all above $1600 ha-' year- [1]. Simply using the stand to store timber that was increasing in value gave a great return despite the negative timber productivity. It is striking that all of these overstocked stands were on public lands, where timber productivity was probably not the primary objective. Yet, due to the price increases, they gave the best financial performance. Thus, a surprising outcome for these stands is that given the price history, conservation was also a sound financial investment over the period studied.

Price changes played a crucial role in the financial performance of loblolly pine mixed-age forests in the south central from the late 70s to the late 90s. Buongiorno and Hseu (1993) also found that price changes dominated economic return in northern hardwoods during a period when real prices stagnated or decreased. But, predicting price changes is very difficult. The large returns are fleeting if they are based on an appreciation in the value of standing timber and the prices drop before the timber is harvested. This is the same problem facing any manager of any asset, including stocks, bonds or other financial assets, which can be liquidated at high prices.

3.2. Effects of site and stand characteristics on performance

The results of the regressions of EAI, at constant or real price, on the site and stand characteristics are in Table 7. Dummy variables were used to distinguish sites, and type of ownership.

As noted above, the real price EAI was dominated by price changes. As a result, the goodness of fit (R^2) was lower for the REAI than for the CEAI.

The site class, in and of itself had no effect on CEAI. Indeed, CEAI varied little across productivity classes. The data in Table 5 have already shown the weak correlation between volume growth (presumably affected by site) and CEAI. Table 8 shows that the unconditional mean CEAI was almost constant for the six site classes. In contrast, the REAI increased significantly with site quality. This is in agreement with the positive effect of the dummy variable Site 1 or 2 on REAI. But the effect may be indirect, and due mostly to the fact that better sites tended to carry more volume, so that with rising prices they performed better. Earlier studies have suggested that site productivity influences financial performance (e.g. Busby et al., 1998), but in our sample this connection might be obscured by other variables, especially the composition of the stand. Alternatively, the method for determining site class might not accurately distinguish the narrow range of site quality in which the bulk of our data falls.

The aspect, slope, and physiography of a site had no apparent effect on CEAI. But, the REAI was significantly lower on dry and wet sites, possibly because they were less well stocked, other things being equal. While the CEAI did not differ significantly across physiographic class, well

Table 4
Softwood stumpage price ($1988 m^{-3})

	Saw log		Pulp wood	
	Past survey	Current survey	Past survey	Current survey
Alabama				
North	54	52	5.6	6.8
South	63	64	8.1	8.1
Arkansas				
South	94	56	5.3	5.2
Louisiana				
North	64	54	7.5	1.3
South	64	52	6.1	7.3
Mississippi				
North	44	81	4.0	8.4
South	47	104	4.2	7.7
Oklahoma				
South	64	69	5.2	6.6
Tennessee				
West	32	23	2.9	2.4
East	27	30	2.4	4.4
Texas				
North	47	54	6.6	5.8
South	42	62	5.8	7.6

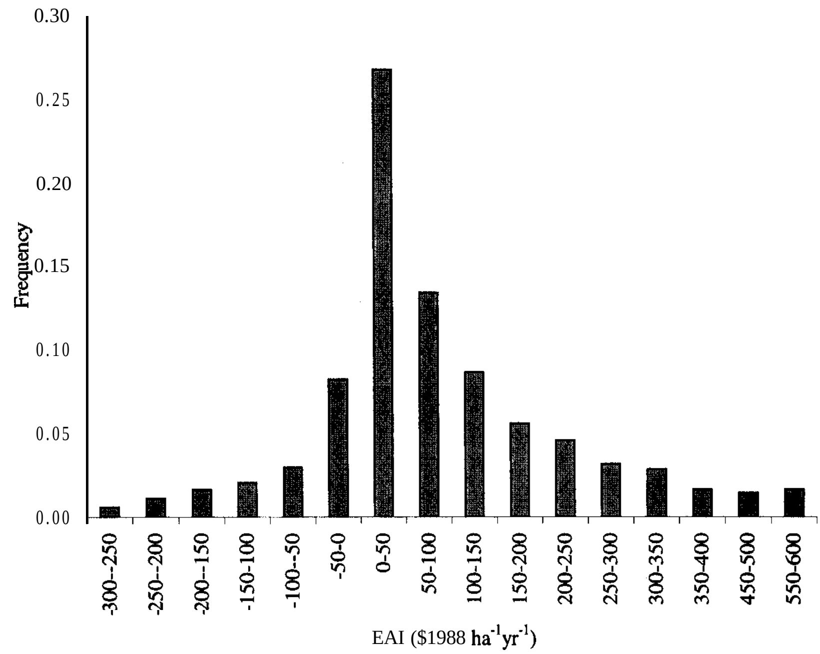

Fig. 6. Real price equivalent annual income for naturally regenerated, mixed-age loblolly pine stands in the south central USA. Median \$61 ha^{-1} $year^{-1}$. Mean \$158 ha^{-1} $year^{-1}$.

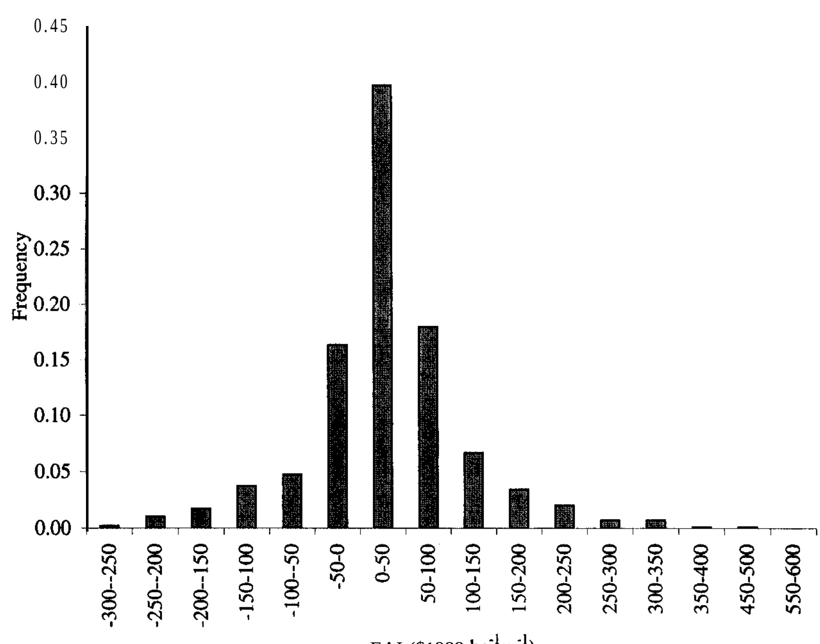

Fig. 7. Constant price equivalent annual income for naturally regenerated, mixed-age loblolly pine stands in the south central USA. Median \$21 ha^{-1} $year^{-1}$. Mean \$24 ha^{-1} $year^{-1}$.

Table 5
Average equivalent annual income and volume growth of FIA plots of naturally regenerated, mixed-age loblolly pine stands in the south central USA[a]

	Number of plots	Average equivalent annual income		Volume growth (m^3 ha-' year-')
		At real prices ($1988 ha^{-1} $year^{-1}$)	At constant prices ($1988 ha-' $year^{-1}$)	
Alabama				
North	114	37 (5)	13 (5)	2.0 (0.1)
South	178	40 (6)	31 (6)	2.3 (0.1)
Arkansas				
South	53	− 80 (24)	53 (16)	2.8 (0.2)
Louisiana				
North	134	− 81 (16)	3 (10)	2.5 (0.2)
South	109	7 (12)	38 (10)	2.5 (0.2)
Mississippi				
North	140	397 (30)	26 (6)	3.3 (0.2)
South	130	494 (42)	26 (9)	3.3 (0.2)
Oklahoma				
South	4	95 (117)	− 87(134)	3.7 (0.8)
Tennessee				
West	1	2	-16	2.5
East	1	18	5	1.1
Texas				
North	26	185 (35)	59 (25)	6.9 (0.7)
South	101	338 (29)	15 (7)	5.8 (0.4)
All	991	158 (11)	24 (3)	3.1 (0.1)

[a] Standard error is given in parentheses.

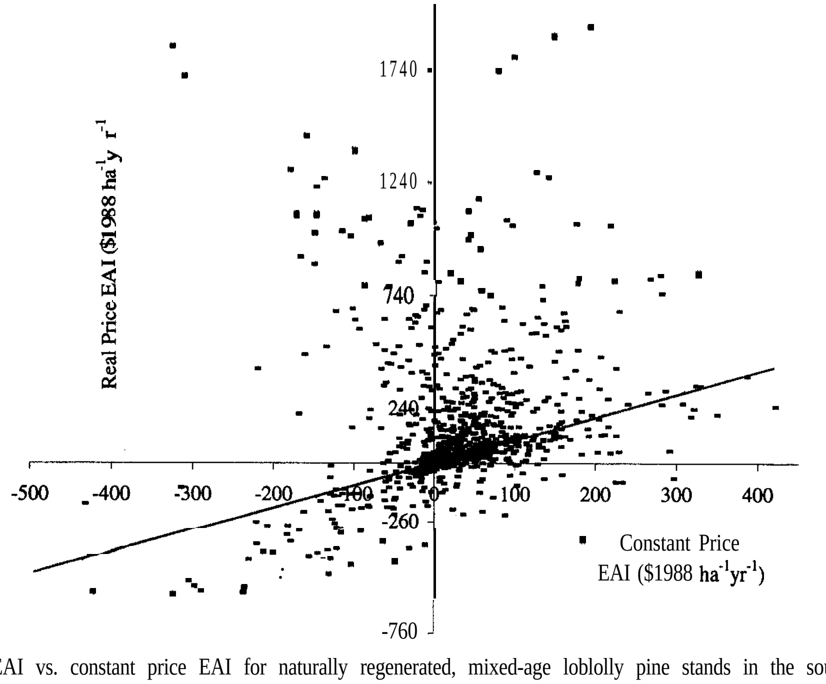

Fig. 8. Real price EAI vs. constant price EAI for naturally regenerated, mixed-age loblolly pine stands in the south central USA.

Table 6
Plots with the greatest difference between real price EAI and constant price EAI[a]

Plot location	Plot owner	Softwood sawtimber (m^3 ha^{-1})			Price (\$1988 m^{-3})		EAI (\$1988 ha^{-1} $year^{-1}$)	
		Past	Current	cut	Past	Current	Real price	Constant price
South Mississippi	National forest	236	235	0	47	121	2084	-324
South Mississippi	National forest	205	204	0	47	121	1848	-327
South Mississippi	National forest	218	217	0	47	119	1749	-312
North Mississippi	National forest	196	205	1	46	103	1675	-190
Mean of 991 plots		30 (1)	41 (2)	1.5 (0.1)			158 (11)	24 (3)

[a] Standard error is given in parentheses.

drained sites had significantly higher REAI (Table 9).

Other things being equal, the plots with higher basal areas had lower CEAI, so that overstocked

Table 7
Effects of stand characteristics on equivalent annual income of naturally regenerated, mixed-age loblolly pine plots in the south central USA[a]

Stand characteristic	Constant price EAI (\$1988 ha^{-1} $year^{-1}$)		Real price EAI (\$1988 ha^{-1} $year^{-1}$)	
Site 1 or 2			91	(30)
Site 4				
Site 5 or 6				
Basal Area (m^2)	-1115	(155)	1959	(606)
Fraction of BA in hardwood				
Number of trees	0.05	(0.02)		
Square of tree count				
Fraction hardwood trees	-43	(13)		
Large soft pulp wood	2.6	(0.2)	2.0	(0.7)
Large hard pulp wood	2.2	(0.7)		
Aspect				
Slope				
Slope × aspect				
Xeromesic			-195	(44)
Hydromesic			-134	(56)
Public land ×				
Basal area (m^2)	-1867	(379)	6827	(1480)
Fraction BA HW				
Number of trees			-0.9	(0.2)
Square of tree count			4×10^{-4}	(1×10^{-4})
Fraction hardwood trees	135	(48)	450	(188)
Large soft pulp wood	2.3	(0.5)		
Large hard pulp wood				
Industrial land				
R^2	0.37		0.25	
n	991		991	

[a] Only coefficients significantly different from zero at 5% level are shown. Numbers in parentheses are standard errors.

Table 8
Average equivalent annual income of naturally regenerated, mixed-age loblolly pine plots in the south central USA, by site productivity[a]

Class	(m^3 ha-' year-')	n	Mean EAI ($1988 ha-' year^{-1})	
			Real price	Constant price
1	15.5 +	2	993 (300)	-67 (55)
2	11.4-1.5.5	135	284 (45)	21 (12)
3	8.3-11.4	383	184 (18)	26 (5)
4	5.8-8.3	343	116 (12)	24 (4)
5	3.4-5.8	122	44 (7)	23 (4)
6	1.4-3.4	6	17 (24)	22 (28)
All		991	158 (11)	24 (3)

[a]Standard error is given in parentheses.

stands would perform poorly if prices did not appreciate. But the REAI was instead higher at high basal area due to the real price increase applied to more volume during the sample period. Presumably, the CEAI of a stand with an extremely low basal area would suffer, but there were not enough plots with very low basal area to show this. The effect of basal area on financial performance was significantly more pronounced on public lands because they tended to carry more stocking.

The plots with more trees had significantly higher CEAI, possibly because, for a given basal area, more trees meant smaller, more vigorous trees. A higher fraction of hardwood trees entailed a significantly lower CEAI, more so on public lands, in accord with the lower growth rate of hardwoods. However, the rise in prices of hardwoods was such that a higher fraction of hardwoods increased the REAI significantly.

Stands were more productive, at constant prices, with more softwood and hardwood trees just below sawtimber size. Despite the opportunity cost of not harvesting the trees for pulpwood, waiting for sawtimber of higher value is worthwhile. Hseu and Buongiorno (1993) also observed this effect in northern hardwoods.

The lands owned by the forest products industry did not perform differently from the non-industrial privately owned lands after correcting for the other factors. However, as summarized in Table 10, the unconditional mean performance of

Table 9
Financial return of naturally regenerated, mixed-age loblolly pine plots in the south central USA, by physiographic class"

Physiographic class	Definition	n	Mean EAI ($1988 ha^{-1} year-')	
			Real price	Constant price
Xeromesic	Moderately dry, excessive drainage	48	-32 (19)	30 (15)
Mesic	Deep, well-drained, only climate limits growth	913	173 (11)	24 (3)
Hydromesic	Moderately wet, insufficient drainage	29	-15 (37)	13 (23)
Hydric	Very wet sites	1	10	3
All		991	158 (11)	24 (3)

[a]Standard error is given in parentheses.

Table 10
Financial return of naturally regenerated, mixed-age loblolly pine plots in the south central USA, by ownership[a]

Ownership class	n	Mean EAI ($1988 ha^{-1} year^{-1})	
		Real price	Constant price
Private	653	140 (11)	32 (3)
Industry	238	94 (15)	33 (6)
Public	100	425 (58)	−46 (13)
All	991	158 (11)	24 (3)

[a]Standard error is given in parentheses.

public lands was significantly worse than that of private lands at constant prices, but significantly better at real prices.

4. Summary and discussion

This paper examined the financial performance of mixed-age, naturally regenerated loblolly-hardwood stands in the south central region of the United States, from 1977 to the late 1994. The main finding was that timber price changes during that period dominated all other factors influencing financial performance. While the equivalent annual income averaged $158 ha^{-1} year^{-1} at real prices, it was only $24 ha^{-1} year^{-1} at constant prices.

Hseu and Buongiorno (1997) used similar methods to measure the productivity of northern hardwoods in Wisconsin from 1966 to 1984. Like the southern stands investigated here, the northern hardwood stands were all mixed-age and naturally regenerated. The authors found a mean REAI of $22 ha^{-1} year^{-1} ($32 ha^{-1} year^{-1} on industrial lands). They did not compute the CEAI. However, because real prices of the dominant northern hardwood timbers decreased from 1967 to 1989 (Buongiorno and Hseu, 1993), the CEAI of northern hardwoods must have been at least as good as that of mixed-age loblolly stands in the South. Thus, for equal price trends, investments in northern hardwoods should yield equal or better returns than loblolly-hardwood stands.

A valid comparison of financial performance to even-aged stands must be on equivalent sites. Although we do not have such a controlled comparison, we can consider the performance of even-aged loblolly test plots in central Georgia (Busby et al., 1998). These plantations on more productive land than our average site had constant price EAIs between $4 ha^{-1} and $132 ha^{-1}. This is not very different from the values obtained for the stands considered in this study.

For the loblolly-hardwood stands, given the overall increasing price trend during the period considered here, the best performing sites were overstocked stands. They gave REAIs as high as $2100 ha^{-1} year^{-1}, even though at constant prices they would have given negative returns. In these overstocked stands, conservation actually was profitable since the payoff was higher for retaining the mature trees than for harvesting earlier. However, realization of this conservation profit does depend upon the eventual harvest of the timber, so old growth will not be held indefinitely under a pure profit motive. Also, the profit incentive to hold old growth longer in periods of rising prices would lead to earlier cut of stands when prices decline.

The effects of silvicultural choices depended critically on price movements. While at constant prices it was preferable to keep low basal areas to encourage growth rates, at rising real prices, maximum stocking was best due to the appreciation of a large capital stock. Somewhat paradoxically, the stands that performed best financially during the period of observation were on public lands, which had better stocked, older stands and where timber productivity was generally secondary to other multiple use objectives, such as high quality recreation.

The results showed that in periods of real price change, the changes in asset value of the forest could dwarf the income from harvesting alone. Thus, the main forest economics issue is not the optimal management of the resource for a given price, but the prediction of the price itself. Given the state of the art, such prediction remains very uncertain. As a result, it is plausible that many managers will plan for constant real prices. At constant prices, then, the results have shown that good financial performance would occur in stands of moderate basal area, with many trees, few hardwoods, and many trees near sawtimber size.

More knowledge will be needed to plan the organization of forest estates, be they public or private, as a diverse portfolio of forest stands to hedge against price changes, while contributing to a rich ecological landscape. Meanwhile, the results of this study suggest that diverse, natural looking mixed-age loblolly-pine hardwood stands with natural regeneration are sound financial investments over a wide range of conditions, even at constant real prices.

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