occidentalis are present. Sampling decision lines comparable to those used in developing figure 1 can be derived using the sequential sampling program available on the Statewide IPM computer system.

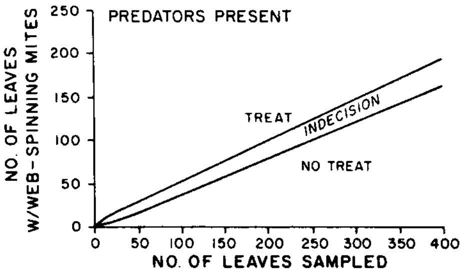

Fig. 3. Presence-absence sequential sampling decision guidelines for web-spinning mites on almond with predators present.

The actual number of trees sampled depends on an estimate of acceptable sampling time and knowledge of the minimum treatment area. Some areas within an orchard, such as those near roadways or on a streak of sandy soil, have greater potential for mite outbreaks than the rest of the orchard. If it is possible to treat only those areas instead of the entire orchard, they should be sampled separately. To reduce the effect of between-tree variance within an orchard, the number of leaves sampled from each tree should be reduced, thus increasing the number of trees sampled. At least five trees should be sampled from each orchard unit. Trees within each unit should be sampled at random, but the trees chosen should not be obviously different from others in the unit.

The leaves chosen are selected at random around the circumference of the tree above the sprinkler line. Each leaf is examined only for the presence or absence of any life stage of the web-spinning mite species. Actual mite numbers per leaf or presence or absence of damage is not important.

Monitoring in almonds

Early in the season, mites are concentrated on the tree's lower portions and centers. Later, they disperse to the outside of the tree and become uniformly distributed. After early June, leaves removed randomly from any portion of the tree above the sprinkler line will provide an accurate estimate of web-spinning mite abundance.

Monitoring should begin in early June with random sampling of leaves for predators, including those other than *M. occidentalis*, such as *Stethorus* spp., lacewings, and six-spotted thrips. Predatory mites are most often associated with colonies of spider mites. Their presence should be considered before any pest management action is taken, because the predators may reduce web-spinning mite populations. The presence or absence of *M. occidentalis* will determine which sampling decision rules to use.

When either a "treat" or "no-treat" decision is reached, sampling can stop. If no decision can be reached, sampling should continue as long as time permits.

The presence-absence sequential sampling plan provides an estimate of whether or not a treatment is required, and can be used as part of a weekly orchard monitoring program. The sampling plan could prove valuable when used after mid-June in orchards where mites may become a problem because of cultural practices, insufficient predators, or pesticide intervention. Presence-absence sampling should follow an early-season program of monitoring densities of web-spinning and predator mites and applying low rates of acaricides when necessary to reduce high infestations.

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Under projected interest rates, plantations wouldn't be profitable on low-quality sites

Blue gum plantations analyzed for economic return

James A. Rinehart □ Richard B. Standiford

Increased demand for firewood and a growing market for hardwood fiber have created interest in planting eucalyptus in California, prompting this assessment of growth and potential economic return for eucalypt plantations. We have developed a variable site-density growth model for blue gum, *Eucalyptus globulus*, and have used the yields predicted to evaluate blue gum plantations under certain cost and revenue assumptions. From such information, we have derived the optimum number of trees and rotation length under different management conditions.

Growth and yield model

A 1929 University of California publication by Woodbridge Metcalf presents data on 96 blue gum stands throughout California. From this information, he constructed site class curves to predict soil productivity and presented empirical yield tables for three site classes. Using modern computer techniques not available in the earlier evaluation, we developed a more powerful blue gum growth model. The original data came from stands that received little management after plantation establishment; thus the following model applies only to low management conditions.

(1) $\text{Ln } Y = 4.86449 + .02547(SI) + .34896(\text{Ln } TPA) - 10.41628(1/A)$

where:

Ln Y = the natural log of yield in cubic feet per acre

SI = site index in feet at a base age of 10

Ln TPA = the natural log of initial trees per acre

A = age of the stand in years

The site index represents the height of the dominant trees in the stand at age 10. Figure 1 shows the blue gum site index curves used in this model, which are derived from Metcalf's original site class curves. Site index for an area is estimated by measuring the height of the dominant trees in the stand and their age, and finding where a similar curve containing this point intersects the 10-year base line shown in figure 1. Figure 2 shows the generalized growth curves for three sites using this model for 680 trees planted per acre.

Since tree diameter has a bearing on when trees can be economically harvested and processed, it was also necessary to develop models for estimating average stand diameter:

(2) $\text{Ln } BA = 2.07854 + .1496(\text{Ln } TPA2) - 6.5518(1/A)$

(3) $TPA2 = 138.69 + .56(TPA)$

(4) $AD = BA/(TPA2 \times .00545)$

where:

Ln BA = natural log of basal area

TPA2 = surviving trees per acre at harvest

AD = average stand diameter

In the subsequent analysis, it is assumed that a stand must achieve an average diameter of 6 inches to be harvested, based on current harvesting technology and cost.

By systematically varying site index, initial stocking, and age in equations (1) through (4), one can develop yield tables (table 1 is an example). From such tables, the planting density and rotation can be chosen that meet the grower's management criteria.

Management goals

If the management goal is to produce the maximum salable biomass, rotation length and initial density level will be chosen for the greatest mean annual increment, or average annual production. In table 1, mean annual increment for the density of 680 trees per acre is maximized at 4.3 cords per acre per year at age 10. If the site index for an area is known, it is possible to generate a series of tables for different planting densities. Density and rotation length are chosen for the highest mean annual increment while meeting the 6-inch average diameter constraint.

Table 2 shows the optimum initial planting densities and rotation lengths for site indexes 60, 85, and 105 that maximize mean annual increment and result in an average diameter of at least 6 inches. As site index increases, optimal density increases and rotation length decreases.

Under most circumstances, landowners will seek to maximize financial return, given other management constraints, rather than biomass production. To evaluate the effect of economic criteria on optimal planting density and rotation length, we developed an economic model based on the following assumptions:

Biological assumptions:

□ The biological model assumes no management input beyond the site preparation, weed control, and irrigation occurring at the time of planting.

□ Since blue gum regenerates by coppicing, or resprouting, it is not necessary to replant after each harvest. We assume four rotations will occur before replanting (three coppice rotations following the seedling rotation).

□ Since coppice growth begins on a mature root system, the coppice rotations are assumed to be 70 percent of the seedling rotation.

□ Following each harvest 5 percent of remaining stumps produce no sprouts.

Economic assumptions:

□ Financial calculations are before income tax. Property tax is included as a cost, yield tax as an adjustment to revenue.

□ No outside bank financing is obtained; all capital is provided by the investor.

□ Annual inflation by decade will be 7 percent until 1990, 5 percent from 1991 to 2000, 3 percent from 2001 to 2010, and 0 thereafter.

□ Management is in perpetuity. Calculations are based on an infinite series of four rotation cycles (one seedling and three coppice). Stable price and cost conditions are assumed after the first rotation cycle.

□ A minimum average stand diameter of 6 inches is required for harvest.

Cost and revenue assumptions:

□ Land values for property tax calculations are based on the California State Board of Equalization Harvest Value Schedule for Timberland Production Zone land in the Pine Region, and range from \$40 to \$84 per acre depending on site quality.

□ Effective yield tax is 2 percent of harvest value.

□ The amount of revenue foregone by investing in eucalyptus depends on other opportunities available to the landowner. In this case, land rent is based on rent for irrigated pasture, \$40 per acre per year being a representative amount for timber counties in California.

□ Costs and their time of occurrence as shown in table 3.

□ Revenues are received in the form of stumpage payments for cordwood. A current stumpage price of \$25 per cord for fuelwood and pulpwood is assumed, with a real price increase of 0.5 percent per year through 2010.

Present-net-worth framework

A present-net-worth framework was selected as an appropriate measure of economic efficiency for landowners interested in maximum return per acre. In this calculation, all costs and revenues are discounted to the present at an appropriate interest rate, usually determined by the individual investor according to his or her own investment constraints. For a given site index, present net worth is calculated for a series of ages and initial planting densities. The optimal density and rotation length is the combination that yields the highest present net worth and meets the 6-inch average diameter constraint. Table 4 shows the results of the analysis using four guiding interest rates (including inflation).

We noted the following trends:

Present net worth increases with site index.

Optimal rotation length is relatively stable across all rates considered. One would expect it to decrease as the site index increases, but table 4 indicates a nearly constant optimal rotation length of nine years. This is a result of the compactness of the blue gum growing cycle. Greater increments of variation in interest rate are required to decrease rotation length. Only at a discount rate of 20 percent on site 105 was rotation length shortened.

Optimal initial planting density increases with site.

Under these cost and revenue assumptions, present net worth is negative on low-quality sites at all interest rates considered, and serious investment in blue gum plantations is unlikely. On medium-quality sites, present net worth is positive at 13, 15, and 17 percent discount rates. Thus, private land-

TABLE 1. Yield table for blue gum plantations with site index of 85 and 680 trees planted per acre

Site index = 85			Trees/acre: initial = 680; surviving = 519					
			Yield		Mean annual increment		Current annual increment	
Age	Average diameter	Basal area	Ft^3/ac	Cd/ac	$Ft^3/ac/yr$	Cd/ac/yr	$Ft^3/ac/yr$	Cd/ac/yr
years	*inches*	*ft^2/ac*						
2	1.8	9.5	60.2	.7	30.1	.3	.	.
4	4.1	48.8	813.5	9.0	203.4	2.3	376.6	4.2
6	5.5	84.2	1,937.9	21.5	323.0	3.6	562.2	6.2
8	6.3	110.6	2,990.9	33.2	373.9	4.2	526.5	5.9
10	6.8	130.3	3,880.6	43.1	388.1	4.3	444.8	4.9
12	7.2	145.4	4,616.3	51.3	384.7	4.3	367.9	4.1
14	7.5	157.2	5,225.8	58.1	373.3	4.1	304.7	3.4
16	7.7	166.6	5,735.1	63.7	358.4	4.0	254.7	2.8
18	7.8	174.4	6,165.3	68.5	342.5	3.8	215.1	2.4
20	8.0	180.9	6,532.6	72.6	326.6	3.6	183.7	2.0

Abbreviations: ft^2/ac = square feet per acre; ft^3/ac = cubic feet per acre; $ft^3/ac/yr$ = cubic feet per acre per year; cd/ac = cords per acre.

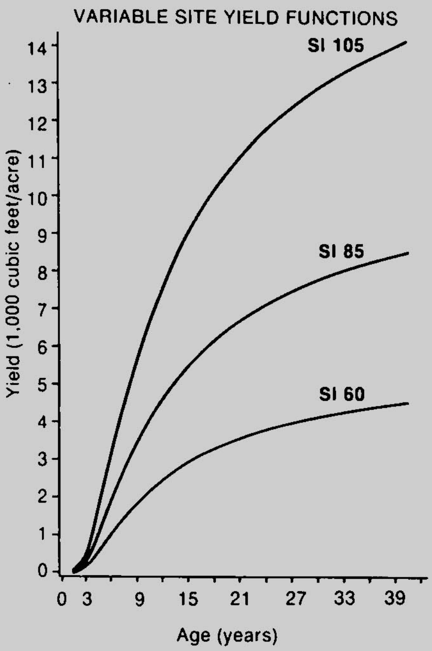

Fig. 1. Blue gum site index (SI) curves used in model are based on height of dominant trees in stand at 10 years of age.

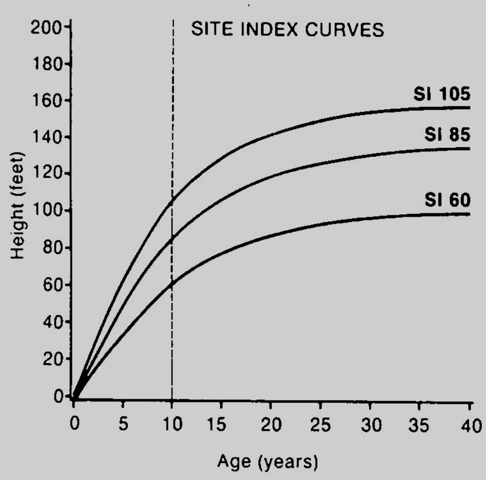

Fig. 2. Generalized yield for blue gum at 680 trees per acre on low-, medium-, and high-quality sites.

TABLE 2. Optimum planting density and rotation length to maximize mean annual increment (MAI) for blue gum at three site indexes

Site index	Planting density	Rotation length	MAI
feet	*trees/ac*	*years*	*cd/ac/yr*
60	680	13	2.23
85	1,210	11	5.27
105	1,210	10	8.77

TABLE 3. Typical costs for blue gum plantation establishment and management in California under minimal management

Cost item	Amount
First year	
Site preparation	\$50/acre
Herbicide application	\$27/acre
Second year	
Seedlings	30¢/seedling
Planting labor	5.5¢/seedling
Irrigation	\$200/acre
Weed control	\$40/acre
Yearly	
Property tax rate	1%
Land rent	\$40/acre
Administration	\$4/acre

TABLE 4. Optimum planting density and rotation length to maximize present net worth (PNW) of blue gum plantations at three site indexes for nominal discount rates of 13, 15, 17, and 20 percent

Site index	Guiding rate	Planting density	Rotation length	PNW
feet	*%*	*trees/ac*	*years*	*\$*
60	13	435	10	−278
	15	300	9	−343
	17	300	9	−378
	20	300	9	−410
85	13	890	9	466
	15	890	9	193
	17	890	9	3
	20	680	8	−184
105	13	1210	9	1636
	15	1210	9	1069
	17	1210	9	669
	20	1210	7	296

owners committed to production are likely to invest, whereas investors requiring higher returns are not. On high-quality sites, present net worth is significantly positive at all interest rates considered.

Conclusions

The yield model confirms that blue gum is a fast-growing species that can generate large amounts of salable biomass in a relatively short time. The biological and economic models developed allow an assessment of optimal planting density and rotation length for different cost and revenue assumptions. Under the assumptions we have presented, a landowner interested in maximizing biomass yields would plant more trees and have a longer rotation length, in general, than a landowner concerned with the economic efficiency of capital invested in the plantation. For both a biological and economic management objective, the models indicate that fewer trees per acre and longer rotation lengths are required to maximize output on lower quality planting sites.

These models indicate that questions remain about the economic feasibility of eucalyptus plantations. At current and projected prices, profitability is assured only on higher quality sites. On medium sites, where returns are moderate, private owners with management goals other than or in addition to direct financial return may be attracted. One must bear in mind, however, that on high- and medium-quality sites, eucalyptus must compete with other land uses that may be more profitable.

On low-quality sites, this model indicates that blue gum investments are not feasible under the interest rates considered here. Under any circumstances, care must be taken that all site and financial factors pertinent to the land and to the individual are properly assessed.

These biological and financial models have recently been written into the BASIC programming language and are available on the Cooperative Extension county-based microcomputer system. For information on using these models, contact the University of California Cooperative Extension county office or the authors.

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