An Examination of the Oak Woodland as a Potential Resource for Higher-Value Wood Products[1]

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Abstract: *California is a leading consumer of hardwood lumber and goods manufactured from hardwoods, but less than 5 percent of the hardwood lumber used by California manufacturers is produced in California. A preliminary survey of the California hardwood lumber industry revealed a fragmented industry with many sole proprietorships and a raw-material mix ranging from timberland species to exotic trees in the urban landscape. In certain situations woodland hardwoods may be a viable resource for local needs or specialty products. On the basis of wood properties and the experience of local artisans and woodworkers, successful markets for high-value wood products are deemed possible, but special manufacturing techniques and innovative marketing strategies may be required to do it economically. A review of the available information on physical and mechanical properties of some woodland species indicates a potential for niche marketing for various wood and wood-based products.*

California, as the most populous state in the country, is a major consumer market for wood products. This market, combined with the substantial forest resource in the state, has contributed to the development of a major wood products manufacturing industry. A few recent reports give an indication of the vast size of this industry. In 1990, California manufacturers used an estimated $2.5 billion worth of wood (US Department of Commerce 1993). A 1993 survey identified 860 furniture manufacturers in California (Cohen and Goudie 1995). In 1989, an estimated 108 million board feet of hardwood lumber, or about 5 percent of the national consumption, was used by West Coast furniture manufacturers (Meyer and others 1992).

The forest resource in California is usually characterized by the 46 billion cubic feet of merchantable coniferous forests (growing stock volume) (Waddell and others 1989). However, forest inventories also reveal a sizable hardwood resource of approximately 12.5 billion cubic feet, of which approximately 29 percent is of commercial timber size (Bolsinger 1988). The combination of a large demand for hardwood lumber and a substantial hardwood resource should result in a healthy, thriving hardwood lumber industry in the state; however, it has not worked out that way. According to USDA Forest Service estimates, approximately 500,000 board feet of hardwood lumber were produced from the California hardwood resource in 1992 (Ward 1995). That is only about 0.5 percent of the manufacturing demand in the state. Clearly there is a potential for increased hardwood lumber production.

Sixty percent of the state's hardwood resource occurs in timberland regions (Bolsinger 1988). The major timberland hardwood species will undoubtedly provide most of the growth in hardwood lumber production. The remaining 40 percent of the hardwood resource occurs in the non-timberland (woodland) regions of California. In this paper the woodland species are defined as those which occur on land not capable of producing 20 cubic feet per acre per year of commercial timber (*table 1*).

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Table 1—Hardwood species commonly found in the timberland and woodland regions of California, listed by estimated volume of growing stock.[1]

Common name	Scientific name	Volume in million cubic feet	
		Timberland	Woodland
Alder, red and white	*Alnus rubra, A. rhombifolia*	163	4
Ash, Oregon	*Fraxinus latifolia*	<1	nf[2]
Aspen	*Populus tremuloides*	20	9
Buckeye, California	*Aesculus californica*	1	24
Chinkapin, giant	*Castanopsis chrysophylla*	50	nf
Eucalyptus	*Eucalyptus* spp.	10	221
Laurel, California bay	*Umbellularia californica*	273	154
Maple, bigleaf	*Acer macrophyllum*	150	6
Madrone, pacific	*Arbutus menziesii*	1116	401
Oak, blue	*Quercus douglasii*	1	1112
Oak, California black	*Quercus kelloggii*	2254	277
Oak, California white (valley)	*Quercus lobata*	34	164
Oak, canyon live	*Quercus chrysolepis*	1302	731
Oak, coast live	*Quercus agrifolia*	126	755
Oak, interior live	*Quercus wislizeni*	45	508
Oak, engelmann	*Quercus engelmannii*	nf	10
Oak, Oregon white	*Quercus garryana*	211	389
Poplar/cottonwood	*Populus* spp.	10	32
Sycamore, western	*Platanus racemosa*	nf	<1
Tanoak	*Lithocarpus densiflorus*	1887	51
Walnut, California black	*Juglans hindsii*	1	<1
Willow	*Salix* spp.	7	6

[1] Source: *The hardwoods of California's timberlands, woodlands, and savannas* (Bolsinger 1988)
[2] nf = not normally found

The purpose of this paper is to examine the utilization potential of the woodland species.[3] Information is provided on the structure of the hardwood industry as well as the basic wood properties and manufacturing characteristics of various woodland species. An understanding of the hardwood industry in California provides the framework for analyzing the utilization potential for woodland hardwood species. Knowledge of the basic wood properties and manufacturing characteristics provides the criteria to evaluate the utilization potential of woodland species.

There is no doubt that these woodland species can be used to make a wide variety of wood products; our indigenous cultures proved that centuries ago. The ultimate question, as to whether woodland hardwoods can be used on a commercial scale, both economically and without unacceptable environmental damage to wildlife habitat and woodland ecosystems, is beyond the scope of this paper, but has been discussed by others (McDonald and Huber 1995).

[3] Portions of this discussion also appear in Shelly and others (1996).

California Hardwood Industry

The California hardwood industry consists of producers (primary manufacturers), suppliers, and secondary manufacturers of finished goods. A survey of these segments revealed a small, fragmented primary industry but mature, well-defined supplier and secondary manufacturing segments (Shelly 1996).

The producers are concentrated in northern California near the timberland hardwood resource, but 59 percent of the 22 producers surveyed also manufacture lumber from woodland species, and 5 of these mills exclusively use woodland species (*fig. 1*). The current total estimated annual production of 2 million board feet and the maximum drying capacity of 1.3 million board feet distributed amongst 22 independent producers are likely too small to compete in the West Coast hardwood commodity market of more than 100 million board feet.

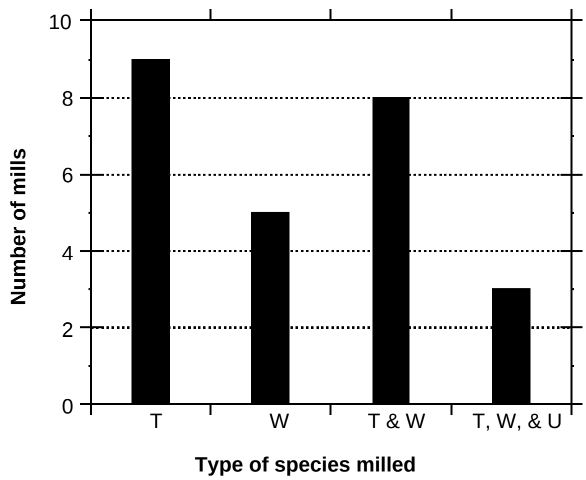

Figure 1—Type of wood processed by California hardwood sawmills. T = timberland, W = woodland, U = urban

The 25 suppliers that are familiar with native hardwood species and the 429 manufacturers in California that use hardwoods form a large commodity network that is centered around the major population centers of the San Francisco Bay Area and the Los Angeles/San Diego region (Lubin and Shelly 1995).

Potential Markets for Woodland Species

The above discussion of the hardwood resource and the industry profile indicate a sizable, underutilized hardwood resource; a large hardwood demand; and a network of hardwood lumber producers and suppliers. The question remaining is whether the 40 percent of the hardwood resource found in woodlands can be used to meet some of the demand for hardwood products. Historically, woodland species, if used at all, were used for low-value products such as firewood and fence posts (Barger and Ffolliott 1972).

Higher value uses of hardwood lumber include furniture, flooring, cabinetry, or various architectural and artistic products. Within each of these categories there is a commodity market and a niche market (Riley 1994). The commodity market demands large volumes of lumber, readily available at a competitive price and manufactured to existing industry standards as defined by the National Hardwood Lumber Association. In contrast, the niche market is more flexible because a specific product or customer is targeted and the product is tailored to the customer's needs. The demands of the commodity market effectively eliminate the possibility of any woodland species being considered. However, the flexibility of the niche market holds promise for many of the woodland species if lumber of acceptable quality can be produced.

In addition to the classic commodity and niche markets, the emerging market for products produced from wood harvested from forests certified as practicing environmentally acceptable, sustainable management has potential for California's hardwoods. Recent surveys indicate that consumers would like to be able to buy products made from wood obtained from certified, sustainably managed forests (Mater and others 1992). However, the message is mixed; it is not clear whether consumers are willing to pay more for these products.

Utilization Characteristics of Woodland Species

Tall, straight trees with few branches on the main stem are the ideal lumber tree. This description does not represent most woodland hardwood species. The spreading, highly branched tree form of most rangeland hardwoods creates numerous grain deviations, making them a low-quality timber tree by standard log- and lumber-grading rules. Grain deviations in wood, such as spiral grain, diagonal grain, or the deviation of grain around knots, are a leading cause of warped lumber. The low proportion of stem to branch wood results in a low yield of usable material. Although many of these branches may be large enough to produce lumber, branches produce poor-quality lumber. Branch wood has a high percentage of reaction wood which is highly susceptible to severe warp and collapse (Zoebel and van Buijtenen 1989).

Very little scientific research has been performed on the wood properties of most California hardwood species because of the lack of a strong commercial interest. The exceptions are California black oak (*Quercus kelloggii*), tanoak (*Lithocarpus densiflorus*), and madrone (*Arbutus menziesii*) (Niemiec and others 1995). These are primarily timberland species, but they can also be found in some woodland regions. Of all California hardwoods, these three species have the greatest utilization potential. What is known about the other woodland species is that the inherent variation in properties and the high density of most of them will make processing difficult.

Because of the limited information and the undocumented performance of wood products made from woodland species, it is difficult to predict product performance. Although machining studies have not been performed on most of these species, machining information on similar species suggests that the higher-density, fine-textured woodland species, such as the live oaks and California white oak, will machine well (Davis 1962). However, the higher frequency of knots and grain deviations in these woodland species may result in a higher percentage of surface defects than found in timberland species. Sometimes the best information available is that passed down by local woodworkers and crafts people who have experience working with these woods, and generally their comments support the contention that the higher-density hardwoods work well. The limitations discussed above do not mean that valuable products are unattainable, but rather that extra processing steps and great care are necessary.

Potential Products

While most manufactured wooden products could be made from the woodland hardwoods, some species are particularly suited for specialty products. For example, wine barrels and implement handles have very special property requirements that can be met with some of these woods. Wine barrels require an impermeable wood with tylosis in hardwood vessels and flavor components compatible with wine, features found in both California white oak or valley oak (*Quercus lobata*) and Oregon white oak (*Quercus garryana*). Implement handles require species with straight grain, high-impact bending and toughness strength properties. The required bending and toughness properties are common in most high-density rangeland hardwoods, especially the oaks. Although woodland hardwoods are generally not straight-grained, straight-grain pieces can be achieved in short lengths.

Based on wood property considerations, other categories of potential wood products can be identified. *Table 2* presents a partial list of potential products and material property requirements which can serve as a guide for identifying potential uses for woodland hardwoods. Trees can be used to make solid wood products where the wood grain and texture qualities are readily apparent, or the wood can be broken down into particles or fibers and used in this form or reconstituted into a composite product. These products have been grouped on the basis of the potential value for the raw material.

Table 2—Preferred wood characteristics important for various products.

Products	Properties
High-Value Products	
Furniture lumber	Good machining and finishing characteristics, attractive appearance
Flooring	Good machining and finishing characteristics, high hardness, dimensionally stable
Custom/artistic	Good machining and finishing characteristics, attractive appearance, interesting character
Cooperage	Low permeability, favorable flavor characteristics
Implement handles	High density and impact strength, knot free, straight grain
Moderate-Value Products	
Non-grade lumber	Moderate to high density, good machining characteristics
Landscape timbers	Natural decay resistance
Pulp or composite panels	Clean, dry chips
Chemical feedstock	Clean, dry chips
Animal bedding	Low density, clean chips
Excelsior	Low density
Cooking/flavor enhancers	Interesting aroma or flavor
Charcoal	High density
Densified fuel	Low ash content
Low-Value Products	
Firewood	High density, air-dried
Hogged fuel	No special requirements
Mulch or compost	No special requirements

Based on the information summarized in *table 2* and a knowledge of basic wood properties, it is possible to identify some possible uses for woodland species. *Table 3* is a compilation of the best available information for some woodland species, tempered by the experience of past and present woodworkers. The information in this table should be considered only a starting point for determining the viability of using particular woods for various products. Because of the inherent variation in wood properties and the small sample sizes used in many of the studies referenced, the properties may be noticeably different from location to location. When considering this information for developing new enterprises, it is important to remember that species can be matched to products on the basis of material property criteria, but the limiting factors are usually availability, size, and quality of the resource.

Manufacturing Considerations

All of the major lumber-processing steps (harvesting, milling, and drying) are important, but drying is the most critical step in producing quality hardwood lumber (Quarles 1986, Shelly 1995). As a general rule, the higher-density California hardwoods present more manufacturing difficulties than the low-density hardwoods. These difficulties must be considered in processing the

Table 3—Selected physical and mechanical properties of some California hardwoods.

Common name	Density[1] at 12 pct moisture content	Hardness[1]	Shrinkage[1]		Machinability[1]	Ease of drying[2]
			tang	radial		
	g/cm[3]	*lb*	*pct*			
Alder, red	0.43	620	7.3	4.4	Good	Easy
Ash, Oregon	0.61	1160	8.1	4.1	Good	Moderate
Buckeye, California[3]	<0.5	?	?	?	Fair	Easy
Chinkapin	0.50	780	7.4	4.6	Good	Easy
Eucalyptus, blue gum[4]	0.8	?	11	5	Good	Difficult
Laurel, California bay	0.62	1270	8.1	2.8	Good	Easy
Madrone	0.68	1530	11.9	5.4	Excellent	Difficult
Maple, bigleaf	0.48	850	7.1	3.7	Good	Easy
Oak, blue[3]	>0.6	?	?	?	?	Difficult
Oak, California black	0.60	1080	6.6	3.6	Good	Moderate
Oak, Calif. white (valley)[5]	0.68	1570	?	?	Good	Moderate
Oak, Engelmann[6]	>0.6	?	?	?	?	?
Oak, live [2]	>0.6	2420	9.5	5.4	?	Difficult
Oak, Oregon white	0.74	1780	9.0	4.2	Good	Difficult
Poplar/cottonwood[3]	0.38	390	8.6	3.6	Poor	Easy
Sycamore, western [3]	0.58	?	?	?	Poor	Moderate
Tanoak	0.67	1450	10.0	5.5	Good	Difficult
Walnut, California black[6]	>0.5	?	?	?	Good	Moderate
Willow[3]	0.48	?	?	?	Good	Easy

[1]Information compiled from the following references: Niemiec and others (1995); Markwardt and Wilson (1935); Davis (1962); and Schniewind (1960 a,b,c).

[2]Assessment based on information in the reference noted in footnote 1 above plus the anecdotal comments of practitioners.

[3] Estimates based on characteristics of similar species (same genus) which are reported in Markwardt and Wilson (1935), and Davis (1962).

[4] Estimated from information reported in the Australian literature, as summarized in Shelly (1991).

[5] Assessment based on information reported by Schniewind (1959).

[6] Estimated from comments in Harrar (1957).

higher-value, solid wood products. In most situations the extra effort and care required to deal with these difficulties will not pay off for most of the low- and moderate-value products. The following discussion refers specifically to high-value uses, but many of the same ideas can be applied to the lower-value uses.

The hardwood industry in the United States developed around the large diameter, high-quality trees of the Northeast and a minimum log length of 8 feet. The decreasing quality of the available resource has led to innovations in processing aimed at maximizing quality lumber production from small-diameter, low-grade trees. A basic knowledge of wood behavior and processing techniques is important to minimize the problems associated with lumber production from high-density California hardwoods.

Harvesting

It is important to recognize the utilization potential of trees before they are cut. Some trees will have very little potential and should be left in the forest or removed as firewood or other low-value product. Of the trees that are selected for removal to be processed as lumber, it is important to cut log lengths that maximize the highest quality lumber. This means cutting to lengths that maximize straight grain and minimize the presence of knots or other defects such as decay or insect damage. For woodland hardwoods this often means short log lengths of 6 feet or, if the sawmill can handle it, even 4 feet.

Milling

The goal of any sawmilling operation is to produce rectangular boards from round logs with as little waste as possible. Some of the sawing philosophies to accomplish this are discussed in this section. Although there are some major differences between these methods, two basic decisions common to all of them are a selection of a green board thickness and the grain orientation of the wide face of the board.

To maximize yield it is important to carefully select a rough/green thickness and to remove as little as possible when squaring up the round log. The rough/green thickness must take into account the amount of thickness reduction due to planing (about 0.19 inches) and the loss to shrinkage when the board is dried (about 5 percent of the green dimension). As an example, to produce a surfaced, 1-inch thick, kiln-dried board the rough/green thickness should be 1.25 inches (0.19 inches planing allowance + 0.06 inches shrinkage allowance).

Another important milling decision is to decide whether to maximize flat-sawn or quarter-sawn boards. Quarter-sawn boards are generally considered a more dimensionally stable product because they exhibit less dimensional change (shrinking or swelling) across the wide face of the board than flat-sawn boards exhibit. This is due to the fact that wood shrinks or swells about twice as much in the direction tangent to the growth rings (tangential) than it does in the direction perpendicular to the growth rings (radial). Flat-sawn boards are generally considered to exhibit a more interesting appearance than quarter-sawn boards because of the exposed grain patterns exhibited on the wide face of the board.

For certain uses, quarter-sawn material is desired. For example, in hardwood flooring, quarter-sawn stock is often desired as it will be less sensitive to dimensional changes resulting from the relative humidity fluctuations that occur in many structures. Another example is barrel staves for tight cooperage. Quarter-sawn material is less permeable because the permeable ray cells are oriented parallel to the surface of the stave and thus are not a conduit for fluid flow across the thickness of the stave.

Once a thickness and preferred grain orientation are determined, it is helpful to visualize how the boards can be cut from a log before sawing it into lumber. This is often interpreted as finding the greatest number (maximum yield) of uniformly thick, high-quality boards possible in each log. Over the years, numerous methods were developed for sawing hardwood logs, often using computer simulations (Richards and others 1980). In practice, most hardwood sawyers obtain the highest quality boards by positioning the log in such a manner that the knots will tend to be located near the edges of a board. These edge defects can then be removed by edging the lumber, resulting in a higher-quality board (Malcolm 1965). However, attempting to produce the highest lumber grades may not be the best approach. Recent studies indicate that sawing hardwood logs into three or four large cants which are then sawn into lumber results in improved recovery (less waste) (Lunstrum 1994). This lumber can be further processed by crosscutting and ripping to produce custom sizes for niche market customers, or into small clear sections that can be edge-glued into standardized furniture blanks (Reynolds and Araman 1983).

Drying

California hardwoods have a reputation for being hard to dry. However, with the proper care, good results can be obtained. Knowledge of physical properties provides a basis for predicting how wood will dry and how it will perform in service. Density is a good predictor of the ease of drying, and relative amounts of dimensional change in response to changes in wood moisture content is a good predictor of the potential for warp. Wood with a density, at 12 percent moisture content, higher than 30 lb/ft^3 is generally more difficult to dry and less dimensionally stable than wood with a lower density.

Most of the problems encountered in drying are related to stresses that develop during drying. For example, the stresses that cause lumber to warp are a direct result of the differential shrinkage in wood between the tangential (tangent to the growth rings) and radial directions (parallel to the rays). The drying defects of surface checking, collapse, honeycomb, and casehardening are also related to drying stresses.

A contributing factor to warp is the variation in the direction of the grain within a board (grain deviation). These grain deviations can be growth related, such as spiral or interlocked grain (common in many eucalyptus trees); a result of the sawing method, especially in crooked logs; or, due to the presence of knots. The high degree of grain deviation expected in most woodland hardwoods suggests that lumber cut from them would have a tendency to warp. Warp can be minimized by drying lumber in thicker dimensions and then re-sawing it, or by placing restraint on the boards to keep them flat during drying. The disadvantage of drying thicker lumber is that the technique lengthens the time to dry the lumber and increases the chance of developing other drying defects such as surface checking, collapse, honeycomb, and casehardening. If time is not a concern, this method has great potential for producing high-quality lumber. However, if time is an important consideration in the optimization of the drying process, the risk of incurring other drying defects is too great in the higher-density California hardwood species. Restraining the lumber from warping is the preferred method. Two methods for restraining the lumber are to place a 50- to 100-lb/ft^2 uniform load on the top of the lumber stack, or to keep a continuous force (equivalent to the 50- to 100-lb/ft^2 load) on the stack by using adjustable, non-metal straps (McMillen and Wengert 1978).

Collapse, honeycomb, and casehardening are drying defects that occur because stresses are created in the wood as the water leaves and the wood shrinks. Although these defects are not apparent until the wood is nearly dry, they actually begin developing very early in drying. Surface checking is a stress-related defect that actually occurs early in drying. Because these defects are developed early in drying, drying wood when the moisture content is more than 25 percent is considered the critical stage of drying. Once the average moisture content reaches about 25 percent, then more severe drying conditions can be used safely.

With a knowledge of drying principles and adequate control over the drying conditions, quality dry lumber can be produced with any drying method. If long drying times are not a concern, air drying can be an effective method for the critical drying stage, but even in an air yard the drying conditions can be too severe. Avoiding direct sun exposure on the wood and positioning lumber stacks (relative to wind direction) to increase or decrease the amount of air that passes through the lumber stack are ways to gain some control over nature's drying conditions. Ideally, the drying method should be capable of drying wood to 8 percent moisture content, achieving a temperature of 160 °F (the temperature required to sterilize insect-infested wood), and having a method to reintroduce moisture at the end of drying so that casehardened lumber can be conditioned to relieve the drying stresses. A kiln is needed to accomplish these goals.

The cost of drying is an important consideration. There are many types of drying methods available for drying wood, including air drying, solar kilns, dehumidification kilns, radio frequency units, vacuum kilns, and conventional steam-heated kilns. The equipment costs for each type of method vary greatly with radio frequency and vacuum methods generally being the most expensive. However, these units are capable of drying wood much faster than the other methods and are very effective in drying short lengths and thick stock. A thorough analysis of drying cost on an annual production basis is beyond the scope of this paper. However, in general, on a comparable volume basis, a passive solar kiln is the least expensive kiln method, but it is difficult to achieve the recommended 160 ˚F and to condition the lumber without auxiliary equipment. A dehumidification kiln is generally less expensive than a steam-heated kiln, unless an inexpensive steam source is available. Some dehumidification units have a maximum operating temperature of only 120 ˚F, but units are available that can reach 160 ˚F. A small steam generator should be added to a dehumidification kiln in order to have the ability to condition the lumber and minimize the problem of casehardened lumber. A steam-heated kiln gives you the most control over the drying conditions, but it is also the most expensive unit to purchase.

Concluding Remarks

As discussed above, on the basis of their physical and mechanical properties, many of the common hardwood consumer goods could be manufactured from woodland hardwoods. Obviously, some woods are better suited for particular products than other woods. Also, factors such as ecology concerns, resource availability, cost of production, and quality of the end product are important in determining the long-term utilization potential of woodland hardwoods.

Niche markets hold the most promise for a woodland hardwood enterprise. The commodity lumber markets demand large volumes of lumber, readily available at a competitive price and manufactured to existing industry standards. In contrast, the niche market is more flexible because a specific product or customer is targeted and the product is tailored to the customer's needs.

A key to the success of any processing enterprise is to produce products of consistent quality. For wood product operations using woodland hardwoods targeted to niche markets, this usually means that product quality needs to be defined. Once product quality is defined, in terms of moisture content, size tolerances, surface quality, etc., a method of measuring quality parameters during production should be created. Any materials not meeting the quality standards should be reprocessed to achieve desired quality or marketed as a below-grade product.

Although there are exceptions to all the above factors, availability of the resource and the associated cost of transportation are often the limiting factors, particularly for the low- and moderate-value products listed in *table 2*. Woodland hardwoods are not concentrated in high-density stands the way hardwoods are in the timberland regions which means that hauling distance to obtain an adequate supply may be too large to justify the relatively low value. A careful assessment of the resource availability and the cost of production is needed to determine the feasibility of processing woodland hardwoods.

Throughout history woodland hardwoods provided a resource for local needs. In certain situations woodland hardwoods may still be a viable resource for these local needs or specialty products. Availability and quality concerns make it unlikely that any woodland hardwoods could supply a commodity market; however, based on the properties and characteristics of the wood successful niche markets are possible. Local products made by artisans, woodworkers, and hobbyists prove that high-value products can be made. In fact, value-added products can be produced from any type of wood, but special manufacturing techniques and innovative marketing strategies may be required to do so economically.

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