Coast Live Oak Thinning Study in the Central Coast of California—Fifth-Year Results[1]

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Abstract: A long-term thinning study was established in ten stands of coast live oak (*Quercus agrifolia* Née) in the Central Coast of California. Information about diameter, basal area, and volume growth and yield has been obtained from unthinned control plots and from plots thinned to 50 and 100 square feet of basal area per acre measured in 1984 and 1989. Both basal area and total volume growth percentages were significantly greater in the thinned plots compared to the control plots. A preliminary economic analysis indicates the potential for modest returns on a thinning operation similar to this study. The possibility of increased production of forage following thinning was less promising due to residual canopy covers of 50 pct and greater on thinned plots.

During the past decade there has been increasing interest in the potential of wood for supplying energy. California's oak woodland are one source receiving increasing pressure for harvesting. These woodlands are an under-utilized resource that could provide a continuous source of wood fiber for energy and wood products, given better management.

Coast live oak (*Quercus agrifolia* Née) was selected for this study because of its extensive range in California covering about 750,000 acres, from San Diego to Mendocino County. Previous studies (Pillsbury 1978; Pillsbury and De Lasaux 1985) involving inventory of coast live oak stands showed that they are typically dense, ranging from 100 to over 700 trees per acre (averages for these studies varies from 300-350) and basal area ranges from about 75 to 250 square feet per acre (averages for these studies is 150-160). Tree spacing ranged from about 7 to 20 feet (average of 12-13) while average tree diameter for the stands varied from about 5 to 17 inches (averages of 10-11). Coast live oak stands are largely between40 and 110 years of age although stands have been measured as young as 28 years and as old as 131 years. Typically they average 60-80 years in age. Site index values varied from a low of 32 feet to a high of 84 feet at 50 years.

We are unaware of coast live oak studies that show the effects of thinning on the growth of the residual stand. Thinnings are normally conducted to stimulate the growth of the trees that remain and to increase the total yield of useful fiber from the stand. The basic objectives of thinning are: a) to redistribute the growth potential of the stand into fewer but larger trees, and b) to utilize all the merchantable material produced by the stand prior to harvest (Smith 1962).

Currently, little is known about site productivity, regeneration, tree growth and the potential effects of harvesting on oak woodlands. Little information is available on different management practices and their effects. By developing a number of permanent plots, growth can be documented over time. These data will prove valuable to foresters and landowners who wish to maximize fiber production in existing stands or want to compare the potential for different management strategies.

The primary long-term goal of this study is to: establish a series of permanent plots to develop long-term diameter, basal area and volume growth and yield information for thinned and unthinned stands of coast live oak in Monterey, San Luis Obispo, and Santa Clara counties.

Other objectives of this study include to: a) evaluate the changes in understory vegetation following thinning, b) evaluate the regeneration of coast live oak (stump sprouts and seedlings) following thinning, and, c) evaluate disturbance of soils during the thinning process and the effects of such disturbance.

Many of the stands measured in previous studies are near rotation age, therefore it is important to know if they could benefit from thinning. This study may help to determine if a thinning of older stands will yield increased fiber while allowing for immediate income from the removed trees.

PLOT ESTABLISHMENT AND INITIAL INVENTORY

Plot Selection

Ten sites were selected for this study and were distributed as follows: Monterey County - four sites, San Luis Obispo County - five sites, and Santa Clara County - one site. Three plots were established at each site consisting of one control plot and two plots that were thinned to 50 and 100 square feet per acre respectively. Plots were established in stands approximately 40 to 85 years old.

Each plot is one-fifth acre in size and surrounded by a two-fifths acre buffer zone for a total area of three-fifths acre. Plots were established by compass and tape; metal rebar was used to monument plot corners.

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Thinning Prescription

The strategy used for cutting was a combination improvement cut and low thinning. Trees on thinned plots were removed if they: a) were not coast live oak, b) were damaged or defective, c) were less than 6 inches dbh, d) were one stem of a forked tree, e) were of suppressed or intermediate crown class, or f) were of poor vigor (Pillsbury and others 1987).

In most cases further basal area reduction was needed to obtain either 50 or 100 sq. ft. basal area for the plot. Additional trees were removed if they: g) were obviously from a previous stand, h) were not sawlog quality or size, or i) were too closely spaced to an adjacent tree.

An example of how one plot appeared before and after thinning is shown in figure 1. Circles in the plot represent tree basal areas at breast height. Because live oak trees do not always grow straight it is difficult to visualize crown cover from stem maps.

DATA COLLECTION

The following information was obtained for each tree in the study: tree number, species, dbh, total height, merchantability indicator, tree vigor, azimuth and horizontal distance from plot center, crown class, shrubs, ground cover, woody shrub cover, clumps, sprout height, sprout number, stump diameter, stump angle, and stump height. Stand and site information includes: forage (species, extent, weight), other (percent of ground, rock, litter), soil surface condition (erosion), stand and site information (slope, aspect, elevation, soil type, stand crown cover, site age, site index).

Development of Stand, Basal Area and Stock Tables

Basic mensurational data were compiled for each plot before and after thinning and extrapolated to a per acre stand basis. A stand table consisting of the number of trees of a given species per diameter class per acre was developed. Trees were grouped into 2-inch diameter classes (e.g., the 8-inch class includes trees 7.00 through 8.99 inches). Basal area tables were also developed by species and diameter class on a per acre basis. Stock tables, the cubic foot volume of trees of a given species per diameter class per acre, were also developed.

Tree volumes for hardwoods were computed according to three utilization standards, total volume, wood volume, and sawlog volume. Total volume is the total outside bark volume including the stump. Wood volume is inside bark volume from stump height (1 foot) to a 4 inch top (inside bark) for all stems. Sawlog volume is the inside bark volume found in trees having an 11-inch or greater dbh and have straight, sound segments 8 feet or greater in length, from stump height to a 9 inch top diameter inside bark (Pillsbury and Kirkley 1984). Only total volumes were computed for non-hardwood species.

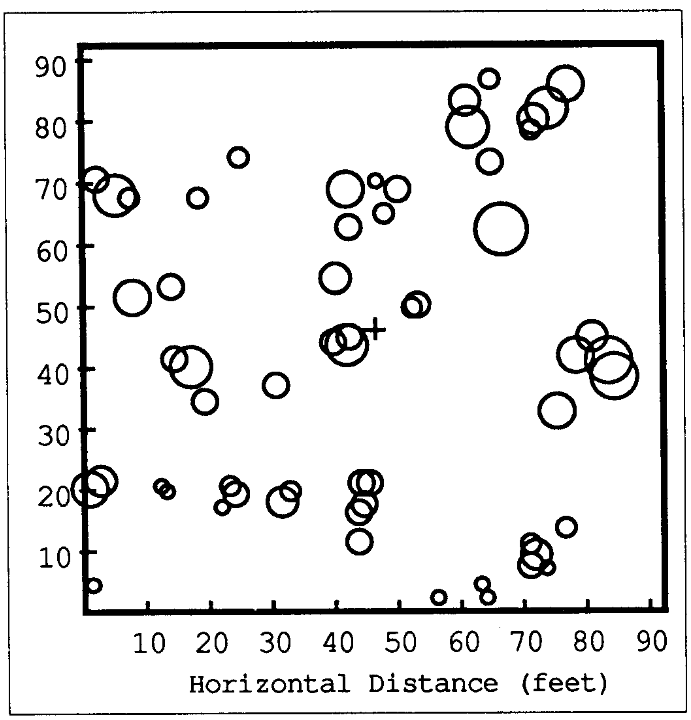

Figure 1a—Stem map for Plot 2-3 before thinning (about 240 ft^2/ac).

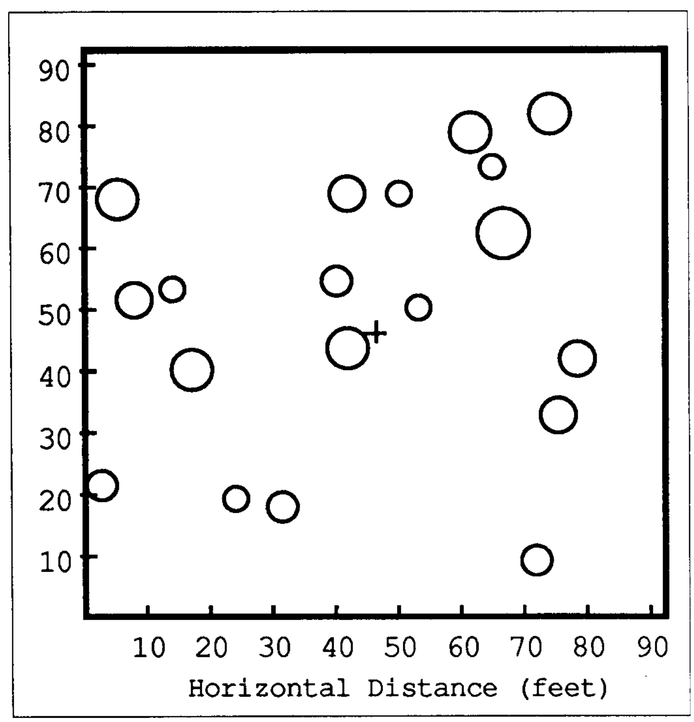

Figure 1b—Stem map for Plot 2-3 after thinning (about 100 ft^2/ac).

REMEASUREMENT OF STANDS (1989)

Analysis

Coast live oak plot data were analyzed for change in stand density and volume growth. It should be noted that thinning studies have traditionally been evaluated solely on change in basal area per acre of the stand. The traditional approach is relatively simple and therefore easily understood. A disadvantage is that it does not evaluate changes in stand volume which is the desired product. The approach used in this study is to look at all five variables to improve our interpretation of the stands' response to thinning: number of trees, basal area, and volume (total, wood, and sawlog).

Using a series of computer programs, a total of 90 stand, basal area and stock tables were developed plus a number of other tables needed to summarize the data. From this array of information we were able to begin charting the course of stand growth and change in the thinned coast live oak plots.

Five-year Results of Thinning Treatments

The effects of the thinning treatments after five years is discussed below for the stand characteristics of number of stems, basal area, total volume, wood volume and sawlog volume. Three treatments were used: control plots (no thinning), plots thinned to 100 ft^2/acre, and plots thinned to 50 ft^2/acre.

At each site a control plot was established and measured to provide a benchmark for comparing the response of the thinned plot.

Number of Stems Per Acre

Any change in the number of stems per acre that would occur would be due to either in-growth or mortality. In-growth, when trees finally reach 4.5' in height and then would be included in the sample, did not occur during this five year period (figure 2). Although hundreds of stumps sprouted vigorously, none attained the necessary height, primarily due to deer browsing. The growth and development of sprouts is examined in a later section.

Mortality, however, did occur and had a definite impact on the study, especially for the control plots (figure 3). The wildfire that occurred during the summer of 1985 produced very intense conditions and was responsible for the majority of tree death that occurred. A total of three of the 10 control plots were affected with an average of 96 trees per acre lost during the interval

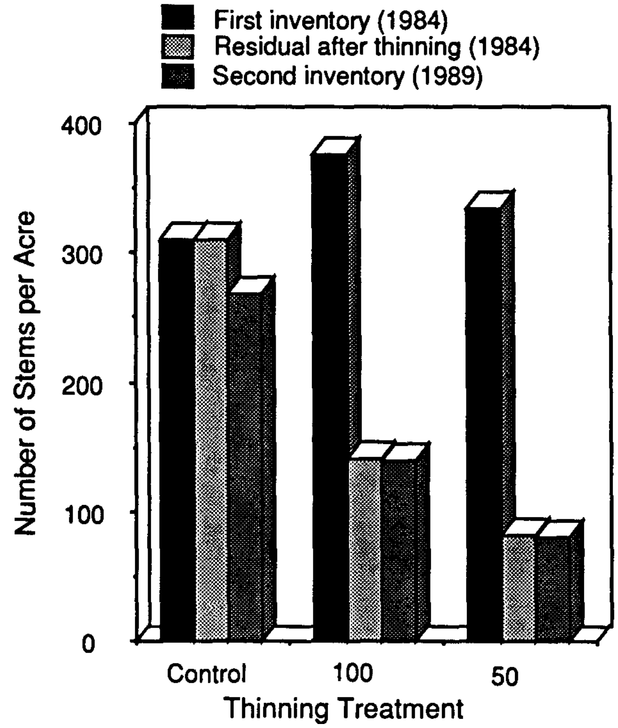

Figure 2—Number of stems per acre by treatment (100 and 50 ft^2/ac).

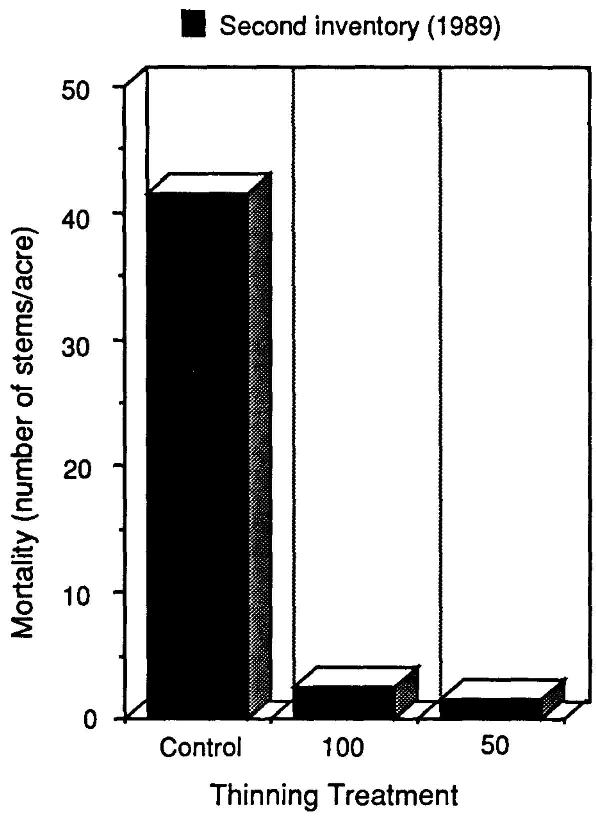

Figure 3—Mortality shown in number of stems per acre by treatment (100 and 50 ft^2/ac).

between inventories. The majority of these were in plot 1-2 which lost an average of 215 trees per acre. By contrast only an average 18 trees/acre died from other causes in the other seven control plots, and only an average of 2.5 and 1.5 trees per acre died in the 100 and 50 ft²/acre plots, respectively. The greater density of trees in the unthinned control plots may have contributed to the fire intensity and subsequent loss.

In addition to the outright death of trees from fire, a number of factors contributed to tree damage during this period. Again, wildfire played an important role. Many trees had scorched trunks, burned crowns and cracked or swollen bark making diameter measurement difficult. Trees which were defoliated by the flames often produced sprouts along the stem and branches. Although they were classified as a living tree, their rate of growth will be greatly reduced.

Another freak incident, an unusually heavy and wet snowstorm, caused crown and limb breakage. In some plots, nearly every tree was impacted by the storm which struck December 16-17,1988 (table 1). So heavy was the snow weight that nearby residents reported hearing explosions and gunshots as the crowns and boles collapsed.

The 1994 inventory will provide more information on the growth impacts of the wildfires and snowstorm.

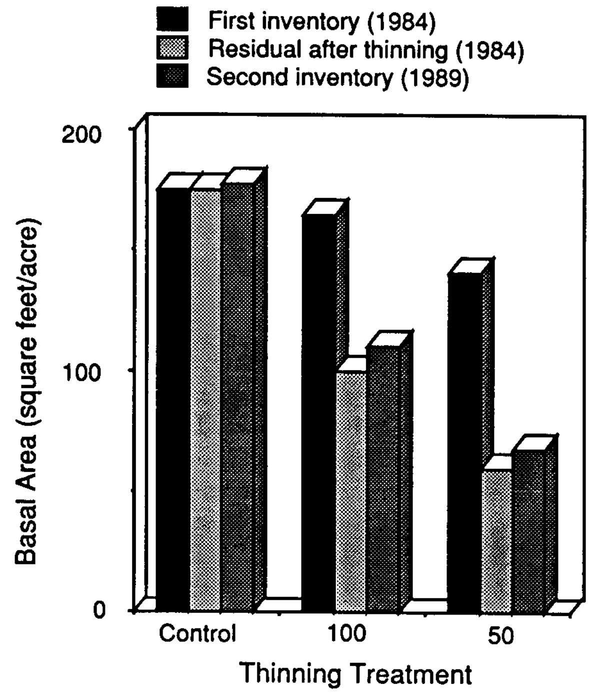

Figure 4—Basal area in square feet per acre by treatment (100 and 50 ft²/ac).

Basal Area Per Acre

Basal area was the variable used to design the thinning treatments in 1984. The changes that occurred are shown in Figure 4.

The average increase for all control plots is 2.7 ft²/acre or about 1.5 pct for the five-year period. The more heavily thinned (50 ft²/acre) plots increased by about 8 ft²/acre (13.3 pct) while the 100 ft²/acre plots increased by 10.4 ft²/acre (10.5 pct) during the same period. Further, these data show that the 50 ft²/acre plots averaged twice the basal area growth when compared to the control plots (figure 5) and the 100 ft²/acre plots averaged three times the growth compared to the control plots.

It could be argued that these ratios and data may be somewhat misleading because of the high rates of mortality in the control plots. On the other hand, one of the reasons for thinning a stand is to reduce the density quickly i.e., speed up the rate of natural mortality, and to improve the vigor and growth rates of the remaining trees. Dense stands will typically have higher rates of natural mortality as well as higher death rates during catastrophic events such as wildfire and extreme snowstorms.

Table 1 — ***Trees affected by snow damage in 1988.***

Plot No.	No. trees after thinning (1984)	No. with snow damage	Percent affected	Treatment
3-1	43	16	37	50
3-2	65	24	37	100
3-3	122	22	18	Control
8-1	22	12	55	100
8-2	9	9	100	50
8-3	54	4	7	Control

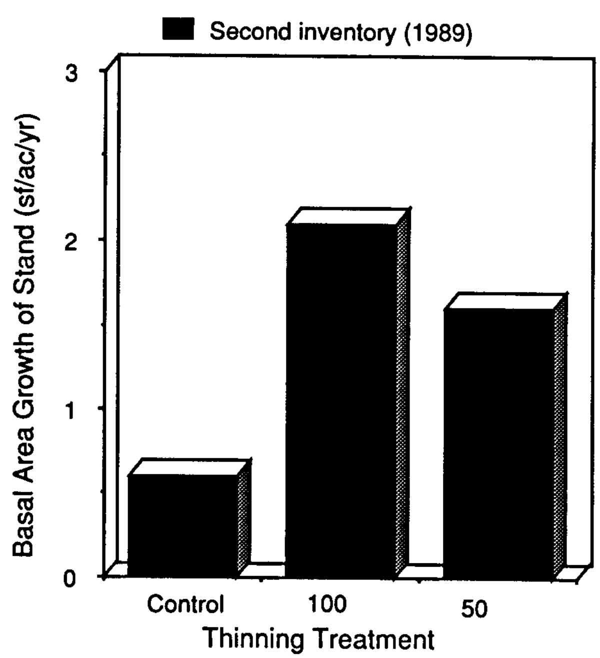

Figure 5—Basal area growth for coast oak stands, by treatment (100 and 50 ft²/ac).

However, because two schools of thought exist on this topic, the average annual tree growth was calculated based on both, a) all trees in the plot (living and dead) and, b) only on living trees.

As expected there is a rather dramatic difference between the average basal area growth rates for "all trees" versus "living trees" for control plots (figure 6). However, even the growth rates for the "living trees" is only 55 pct of the rate for 100 ft^2/acre plots and only about 40 pct of the rate for 50 ft^2/acre plots.

When the rates for "all trees" is compared, clearly the benefits of thinning are apparent; the 100 and 50 ft^2/acre plots exceeded the control plots by ratios of 9:1 and 11:1, respectively.

Because of the mortality caused by fire and snow, these data show not only the positive results of thinning but also the loss of growth that can occur when stands are not under proper management.

Total Volume in Cubic Feet Per Acre

During the five-year period, total volume increased by 182 ft^3/acre (3.9 pct) for control plots (figure 7). Thinned plots incremented by 329 ft^3/acre (12.6 pct) for the 100 ft^2/acre plots and by 241 ft^3/acre (14.9 pct) for the 50 ft^2/acre plots. The average annual total volume growth rate for the control plots is 32 pct lower than the 50 ft^2/acre plots and 45 pct lower than the 100 ft^2/acre plots (figure 8).

Further it must be understood that control plots contain many more trees than the thinned plots and that the total volume growth could be greater simply due to the total number of trees. In total they could produce more volume even though their growth rates might be slower.

For this reason, a more realistic comparison of growth is to calculate growth per tree, or alternately, volume per square foot of basal area. The results are very similar when using the alternate method volume growth per square foot of basal area.

Annual Volume Growth for "all trees" (cubic feet/tree/year) — All trees remaining after thinning in 1984 are used to calculate this data, i.e., the residual inventory.

Annual Volume Growth for "living trees" (cubic feet/tree/year)—This growth rate is based only on the performance of the living trees.

The data show that the thinned plots out grew the control plots by substantial margins (figure 9). The 100 ft^2/acre plots incremented 74 pct more total volume and the 50 ft^2/acre plots incremented 128 pct more total volume for "living trees" than did the control plots. The difference is even more pronounced when using "all trees" in the calculations.

The U.S. Department of Agriculture-Forest Service, 1977 uses the following definition for Productive Forest Land: "Land which is physically capable of producing crops of industrial wood in excess of 20 cubic feet/acre/year." While the wood products from coast live oak are mostly in the form of firewood, it is interesting to note that the rate of growth of coast live oak exceeded 20 cubic feet/acre/year for all plots.

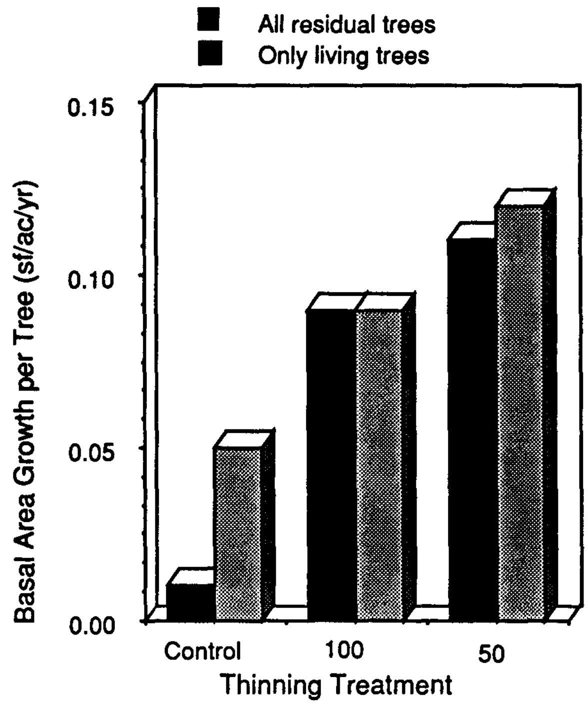

Figure 6—Basal area growth per tree for both residual and "only living" trees, by treatment (100 and 50 ft^2/ac).

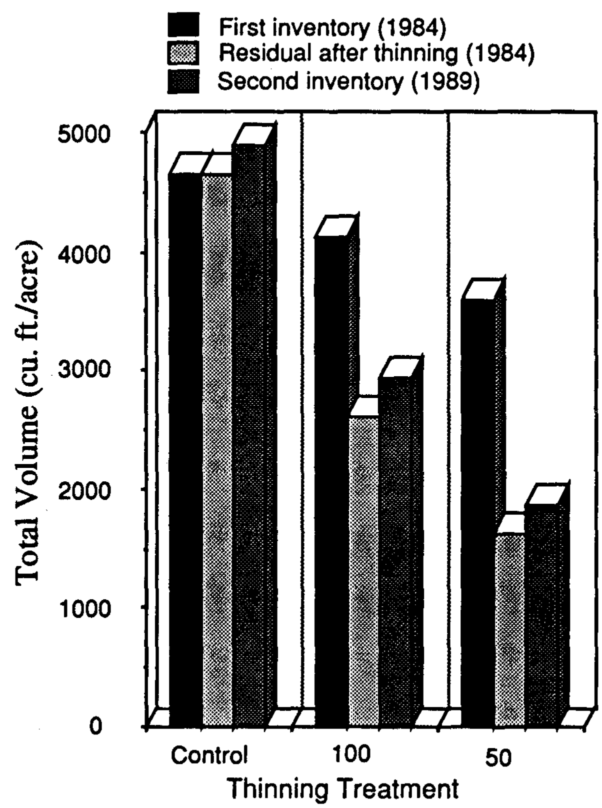

Figure 7—Total volume for coast live oak stands by treatment (100 and 50 ft^2/ac).

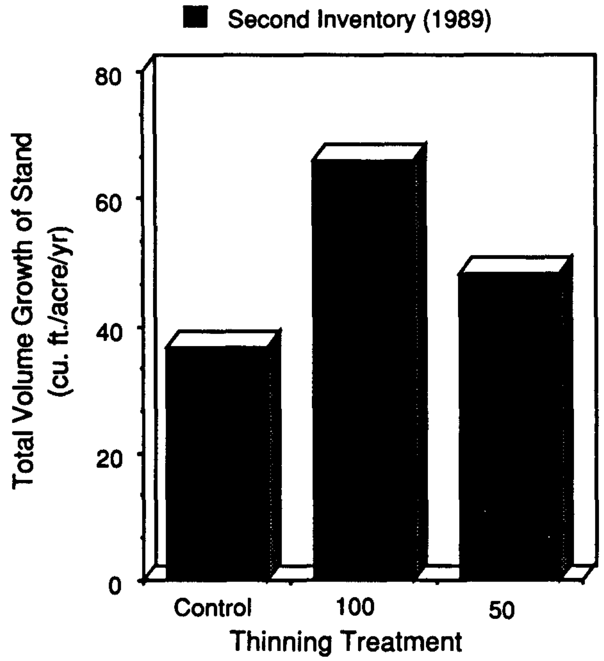

Figure 8—Annual total volume growth for coast live oak stands by treatment (100 and 50 ft^2/ac).

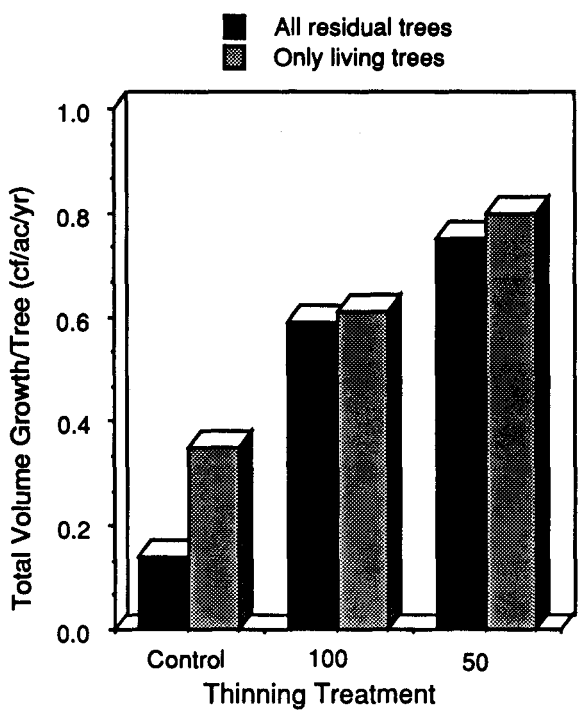

Figure 9—Annual total volume growth for coast live oak stands by treatment (100 and 50 ft^2/ac).

The results of this study were compared with a stem analysis study conducted on 25 plots in 1985 (Pillsbury and De Lasaux) with similar results. All plots exceed 20 cubic feet/acre/year based on the mean annual increment (MAI). When MAI was computed using the last five-years growth, all plots except one exceeded this value.

Wood Volume and Sawlog Volume in Cubic Feet Per Acre

The wood volume in the control plots grew 5-10 pct slower than the thinned plots. However, the sawlog volume in the control plots performed as well as the trees in the thinned plots as the "Percent of volume" data verifies (table 2). This is because trees having sawlog volumes are larger and already dominate the crown and root space in the stand. Consequently their growth rates are not as greatly increased by thinning in the first five-years compared to the changes in total and wood volume. It will take more time before smaller trees will grow into the sawlog category and therefore increase the total sawlog volume.

Greater changes are expected during the 10-15 year inventories. However, it should be noted in table 2 that about 3/4ths of the volume removed in the 100 ft^2/acre plots has already grown back. This is illustrated in figures 10 and 11.

Also the wood and sawlog volumes are calculated based on diameters and heights. A more precise method, when comparing volumes at different intervals, is to only use diameter as this will eliminate the variation observed in height measurement. Until this method is used the wood and sawlog volume data should be considered preliminary.

Table 2—***Preliminary estimates of the effects of thinning on wood and sawlog volume in coast live oak.***

Wood Volume		-------- Five-year growth data -------		
Treatment	Volume Thinned (cf/acre)	Volume Growth (cf/acre)	pct of Thinned (cf/acre)	pct of Vol. (cf/ac)
Control	0	550.9	n/a	17.5
100 ft^2/ac	875.3	482.2	55.1	27.2
50 ft^2/ac	1224.7	256.4	20.9	23.1
Sawlog Volume		------- Five-year growth data ------		
Treatment	Volume Thinned (cf/acre)	Volume Growth (cf/acre)	pct of Thinned (cf/acre)	pct of Vol. (cf/ac)
Control	0	121.1	n/a	17.0
100 ft^2/ac	75.2	55.5	73.8	18.3
50 ft^2/ac	202.7	27.3	13.5	11.6

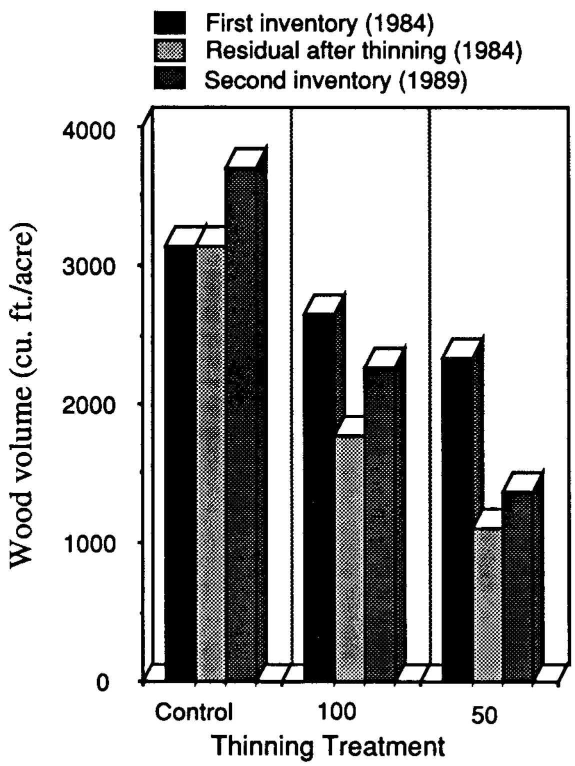

Figure 10—Wood volume for coast live oak by treatment (100 and 50 ft^2/ac).

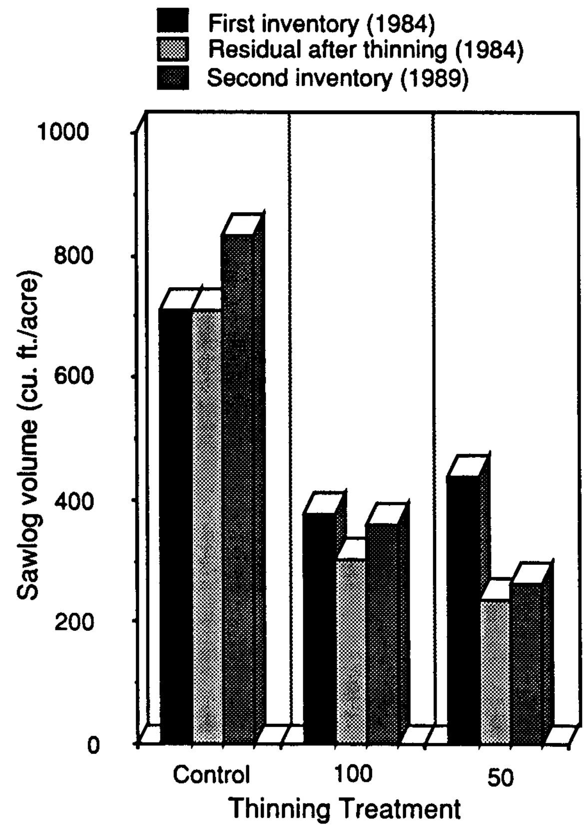

Figure 11—Sawlog volume by treatment (100 and 50 ft^2/ac).

Tree Movement By Diameter Class

Another important facet of the study is to examine how trees "move," that is, how their diameter classes change in relation to the rest of the stand. Figure 12 illustrates the changes that occurred and the regrowth trends that are beginning to appear. Note that the size class removed was primarily in the 2-13 in dbh range. A more thorough analysis will be possible when the 10 and 15 year inventories and growth data are available. At this time, in-growth will also begin to appear.

Preliminary Economic Analysis

At the bottom of every study is the question of cost versus benefit. Although thinning studies are designed for the long-term improvement of the stand, the five-year inventory still allows a rough first-look at the cost/benefit data. The example shown in table 3 is designed to examine the outcome of three separate courses of action by the landowner: a) no thinning, b) thin to 100 ft^2/acre, and, c) thin to 50 ft^2/acre (Richard Thompson, personal communication 1990).

As with any economic analysis a number of assumptions are made to provide a basis for comparison and interpretation. For this example, the following assumptions are used.

1. The property owner, in 1984, thins 10 acres of coast live oak. The average volume on the property is 4150 ft^3/acre which is the approximately the average of the 30 plots used in this study. This is a dense stand that is approximately 60 years old.
2. The property owner employed a Registered Professional Forester who prepared a cutting plan and marked the trees for cutting at a cost of $40/acre for the 100 ft^2/acre option and $50/acre for the 50 ft^2/acre option. The landowner will inspect the operation to insure that the wood cutters are following the guidelines provided by the forester.
3. A local wood cutting outfit will be contracted for the tree removal. Their remuneration will be to keep 2 out of every 5 cords of wood cut (40 pct). They are required to meet all conditions spelled out by the cutting plan such as slash removal, stream-side protection, etc. They will purchase the remaining wood.
4. The stumpage price is $40/cord of wood in 1984 and 1989 and $45/cord in 1994. Obviously as the price of other fuels change, this value will too.
5. The number of cubic feet per standard cord of wood is assumed to be 82. This is based on previous studies by the authors.
6. The percentages of the stand that are thinned to meet the objectives of the options define above are: 36 pct

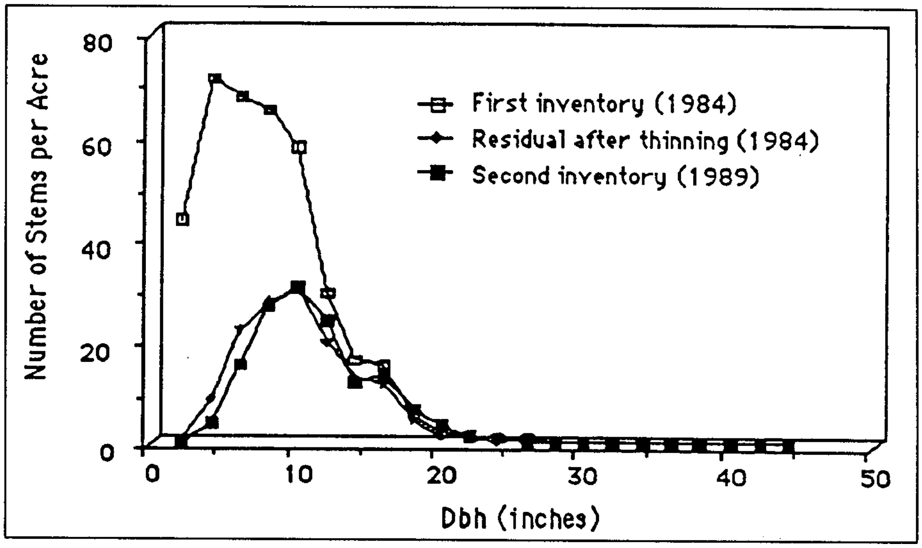

Figure 12—Stand graph showing the distribution of number of stems per acre by diameter class for 100 ft^2/acre plots.

thinned to reduce the basal area to 100 ft^2/acre and 55 pct thinned for the 50 ft^2/acre option. This is based on average percentages calculated from this study.

7. Yield or interest (including inflation) on thinned income is assumed to be 10 pct per year for the period 1984-1989, and 12 pct per year for the period 1989 to 1994.
8. The purpose of the analysis that follows is to show the change in timber valuation for the period 1984-1994. As a preliminary analysis it does not consider taxes, land rent or complex situations that may exist. Also it does not consider the value of other benefits such as increased land value due to the managed condition of the forest, reduced fire risk, and increased forage.

The timber valuation, which includes both the income from thinning and the value of the residual inventory, shows a break-even condition for the three options by the end of the first five-year period. The value based on the thinning options are about $2,120 and $2,050 per acre while the option to not thin yields about $2,110 per acre. In essence, the thinning options have basically paid for themselves in the short span of five-years. In addition, a number of other benefits, discussed above, have accrued.

An estimated timber valuation in 1994 is based on obtaining the same growth rates for the next five-year period. Extrapolating growth and yield data for five- and ten-year periods is common practice. Under these conditions, we estimate that the thinning options provide a valuation to the landowner well ahead of the option to not thin. The 100 ft^2/acre thinning option yields a per acre value of about $2,840 and the 50 ft^2/acre option yields about $3,000. The option to not thin yields a value of about $2,200 per acre.

ANALYSIS OF UNDERSTORY DATA

The Concept of Coppice Management

The revegetation of live oaks through the sprouting of cut stumps, otherwise known as coppice management, is widely used in a variety of forestry and woodlot situations. California coast live oak is well known as a vigorous sprouter. This is especially true when damage is created by fire, wind or harvesting. Most common are sprouts from the cambial layer which form a ring on top of the stump.

In this study sprouts took on two distinct forms: 1) mound or "clump" form, and, 2) sprouting form. Clumps occurred when the succulent sprouts are browsed by wildlife and domestic animals. These sprouts become rounded into a dome or mound shape. The mounds continue to expand outward, growing mostly in diameter rather than height, until an animal can no longer reach the sprouts in the center or until a growing season passes when browsing fails to occur. The center sprouts then will "escape" and grow into a new tree. This process could take anywhere from 2 or 3 years up to 15 or 20 years. If the stump had one or more dominant leaders it was classified as a sprout (as opposed to a clump).

The rapid growth of the sprouts was greatly reduced by browsing of domestic and wild animals. Eight of the sites showed evidence of recent activity by domestic livestock. In plots where domestic and wildlife activity is high, the instance of "clumping" is much higher.

In order to better understand the process of tree development from clumps, they were grouped into three size categories.

Table 3—*Preliminary timber valuation for a l0-year period of woodlot management*.

NET INCOME FROM THINNING (before taxes)

Item	Control (per acre)	Treatment 100 ft^2 (per acre)	Treatment 50 ft^2 (per acre)
(1)Initial inventory (1984); (cf/acre)	4150.00	4150.00	4150.00
(2)Total volume thinned (1984); (cf/acre)0.00		1494.00	2282.50
(3)Number of cords thinned (1984); (cords/ac)0.0018.2227.84			
(4)Share to property owner (60 pct); (cords/ac)0.0010.9316.70			
(5)Income to property owner @ $40/cord =$0.00	$437.27	$668.05	

RESIDUAL INVENTORY VALUE and THINNING INCOME

Item	Control (per acre)	Treatment 100 ft^2 (per acre)	Treatment 50 ft^2 (per acre)
First Inventory (1984)			
(6) Initial inventory (1984); (cf/acre)	4150.00	4150.00	4150.00
(7) Total volume thinned (1984); (cf/acre)0.00	1494.00	2282.50	
(8) Residual (after thinning); (cf/acre)	4150.00	2656.00	1867.50
(9) 1984 Stumpage value @ $40/cord$2,024.39$1,295.61	$910.98		
(10) Income from thinning @ $40/cord (60 pct)$0.00	$437.27	$668.05	
(11)1984 Timber Valuation before expenses =	$2,024.39	$1,732.88	$1,579.02
(12)Cost of cutting plan & tree marking$0.00 $40.00 $50.00			
(13)1984 Timber Management Valuation =	$2,024.39	$1,692.88	$1,529.02
Second Inventory (1989)			
(14)Stand re-growth (cf/ac); (Pillsbury and Joseph 1990)182.50329.00241.00			
(15)Value of re-growth @ $40/cord$89.02$160.49$117.56			
(16)Interest from 1984 thinning income (@10 pct/yr)$0.00$266.96$407.85			
(17)1989 Timber Management Valuation =	$2,113.41	$2,120.32	$2,054.44
Third Inventory (1994)			
(18)Stand re-growth (cf/acre), same rate assumed. 182.50329.00241.00			
(19)Value of re-growth @ $45/cord$100.15$180.55$132.26			
(20)Interest from 1984 thinning income (@12 pct/yr)$0.00$536.86$820.20			
(21)Estimated 1994 Timber Mgm't. Valuation =	$2,213.57	$2,837.73	$3,006.89

Over 83 pct of all clumps are less than 2 ft. in diameter, with 15 pct 2 ft. to 3 ft. diameter. Only 2 pct were greater than 3 ft. in diameter. For the most part, five years is not enough time for clumps to reach diameters of greater than three feet. Until a sprout in the center of the clump can "escape" browsing and obtain a height of four or five feet, little coppice establishment can be expected.

In 100 ft^2/acre plots 32 pct of the stumps formed clumps and 14 pct had advanced to the sprout stage. The percentages for the 50 ft^2/acre plots are 48 and 14. Clump data is presented as descriptive data only at this point in the study. As each five-year inventory is completed changes in their development will be monitored.

The Forage Layer in the Thinning Plots

Part of this study was to examine how the biomass of forage was altered following thinning of the overstory. Forage samples were collected using a 2 ft square (4 square feet) on an area that was subjectively calculated to represent the average of all forage species within the plot. Species were recorded. All above ground grasses and forbs (which an animal would eat) were clipped to the ground. Once air dried, the samples were weighed; and then converted to a per acre basis (lbs/ac). (Stechman 1986).

Wild oats (*Avena fatua*), cheatgrass brome (*Bromus* *tectorum*), ripgut brome (*B. rigidus*) and annual ryegrass (*Lolium multiflorum*) were found to some extent on almost all of the sites. It was estimated that they occupied 50 pct or more of the grass layer. The following species represented about 30 pct of the cover: Indian ricegrass (*Oryzopsis hymenoidies*), foxtail fescue (*Festuca megalura*), wheatgrass (*Agropyron* spp.), mouse barley (*Hordeum leporinum*) and needlegrass (*Stipa* spp.).

We found that the species in the forage layer did not vary by treatment as much as by site. The same forage species were usually found in all three plots of the same site, though in different proportions.

For these reasons, treatment averages are not compared. Instead, figure 13 is provided to show the influence of both site and treatment on individual plots. Note that only four sites show the "textbook" pattern where the 50 ft^2/acre plots produce more forage biomass than the 100 ft^2/acre plots which, in turn, produce more than the control plots.

Clawson, McDougald and Duncan (1982), suggest that 700 lbs/acre is considered the minimum or lower threshold level of residual dry matter on gentle to steep slopes in the Central Coast Foothills. Using this value, figure 13 shows that only three sites (all were 50 ft^2/acre plots) exceed this level, while five other sites are just below the suggested threshold.

It is our conclusion that the level of forage production measured at the end of the first five year period is not adequate to allow grazing because there would not be enough residual dry matter for the next year. There are several other important variables which should be considered in the interpretation of the forage data. Most important is the percentage of crown cover on the site after thinning.

This study was designed using basal area as a method to manipulate the stand primarily because of the ease of application and measurement. However the relationship between a stand's basal area and its percent crown cover is not well defined.

The average crown closure (in pct) for the treatments is shown in the following chart and illustrated in Figures 14-16.

1984	1989		
All plots	Con.	100 ft^2/ac	50ft^2/ac
89 pct	83 pct	71 pct	54 pct

Even though a large volume of wood was removed from the 50 ft^2/acre plots the remaining trees currently occupy 54 pct of the crown space. Clearly a further reduction is needed before significant increases in forage will be obtained; perhaps a crown cover in the 35-40 pct range would yield acceptable levels.

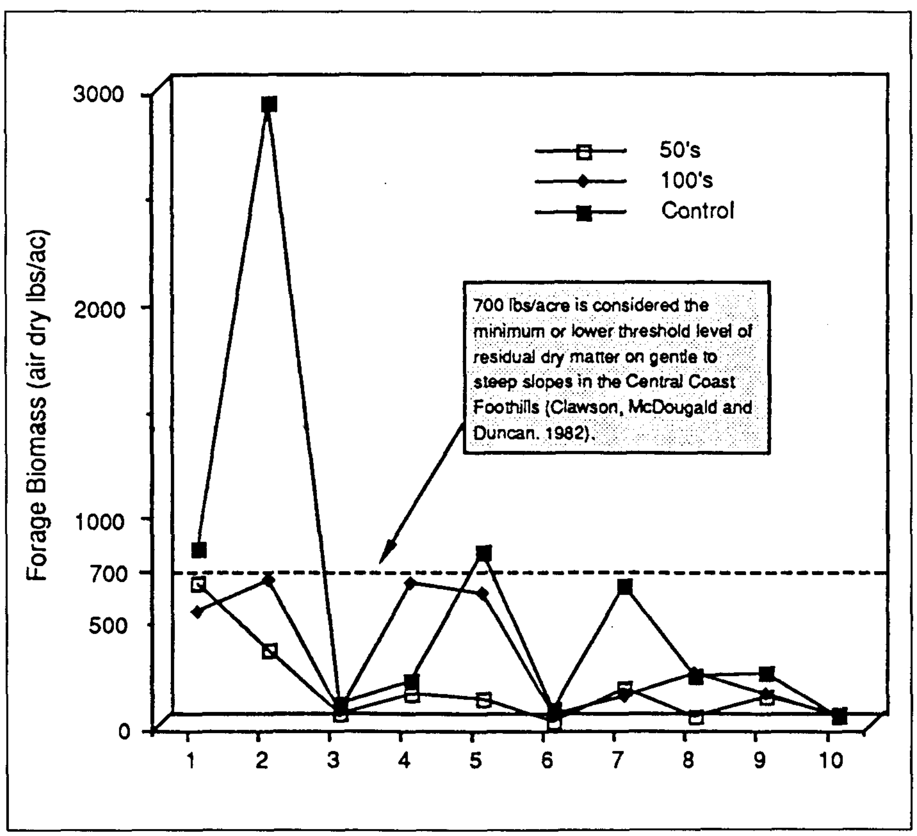

Figure 13—Forage biomass for the coast live oak thinning plots by treatment (100 and 50 ft^2/ac).

Figure 14—A typical control plot of coast live oak.

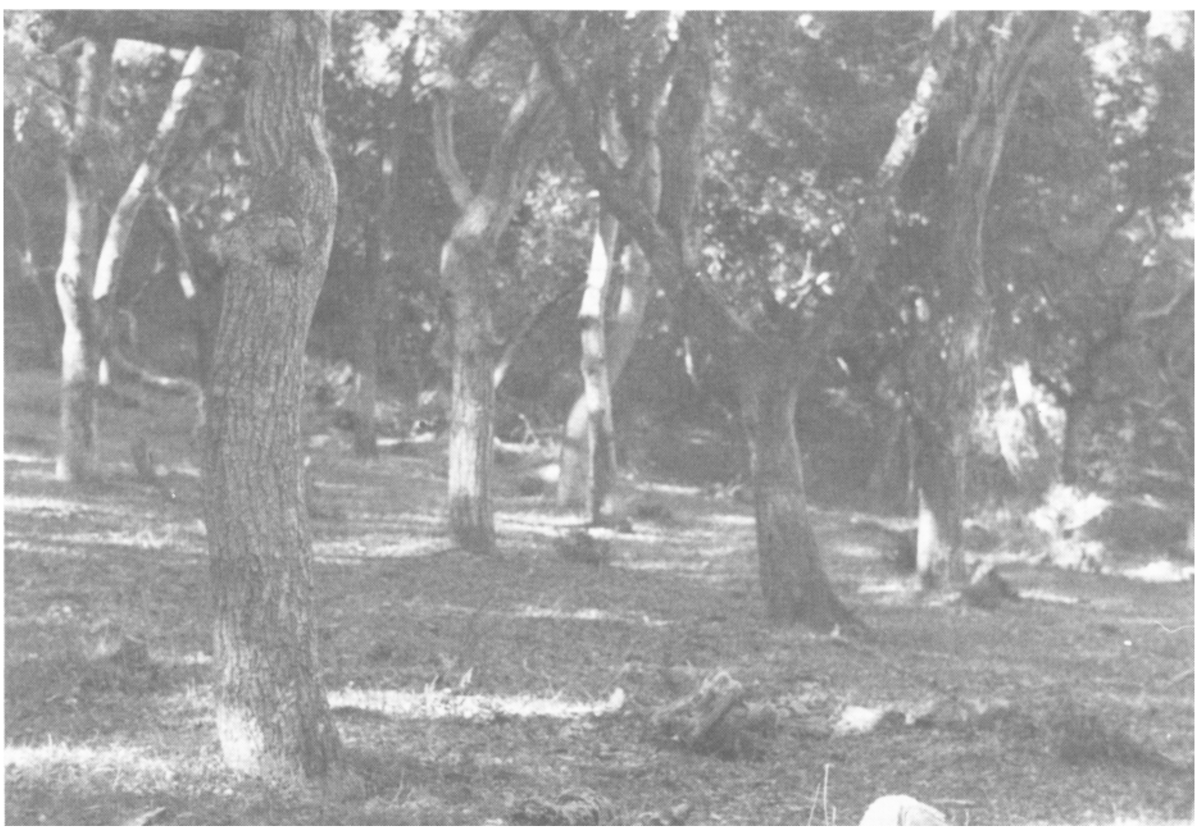

Figure 15—A plot of coast live oak thinned to 100 square feet per acre basal area.

Figure 16—A plot of coast live oak thinned to 50 square feet per acre basal area.

CONCLUSIONS AND RECOMMENDATIONS

The first five years of growth information has been collected and analyzed for the coast live oak thinning study. The interpretation of this data is discussed below in the form of conclusions and recommendations.

1. Two extremes in weather conditions occurred during the five-year interval which affected the study. First, a major forest fire burned through several plots killing a number of trees and causing the bark to crack and swell. This made measurement more difficult. Our data also shows that the more dense, unthinned plots sustained greater damage from fire than did the treatment plots. Proper care and management of the woodland forest can reduce losses from fire and snow, and, in general, protect the value of the resource.

2. Many of the stands in the thinning study are thought to be near rotation age. Could they benefit from a thinning at this age?

The answer to this question is "yes." The benefits are already apparent even after five years of growth.

Both basal area and total volume growth percentages were significantly greater in the thinned plots than the control plots. This was true even if only the surviving trees were included in the calculations (excluding mortality). Per acre growth rates for the five-year interval ranged between 10 and 15 pct for treatment plots and between 2 and 4 pct for control plots.

Clearly coast live oak stands, even if they are older, respond in a positive manner to thinning.

3. Prior to thinning all 30 plots in the study were measured and and their growth rates were found to exceed the Forest Service definition for Productive Land (20 ft^3/acre/year). In fact they averaged about 70 ft^3/acre/year. An independent site, growth and yield study conducted on 25 plots in San Luis Obispo and Monterey counties in 1985 showed similar results. In that study, coast live oak plots averaged about 60 ft^3/acre/year. In both studies the researchers sampled only moderately dense to dense stands; the typical growth pattern for coast live oak.

This information is significant as it relates to the potential for silvicultural practices and management for commercial products.

4. A preliminary economic analysis indicates the potential for modest returns on a thinning operation similar to this study. A rough first-look shows that after five years the value of the residual trees, plus the thinning income and interest, approximately equal the value of the unthinned forest.

A projection for a ten-year period shows that the value derived from the thinned plots is $600-800/acre greater than the control plots.

This conclusion has very important ramifications to forest and woodland property owners and their stewardship practices.

A landowner can conduct an economically viable thinning operation and accomplish several objectives, including land stewardship. The results show that a forest or woodland will continue to grow and increase in value. The temptation to wholesale harvest all trees (clearcut) can be resisted by knowing that some income can be available immediately following thinning and that the remaining trees are also adding value at a more rapid rate than before. Thus the landowner has not only gained some immediate income and enhanced his or her woodlands responsibly, but by retaining the forest cover on the soil has also kept his or her options open to future decisions.

5. Cut stumps on thinned plots were evaluated for their ability to produce sprouts. While between 30 and 45 pct of the stumps produced clumps (a dome-shaped mass of stems created by heavy browsing) only 14 pct of the clumps were able to "escape" into the sprout stage.

This means that regeneration by coppice methods is not going to occur rapidly following thinning. Some method of protection, such as screens or piling brush on the stump, is necessary to encourage rapid regeneration.

6. The possibility of increased production of forage following thinning was less promising. First a tremendous variation by site was observed. This greatly confounds the effects of thinning and interpretations of treatment effect is not advised. In addition, only three plots produced enough forage to exceed the recommended minimum threshold of residual dry matter.

The lack of greater quantities of forage production is due to the relatively high crown cover that was left after thinning. Even the most heavily thinned plots (50 ft^2/acre) averaged over 50 pct crown cover (54 pct), while the 100 ft^2/acre plots averaged 71 pct. If forage production is a major objective of the landowner, further reduction in crown cover is necessary before enough light will be available to produce usable levels of forage.

7. The condition of the soil was evaluated both in 1984 and 1989. In both years, no type or amount of erosion was observed on any plot regardless of the land slope. Apparently the crown and root density left after thinning was sufficient to protect the site.

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