Hardwoods

Hardwood habitats are rich sources of biological diversity. They are also lands into which significant development is projected to occur over the next four decades. A number of different land use and management practices have influence on the conditions and trends presently exhibited by California's hardwood resources. Some of these "ecosystem drivers" are the result of past practices that are centuries old and are still being played out and expressed in conditions seen today. Others are part of recent history.

Hardwoods support some of the richest biological diversity in North America.

This chapter examines several current land use and land management issues influencing hardwood resource values. In addition, it will describe results from recently developed modeling tools and monitoring technologies relevant to hardwood land use issues.

Hardwoods defined

For the FRAP 2003 Forest and Range Assessment, hardwood land cover is grouped into two classes referred to as "Hardwood Woodlands" and "Hardwood Forests." This distinction represents differences in geographic range and species composition or habitat type.

Hardwood Woodlands are generally associated with lower elevation areas absent of conifer species where grazing has been a traditional practice and where encroachment from development and agricultural conversion has been common. Hardwood Woodlands are often referred to as "oak woodlands" because of the dominance of oak species within these vegetation types. However, many other non-oak hardwood species are found within hardwood woodlands. Another common term for the Hardwood Woodlands is "hardwood rangelands," which reflects a dominant land use.

Hardwood Forests are less associated with grazing and development pressures because of their location in higher elevation, rugged mountainous areas. Hardwood Forests are often mixed with conifer species. Issues surrounding the hardwood forests typically involve timber management and wildfire affects.

Hardwood Woodland and Forest cover types encompass nearly 9.9 million acres in California.

Hardwood land cover includes all lands with at least 10 percent tree canopy cover comprised primarily of hardwood species. The extent of Hardwood Woodlands and Hardwood Forests are quantified as part of the Fire and Resource Assessment Program's (FRAP) Multi-Source Habitat Data (FRAPVeg). FRAP merged vegetation data from several sources to compile statewide vegetation data. FRAPVeg data uses the

California Wildlife Habitat Relationships Classification System (CWHR). These mapping and classification data represent an update to the "Extent and Ownership of California's Hardwood Rangelands" (California Department of Forestry and Fire Protection, 2002b,c). Information on the sources of data used to create the hardwood extent can be found at Habitat Data: Forest and Range 2003 Assessment.

Findings on extent

FRAP estimates that there are over 9.8 million acres of Hardwood Woodland and Hardwood Forest statewide (Table 1 and Figure 1). Approximately 53 percent of these acres are classified as Hardwood Woodland. Within the Hardwood Woodlands, the Blue Oak Woodland CWHR type has the most extensive distribution covering about 29 percent of all Hardwood extent, while the montane hardwood CWHR type has the most extensive Hardwood Forest distribution covering about 45 percent of all Hardwood extent. Additional information on hardwood area by county and owner can be found at Habitat types: County – State.

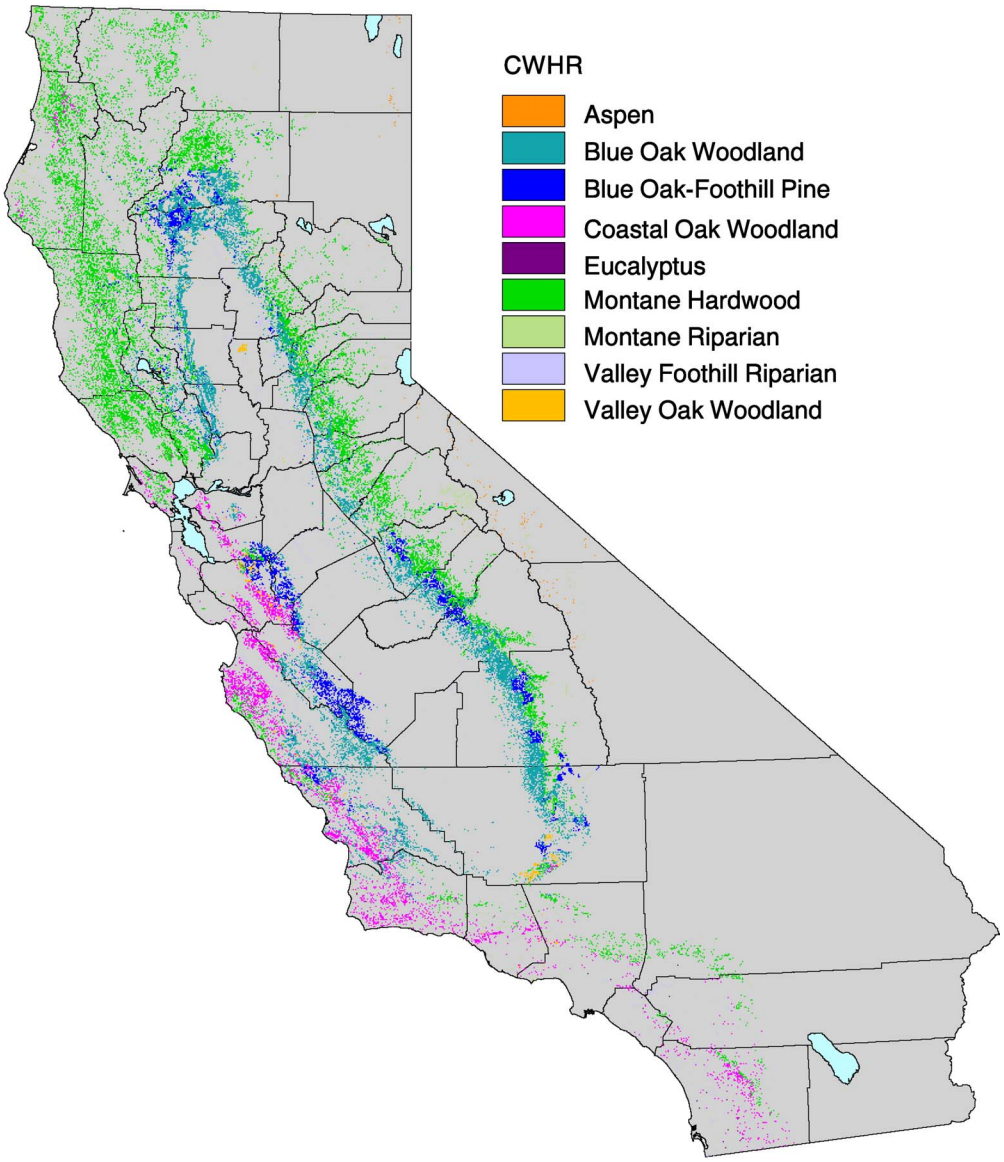
Upland montane hardwood forest, French Creek, Siskiyou County

Table 1. Area of CWHR types and percentage of total hardwood area (thousand acres)

Habitat type (CWHR)	Area	Percentage of total hardwood area
Hardwood woodland		
Blue Oak Foothill Pine	979	10
Blue Oak Woodland	2,819	29
Coastal Oak Woodland	1,095	11
Eucalyptus	11	<1
Valley Foothill Riparian	147	1
Valley Oak Woodland	137	1
Total	*5,188*	*53*
Hardwood forest		<1
Aspen	40	<1
Montane Hardwood	4,439	45
Montane Riparian	211	2
Total	*4,691*	*47*
Total hardwoods	**9,879**	100

Source: FRAP, 2002c

Figure 1. Extent of Hardwood Woodland and Forest land cover by CWHR type



Source: FRAP, 2002c

Regional extent of hardwoods

The extent of hardwood land cover varies among California's bioregions (Table 2). The Klamath/North Coast and Sierra bioregions have the majority of hardwood land cover (5.7 million acres or 58 percent of the State total). Each bioregion has a unique combination of hardwood habitat types (Table 2). Blue Oak Woodland (37 percent of bioregion total) and Montane Hardwood (47 percent of bioregion total) dominate the Sierra bioregion where blue oak, black oak, and interior live oak are the most common species. The Klamath/North Coast bioregion is predominately comprised of Montane hardwoods (77 percent of bioregion total). The Bay/Delta, Central Coast and South Coast bioregions are predominantly Coastal Oak Woodlands, which are comprised of coast live oak, California laurel, bay, and other oak species.

Table 2. Area of Hardwood CWHR types and percentage of total hardwood area by bioregion (thousand acres)

Habitat Type	Bay Area/Delta		Modoc		Klamath/ North Coast		Sierra		Central Coast		South Coast		Sacramento Valley		San Joaquin Valley		All other bioregions*		California	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Hardwood Woodland																				
Blue Oak-Foothill Pine	99	11	9	3	185	6	296	11	329	19	L	<1	50	10	2	1	8	15	979	10
Blue Oak Woodland	107	12	218	63	342	12	1,036	37	576	33	1	<1	374	72	143	81	21	41	2,819	29
Coastal Oak Woodland	195	21			40	1	4	<1	662	38	188	47			1	1	5	10	1,095	11
Eucalyptus	4	<1			L	<1	L	<1	2	<1	4	1	1	<1			L	<1	11	<1
Valley Foothill Riparian	19	2	L	<1	3	<1	L	<1	18	1	40	10	49	9	16	9	2	5	147	1
Valley Oak Woodland	37	4			11	<1	37	1	26	2	3	1	19	4	1	1	3	6	137	1
Total	461	50	227	66	582	20	1,374	49	1,614	92	235	58	493	95	163	92	39	76	5,188	53
Hardwood Forest																				
Aspen			8	2	L	<1	32	1									L	<1	40	<1
Montane Hardwood	460	50	100	29	2,234	77	1,329	47	114	7	151	37	27	5	13	8	11	22	4,439	45
Montane Riparian	4	<1	10	3	93	3	65	2	21	1	18	4	1	<1	L	<1	1	2	211	2
Total	464	50	118	34	2,326	80	1,426	51	135	8	169	42	27	5	13	8	12	24	4,691	47
Total Hardwoods	925	100	346	100	2,908	100	2,799	100	1,749	100	404	100	520	100	176	100	52	100	9,879	100

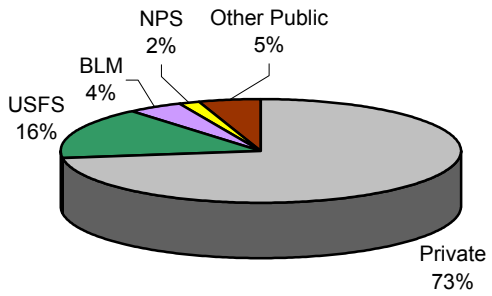
**All other bioregions: includes Mojave, Colorado Desert; L – less than 500 acres*
Source: FRAP, 2002c

Findings on ownership

Eighty-three percent of hardwood woodlands are privately owned.

Hardwood land cover is heavily dominated by private ownership. Private ownership in Hardwood Woodlands is 83 percent of the total acreage, with the remaining 17 percent in public ownership (Table 3). Private ownership in Hardwood Forest is 73 percent of the total acreage with the remaining 27 percent in public ownership. Over 73 percent (7.1 million acres) of all hardwood lands are privately owned (Figure 2). While all individual Hardwood Woodland habitat types have over 70 percent of their extent in private holdings, Valley Oak Woodland has the greatest proportion of ownership in private holdings at roughly 92 percent. Aspen within Hardwood Forest has the lowest portion in private holdings at seven percent. This is primarily due to aspen habitats location in high elevation landscapes, typically characterized by National Forest holdings.

Figure 2. Percentage area of Hardwood by ownership



BLM – U.S. Bureau of Land Management; NPS – National Park Service; USFS – U.S. Forest Service
Source: FRAP, 1999; FRAP, 2002c

Table 3. Area and percentage of Hardwood CWHR types by owner (thousand acres)

Habitat type	Private	USFS	BLM	NPS	Other Public	Total	Percent Private	Percent Public
Hardwood Woodland								
Blue Oak-Foothill Pine	754	39	121	17	49	979	77%	23%
Blue Oak Woodland	2,457	129	104	9	120	2,819	87%	13%
Coastal Oak Woodland	832	138	12	8	104	1,095	76%	24%
Eucalyptus	9	L	L	L	1	11	84%	16%
Valley Foothill Riparian	114	4	2	1	27	147	77%	23%
Valley Oak Woodland	126	1	2	L	9	137	92%	8%
Total	*4,292*	*310*	*239*	*36*	*309*	*5,188*	*83%*	*17%*
Hardwood Forest								
Aspen	3	32	1	2	1	40	8%	92%
Montane Hardwood	2,797	1,215	174	89	165	4,439	63%	37%
Montane Riparian	100	40	1	43	27	211	48%	52%
Total	*2,901*	*1,287*	*176*	*134*	*193*	*4,691*	*62%*	*38%*
Total Hardwoods	**7,193**	**1,597**	**416**	**171**	**502**	**9,879**	**73%**	**27%**

BLM – U.S. Bureau of Land Management; L – Less than 500 acres; NPS – National Park Service; USFS – U.S. Forest Service
Source: FRAP, 1999; FRAP, 2002c

Findings on management patterns in California's hardwoods

Hardwood land cover has the lowest percentage of lands reserved from management activities compared to all other land cover types.

The Management Landscape is a conceptual framework that describes land use and management by associating three unique components: primary land use, ownership and population density. There are eight management landscape classes, five of which are relevant to hardwood habitats (Table 4). See the Assessment document Population and Land Use for the definition of Management Landscape classes.

Table 4. Management Landscape classes relevant to hardwood habitats

Management Landscape class	Management emphasis
Reserve	Consistent with these designations: wilderness, wild and scenic, national parks, national monuments.
Working/Public/Sparsely Populated	Lands under public administration with management consistent with agency mandate.
Working/Private/Sparsely Populated	Resource management and commodity production.
Working/Public/Rural Residential	Lands under public administration with management consistent with agency mandate. Incurs complexities of surrounding people and structures.
Working/Private/Rural Residential	Resource management and commodity production. Incurs complexities of surrounding people and structures. Land is often readily available for conversion to more intensive uses.

Source: FRAP, 2002a

Throughout California, large amounts of hardwood land cover are in the Working management classes and low amounts are in the reserve management classes (Table 5). Hardwood Woodlands have the least percentage amount in the reserve class (6.8 percent) compared to all other land cover classes in the reserve class. Excluding non-native eucalyptus, Valley Oak Woodland has the smallest acreage within the reserve class (approximately 8,000 acres).

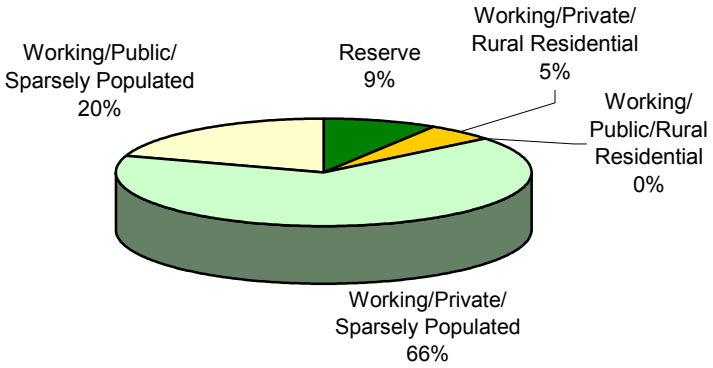
Table 5. Area of Hardwood CWHR type by management landscape class (thousand acres)

Habitat type	Reserve	Working/Private/ Rural Residential	Working/Public/ Rural Residential	Working/Private/ Sparsely Populated	Working/Public/ Sparsely Populated	Total
Hardwood Woodland						
Blue Oak-Foothill Pine	59	32	0	706	175	971
Blue Oak Woodland	112	121	1	2,194	277	2,705
Coastal Oak Woodland	148	77	7	696	145	1,073
Eucalyptus	1	3	0	5	1	10
Valley Foothill Riparian	17	13	0	79	20	129
Valley Oak Woodland	8	8	0	103	6	125
Total	344	253	10	3,783	624	5,013
Hardwood Forest						
Aspen	11	0	0	3	26	40
Montane Hardwood	423	242	2	2,482	1,244	4,394
Montane Riparian	70	10	1	75	42	199
Total	505	252	4	2,560	1,312	4,633
TOTAL	849	505	13	6,343	1,936	9,646

Source: FRAP, 2002a; FRAP, 2002c

As of 2001, the hardwood types contain the greatest proportions of Working management classes (91 percent). Approximately 505,000 acres, or about five percent of all hardwood acreage, is in the Working Private Rural Residential management class (Figure 3) and potentially subject to more immediate development pressure. Regional and county information on management status can be found at Hardwood Habitat by Management Landscape Class.

Figure 3. Percentage area of Hardwood by Management Landscape class



Source: FRAP, 2002a; FRAP 2002c

Habitats with a low percentage in the reserve class have less permanent protection from more intense land use pressures, which may threaten habitat diversity. On average, the statewide amount of hardwood habitat in reserve status is low compared with other habitats (e.g. conifer, grassland). For some individual habitat types this is more pronounced. Valley Oak Woodland and Valley Foothill Riparian are of particular concern as these types are particularly vulnerable to development due to their low abundance, little Reserve status and adjacency to intensively developed land uses. Blue Oak Woodland, Blue Oak-Foothill Pine, and Coastal Oak Woodland also have development pressures but all cover far larger areas. See the Assessment document Habitat Diversity for more information on management status. While these habitats have low amounts of Reserve status, many opportunities are available, beyond permanently reserving these lands, to help avoid development pressures.

Findings on change to hardwood extent and threats

California's Hardwood Woodlands have historically been used for intensive agriculture, range production, and fuelwood harvesting. Recently, uses are changing more to residential and commercial development and vineyard establishment and expansion. Expanding development in hardwood woodlands near existing population centers is particularly notable (Scott et al., 1995). Urban expansion can have a significant effect on hardwood woodlands as development may result in loss of habitat and other watershed values.

The extent and condition of hardwood habitats are also being affected by other factors, particularly in coastal counties (Merenlender, 2000). These include agricultural conversion to high value crops, such as vineyards, the emergence of Sudden Oak Death (SOD), suppression of natural fires and effects on oak recruitment. When combined with studies suggesting that many oak species are not naturally regenerating adequately, concern is heightened over further potential impacts to this resource (Adams et al., 1990; McCreary, 1991).

As these human and natural forces continue to alter the hardwood landscape, monitoring of this resource has become a high priority for many federal, State and local agencies as well as many Californians. The California Department of Forestry and Fire Protection (CDF) has directly addressed this need by creating the California Land Cover Mapping and Monitoring Program (LCMMP), a cooperative

program between the U.S. Forest Service (USFS) and CDF (FRAP, 2002b). The LCMMP creates seamless vegetation and monitoring data across California's landscape for regional assessment across all ownerships and vegetation types. This includes both the Hardwood Woodland and Hardwood Forest types. For methods, see Assessment Information Systems.

FRAP has compiled information from other hardwood monitoring programs and researchers throughout the State to supplement information on the status and trends for these hardwood types. One primary provider of such information is the Integrated Hardwood Range Management Program (IHRMP), an organization that partners with CDF to research issues specific to hardwood woodlands and forests. See the online homepage of the Integrated Hardwood Range Management Program for more information.

Total hardwood land cover change reported by the California Land Cover Mapping and Monitoring Program (LCMMP)

Approximately 96 to 98 percent of all hardwood areas had no detectable change within five-year monitoring periods.

Results for all LCMMP project areas show that the vast majority of Hardwood Woodland and Forests remained unchanged during their respective monitoring periods. Approximately 96 to 98 percent of the total hardwood woodland and forest within each project area had no detectable change (little to no change in vegetation cover change class) (Table 6). However, two to three percent of Hardwood Woodland and forest in each project area did have some level of detectable change, with some areas of change concentrated in relatively small areas (Figure 4).

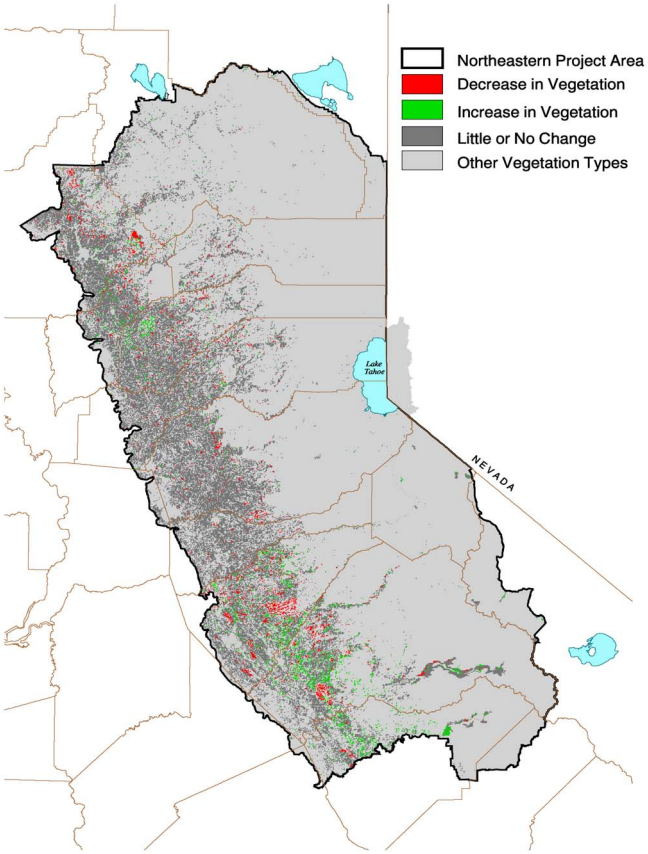
Of particular interest are the large or moderate decreases in canopy cover because these types of decreases often represent long-term or permanent shifts in habitat type particularly in slow growing hardwood woodlands. Approximately 20,000 acres of hardwood forest and woodland showed moderate or large cover decreases within the South Sierra project area, 9,000 acres within the Northeastern project area, 12,000 acres within the South Coast project area and 15,000 acres in the North Coast project area (Table 6).

Table 6. Area of Hardwood change by LCMMP project area and change class during five-year monitoring periods (thousand acres)

	Southern Sierra (1990-1995)		Northeastern** (1991-1996)		South Coast*** (1993-1997)		North Coast*** (1994-1998)	
Change Class	**Acres**	**Percentage of total hardwoods**	**Acres**	**Percentage of total hardwoods**	**Acres**	**Percentage of total hardwoods**	**Acres**	**Percentage of total hardwoods**
Large decrease in vegetation cover	3	<1	2	<1	L	<1	5	<1
Moderate decrease in vegetation cover	17	1	7	<1	12	<1	10	0
Small decrease in vegetation cover	50	2	37	2	18	<1	22	<1
Little to no change in vegetation cover	1,803	75	2,329	96	2,144	98	3,758	98
Small increase in vegetation cover	264	11	41	2	1	<1	9	<1
Moderate increase in vegetation cover	55	2	5	<1	L	<1	2	<1
Large increase in vegetation cover	7	0	1	<1				
Other non-vegetation change*	209	9	4	<1	22	1	33	<1
Total	2,409	100	2,426	100	2,197	100	3,839	100

L – less than 500 acres
**Includes clouds, shadow, change in water or snow level.*
***Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.*
****In these project areas large decrease is 71 to 100% cover loss, moderate decrease is 41 to 70% cover loss, small decrease is 16 to 40% cover loss, small increase is 16 to 40% cover increase, moderate and large increase is 41 to 100% cover increase.*
Source: FRAP, 2002b

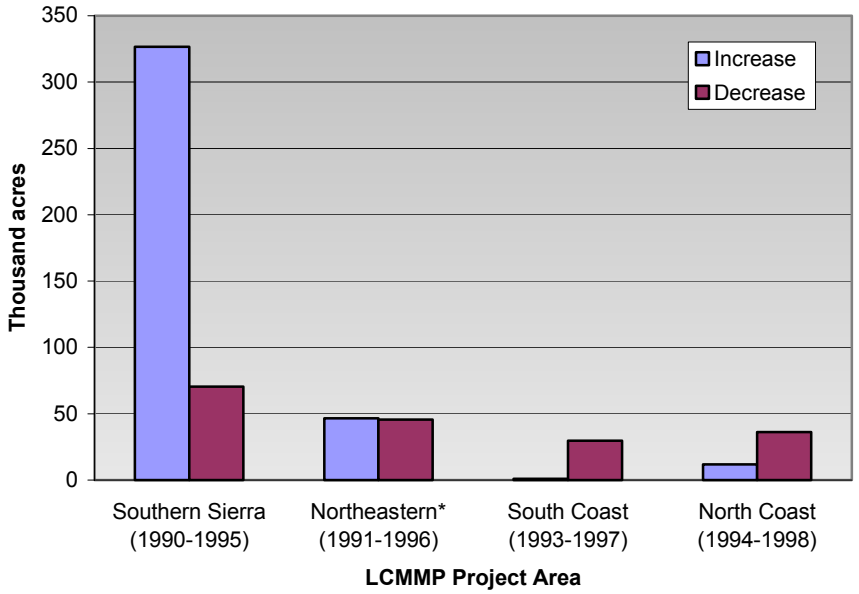
Figure 4. Locations and type of detected Hardwood canopy changes in the Northern Sierra project area, 1991-1996 monitoring period



Source: FRAP, 2002b

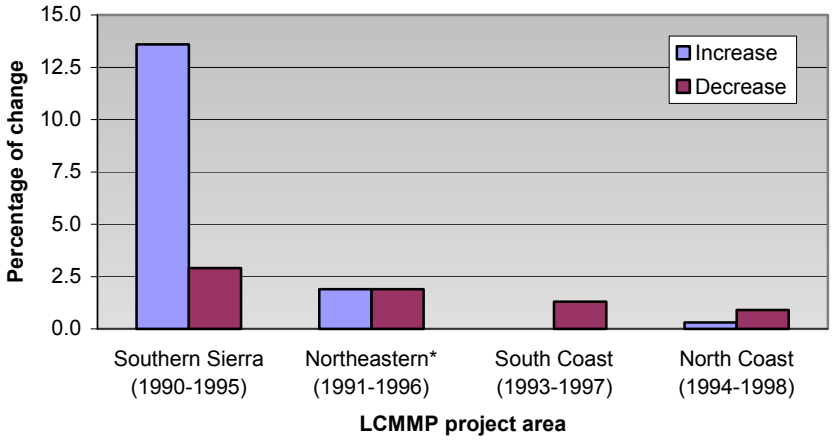
In the Northeastern and Southern Sierra project areas, total acres of Hardwood Woodland and Forest cover increases exceeded cover decreases, while in the South Coast and North Coast project areas, total acres of Hardwood Woodland and Forest cover decreases are larger than cover increases (Figure 5). Total decreases in Hardwood Woodland and Forest cover were approximately 70,000 acres (2.9 percent) in the Southern Sierra, 46,000 acres (1.9 percent) in the Northeastern, 30,000 acres (1.3 percent) in the South Coast, and 36,000 acres (0.9 percent) in the North Coast (Figure 5 and 6). These percentages represent the proportion of Hardwood woodland and Forest area that underwent some decrease relative to the total amount of Hardwood Woodland and Forest in each project area.

Figure 5. Area of hardwood change by LCMMP project area during five-year monitoring periods



**Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.*
Note: The large amount of Hardwood woodland and forest cover increase southern sierra is primarily due to the large complex fires of 1987 that are now regenerating, primarily from hardwood, shrub and grass species.
Source: FRAP, 2002b

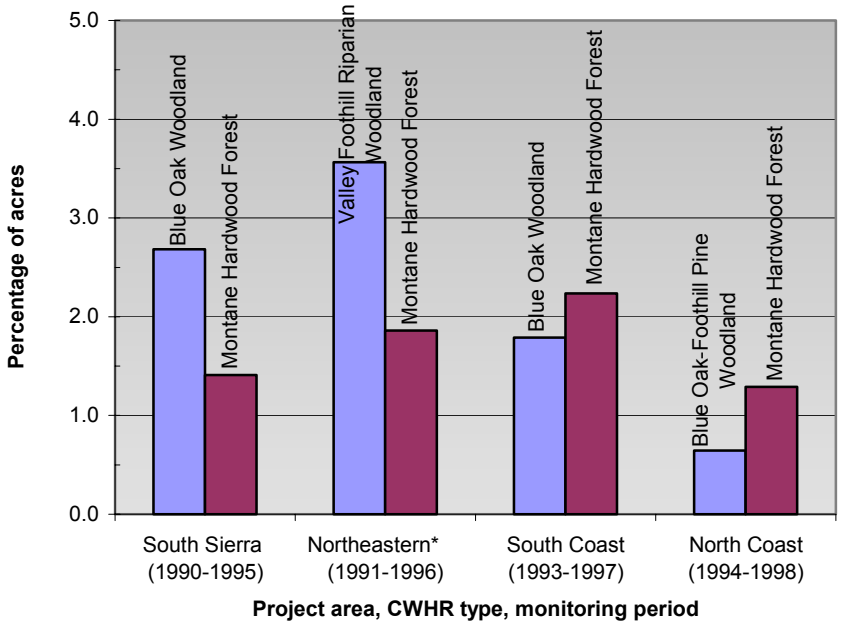
Figure 6. Percentage area of hardwood change by LCMMP project area during five-year monitoring periods



*Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.
Source: FRAP, 2002b

Each CWHR Hardwood Woodland and Forest habitat type is also monitored for change. For the Hardwood Forest type, Montane Hardwood shows the greatest proportion of cover decrease within all project areas (Figure 7). The greatest proportion of cover decrease in the Hardwood Woodland types varies within the project areas. Blue Oak Woodland is the largest in the Southern Sierra and South Coast (2.6 percent and 1.7 percent, respectively), Valley Foothill Riparian is the largest in the Northeastern (3.6 percent) and Blue Oak-Foothill Pine is largest in the north coast (0.7 percent).

Figure 7. Hardwood Woodland and Forest CWHR type showing largest proportion of hardwood cover decrease by LCMMP project area during five-year monitoring periods



*Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.
Source: FRAP, 2002b

Change by cause

Determining cause of vegetation change is another component of the LCCMP. Larger change areas (greater than 25 acres) are more readily attributed compared to smaller change areas (2.5 to 10 acres). A hardwood vegetation decrease of 72,000 acres (39 percent verified) was identified by cause in the Southern Sierra project area, a decrease of 60,000 acres (30 percent verified) was identified in the Northeastern project area, 30,000 acres (90 percent verified) in the South Coast project area, and 36,000 acres (75 percent verified) in the North Coast project area.

Within all project areas, harvest and wildfire were the main agents of change to hardwood canopy cover.

Within all project areas, harvest and wildfire were the main agents of change (Table 7). For a complete breakdown of hardwood vegetation change by cause and region, see Monitoring Land Cover Changes in California.

Development, as a cause of change, is associated with land used for residential and commercial purposes. Land development generally negatively affects habitat value by introducing roads, fences, domestic animals, and other degrading factors. Development, regardless of the change group (large, moderate, or small decreases) represents a more permanent change to the overall habitat value associated with the hardwood area.

Table 7. Percentage of Hardwood decrease by cause and project area during five year monitoring periods

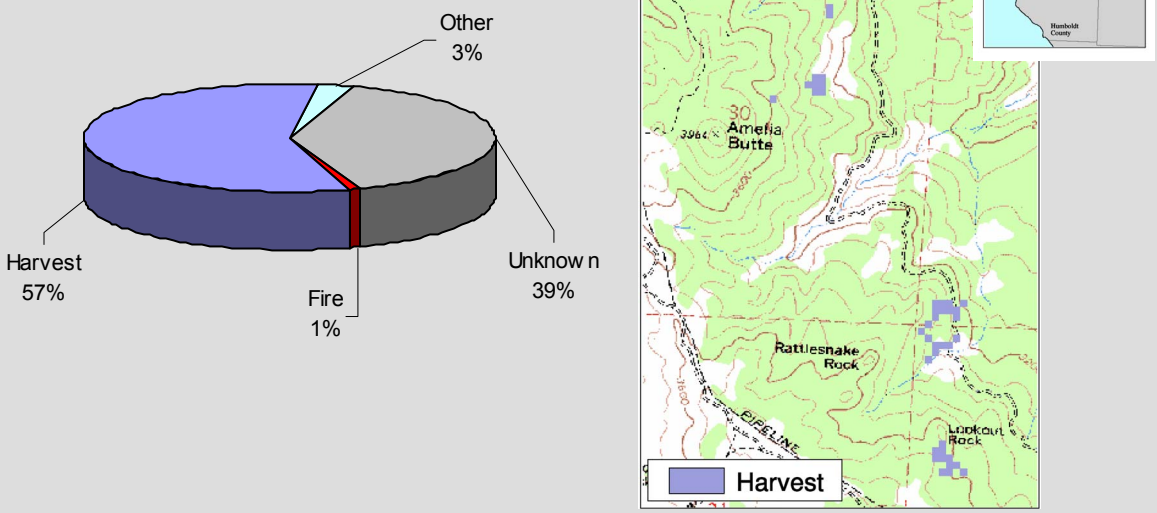
	Southern Sierra (1990-1995)	Northeastern* (1991-1996)	South Coast (1993-1997)	North Coast (1994-1998)
Cause of change	**Percentage of total hardwood decrease**	**Percentage of total hardwood decrease**	**Percentage of total hardwood decrease**	**Percentage of total hardwood decrease**
Harvest	8	14	0	24
Fire	24	11	90	44
Development	3	4	<1	1
Other	4	2	0	6
Unknown	61	69	10	25

**Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.*
Note: Analysis of hardwood woodland and forest change areas, where cause of change has not been determined (unknown class), occurs mostly in small, unconcentrated change patches.
Source: FRAP, 2002b

Causes affecting hardwood cover decrease by county: County level analysis of the causes of hardwood canopy change reveals different patterns than those reported at the regional scale. Examples of different county patterns of cause to hardwood habitat change, such as harvesting, wildfire, and development are shown in Figures 8, 9 and 10.

Harvesting: Humboldt County is an example where harvesting is a leading cause of hardwood canopy change. Harvesting includes removing live or dead trees for products or firewood, thinning to promote tree growth, and constructing fuel breaks for fire hazard reduction. Harvesting or land clearing activities that support silvicultural and fire hazard reduction objectives accounted for 57 percent (3,805 acres) of hardwood canopy change (Figure 8).

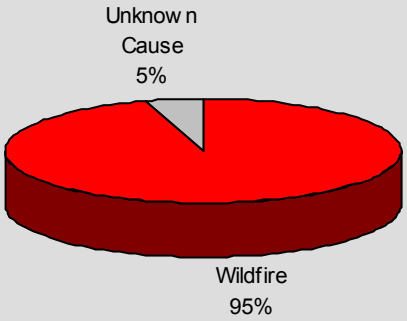
Figure 8. Percentage area of Hardwood vegetation decrease by cause, Humboldt County, 1994-1998 monitoring period

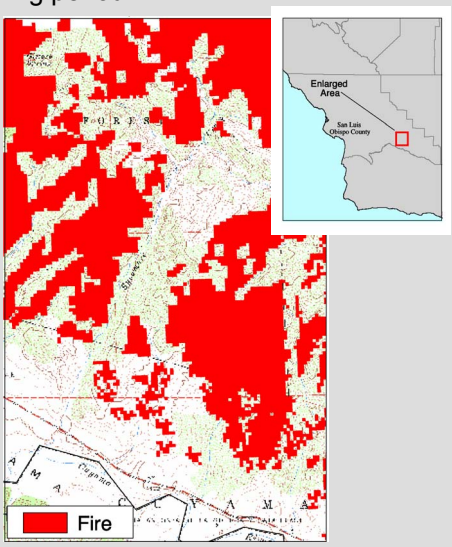


Source: FRAP, 2002b

Fire: San Luis Obispo was a leading county where fire was a dominant agent of change in hardwood canopy cover. Fire as a change agent includes wildfire and prescribed burning. Nearly 95 percent (16,229 acres) of change in San Luis Obispo County was attributed to fire due to the large wildfires of 1997, such as the Logen Fire (Figure 9).

Figure 9. Percentage area of Hardwood vegetation decrease by cause, San Luis Obispo County, 1992-1997 monitoring period

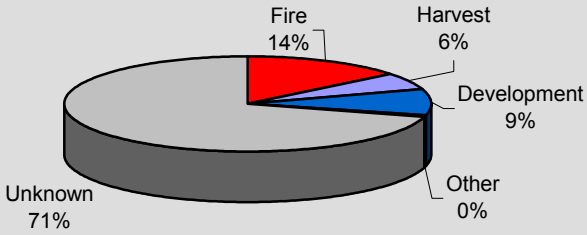


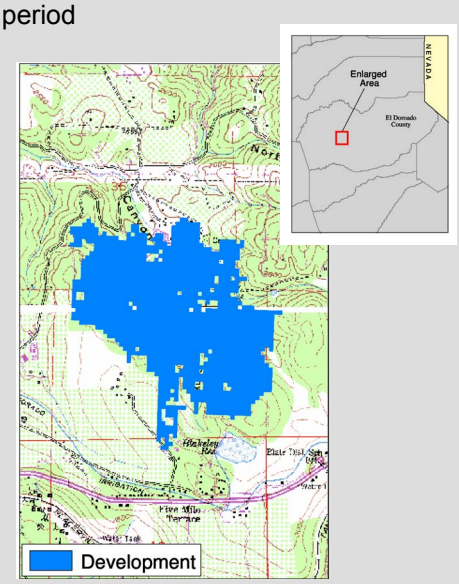


Source: FRAP, 2002b

Development: Residential or commercial development in rapidly growing El Dorado County was a major cause of change in hardwood canopy cover. About 9 percent (393 acres) of change in El Dorado County was attributed to development (Figure 10).

Figure 10. Percentage area of Hardwood vegetation decrease by cause, El Dorado County, 1991-1996 monitoring period





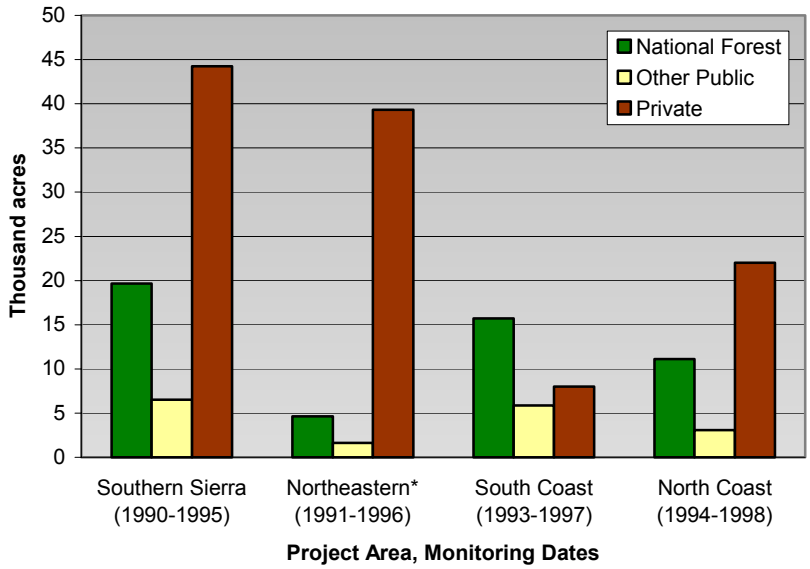
Source: FRAP, 2002b

See Cause of Hardwood Vegetation decrease by Cause in all Counties for profiles of causes of change in hardwoods for every county.

Change by ownership

The LCMMP also monitors change in canopy cover by ownership. The largest acreage of hardwood cover decrease of both Hardwood Woodland and Forest types was seen on private ownerships in all change regions except the South Coast (Figure 11). In that region, hardwoods on national forests had the largest acreage of cover decrease. For a complete acreage summary of hardwood vegetation change by ownership, see Monitoring Land Cover Changes in California.

Figure 11. Decrease in Hardwood vegetation by ownership and LCMMP Project area during five-year monitoring periods



**Includes part of Cascade Northeast and Northern Sierra due to project area boundary change between cycle 1 and 2.*
Source: FRAP, 2002b

Agricultural conversion

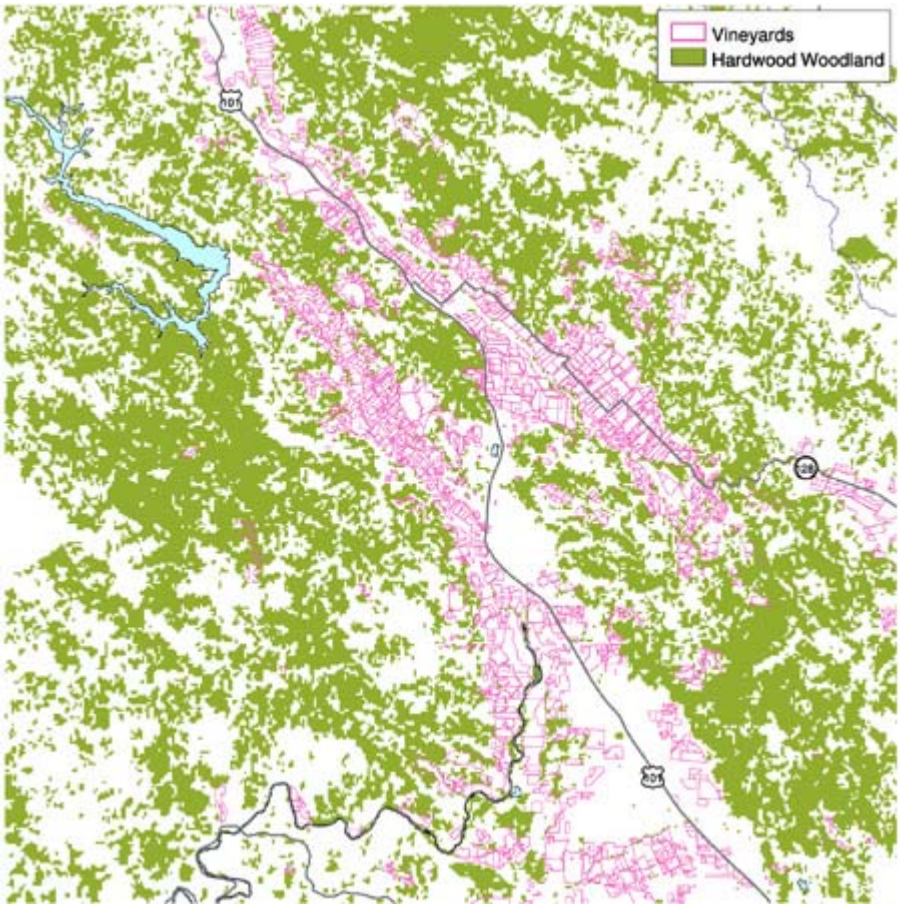
Conversion of Hardwood Woodlands to agriculture uses will probably continue to increase in California. In the last decade, conversion to vineyards has been especially apparent. Soils that favor the growth of premium wine grapes are increasingly used on hillsides where greater land availability and relatively lower land prices occur. These areas often have hardwood cover.

Conversion of oak woodland to vineyard is occurring at an increasing rate.

One example of vineyard expansion on Hardwood Woodlands is in Sonoma County, part of California's premium wine growing region (Figure 12). Approximately 1,631 acres of hardwoods with greater than 50 percent tree cover, and 7,229 acres of oak-grassland savannah were converted between 1990 and 1997 (Merenlender, 2000). The greatest

impact to hardwood woodlands, particularly valley oak, occurs on low elevation slopes and valley bottoms where urban and agricultural development has increased. Similar trends have been noted in Santa Barbara County where vineyard acreage nearly doubled between 1997 and 2000 from approximately 10,000 acres to 18,000 acres, a large portion of which was in hardwood woodland (Standiford et al., 2000).

Figure 12. Vineyards and Hardwood Woodland in Sonoma County, 1999



Source: Merenlender, 2000

For the most part, analysis of the impact of agricultural expansion into hardwood types occurs at the local level. In some cases, counties have developed policies addressing environmental impacts. These policies are generally limited to soil and water quality concerns as increases in hillside erosion and stream sedimentation have been associated with the conversion of areas dominated by native vegetation (Giusti and Merenlender, 2002).

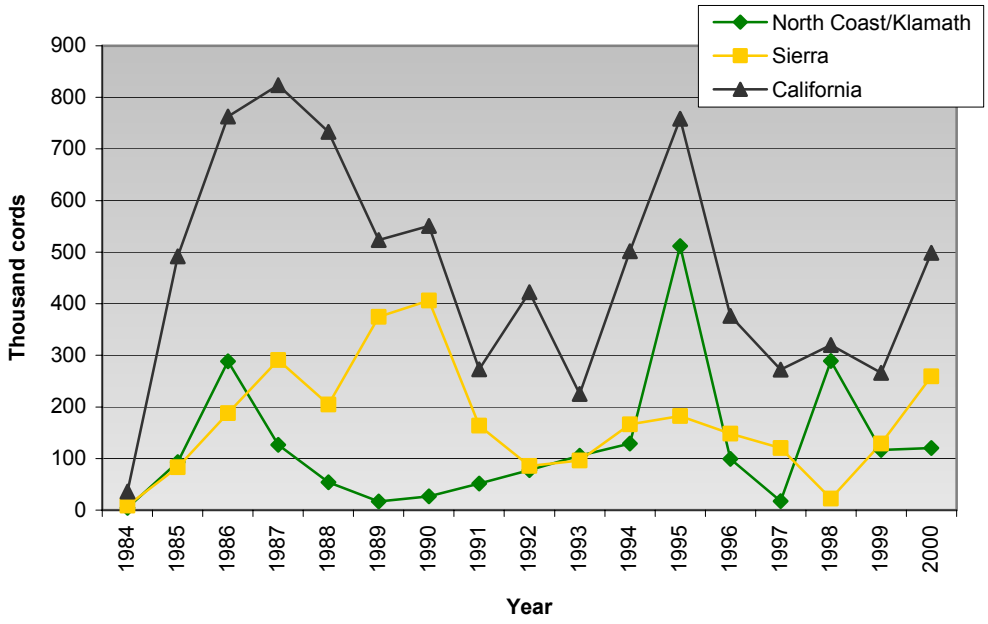
Santa Barbara County has implemented a collaborative public process to address hardwood woodland conversion issues. The University of California, Santa Barbara has recently reported on a Santa Barbara County Oak Woodland Inventory and Monitoring Program (Davis et al., 2000). The objectives of this program are to: 1) develop a mapping strategy for county-wide inventory and monitoring of oak savannah woodland (areas of less than 10 percent canopy cover), and forest ecosystems; 2) develop

predictive models to assess site suitability for oak woodland restoration efforts; and 3) apply the mapping and modeling approaches in selected areas to evaluate present and potential oak habitats. They reviewed the current status and trends exhibited by valley oak and concluded that complete estimates of valley oak distribution, status, and trend were generally insufficient due to the use of different classification systems for mapping and inventory. They also concluded that valley oak is not well represented on public lands or in existing reserves and the remaining area coincides with areas that are predicted to undergo rapid development (agricultural and/or urban) in the future.

Hardwood fuelwood harvesting

Statistics on annual hardwood fuelwood harvesting in California are collected by the Timber Tax Division of the California State Board of Equalization. From 1984 through 2000, just over 7.8 million cords of hardwood fuelwood were reported harvested and subject to timber payments. Of this amount, over 2.1 million cords came from the North Coast/Klamath Bioregion and 2.9 million cords came from the Sierra bioregion (Figure 13 and Table 8).

Figure 13. Volume of Hardwood fuelwood harvested within the North Coast/Klamath bioregion, Sierra bioregion, and California, 1984-2000



Source: State Board of Equalization, 2000

High harvest years occurred in 1986-1988 and again in 1995. High harvests in these years are associated with unusually large harvests in individual counties such as Kern County in 1987, Tehama County in 1988, and Lake County in 1995.

The number of cords of wood per tree per acre differs according to many factors, such as tree size, number of trees per acre, and number of trees harvested. However, using a ten-inch diameter at breast height California black oak tree as a standard, there are approximately eight to nine cubic feet per tree, or

0.11 to 0.10 cords per tree. Assuming 165 trees per acre, there would be 1500 cubic feet per acre of wood, or between 16.5 and 18.1 cords of black oak per acre if all the trees were harvested. Again, for purposes of illustration, assuming that all acres of fuelwood were California black oak, that the average stocking per acre was 165 trees, and that all trees were cut, the impact of harvesting 7.8 million cords would mean the harvesting of between about 430,000 and 475,000 acres between 1984 and 2000. In reality, the acreage is greater and hardwood fuelwood cutting has been a mix of different intensities of harvesting.

Table 8. Volume of annual hardwood fuelwood harvesting, 1984-2000 (cords)

Bioregion	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Bay Area/Delta																		
San Mateo	223	96	47,998	1,405	45,595	2,871	47,823	119	27,661	1,100	61,668	13,657	76,554	5,163	6,565	564		339,062
Santa Clara	97	6,423	21,606	42,891	2,554	11,412	2,549	588	11,076	548	10,951	101	25,974	37,340	3	19		174,132
Sonoma	1,294	5,604	5,069	1,919	11,168	1,100	2,691	164	170,586	20		8,979						208,594
Total	1,614	12,123	74,673	46,215	59,317	15,383	53,063	871	209,323	1,668	72,619	22,737	102,528	42,503	6,568	583		721,788
Central Coast																		
Santa Cruz	2,963	16,313	54,540	100	19,545	33	3,572	19,395	450	4,995	2,940	2,815	2,275	2,178	1,400	2,878		136,392
Modoc																		
Modoc	27	115,076	6,652	49,866	65,620	21,842	13,197	2,441	90	9,932	3,905	11,718	4,241	31,195	19	20	2,791	338,632
Mojave																		
San Bernardino	156	153	95,824	43,127	2,549	3,899	4,140	896	40,092	623	106,192	8,082	35	56,486	74	13,678		376,006
North Coast/Klamath																		
Del Norte	90	3,722	9,282	68,806	223	1,339	12,509	1,124	1,186	559	395	258	60	7,148	5,951	11	2,250	114,913
Humboldt	1,222	230	107,980	51,841	4,098	336	178	126	7,713	98,378	116,190	118,209	94,672	3,494	35,341	96,406	62,718	799,132
Lake	357	35,435	96,222	2,691	2,400	934	64	31,613	1,711	1,967	53	384,200	87	6,493	198,227	20,344	47,921	830,719
Mendocino	2,391	53,716	1,835	1,575	46,720	1,935	64	14,684	66,907	2,571	12,427	2,504	4,571	38	49,450	33	7,438	268,859
Siskiyou	435	78	49,223	671	173	2,542	12,012	4,092	17	2,208	3	6,494						77,948
Trinity	102	10	23,724	976	88	9,554	1,872											36,326
Total	4,597	93,191	288,266	126,560	53,702	16,640	26,699	51,639	77,534	105,683	129,068	511,665	99,390	17,173	288,969	116,794	120,327	2,127,897
Sacramento Valley																		
Butte	8,722	7,978	2,830	20,664	76	125	761	4,484	2,324	825	17,526	13,781	15,879	2,439	186	2,383	103,720	204,703
Shasta	5,713	25	3,969	2,380	37,992	2,785	15,486	21,800	3,558	2,040	444	3,204	2,189	165	4			101,754
Tehama	573	642	7	41	255,138	4,161	40	1,794										262,396
Yuba	1,610																	1,610
Total	16,618	8,645	6,806	23,085	293,206	7,071	16,287	28,078	5,882	2,865	17,970	16,985	18,068	2,604	190	2,383	103,720	570,463
San Joaquin Valley																		
Kern	1,591	162,552	299	244,092	34,864	83,645	27,519	5,608	3,852	2,997	2,742	1,968	1,958	41	281	528	12,459	586,996
Tulare	13	329	48,270			276	313											49,201
Total	1,604	162,881	48,569	244,092	34,864	83,921	27,832	5,608	3,852	2,997	2,742	1,968	1,958	41	281	528	12,459	636,197
Sierra																		
Amador	871	1,500	199	5,459	1,609	361	2,465	631	390	3,331	623	655	110	1,800	4,236	73	6,482	30,795
Calaveras	105	2,112	114	15,921	641	57,408	45,648	200	3,149	13,933	14,466	102,592	98,288	2,557	5,214	27,228	183,629	573,205
El Dorado	1,764	3,976	4,500	61,409	506	956	1,440	1,592	530	19,079	15,065	2,868	13,923	1,027	-	126	5,519	134,280
Mariposa	48	1,713	5,471	41,397	154	5,610	137,428	25,337	17	196	2,063	1,262	217	45,994	3,243	5,880	63,565	339,595
Nevada	1,941	68,355	456	137,686	2,567	4,336	2,850	23,718	63,429	58,895	10	180	16,639	44,092	450	-		425,604
Placer	2,239	96	171,492	20,100	96,387	130,308	82,979	111,720	17,471	77	124,405	52,907	2,684	24,592	233	95,312		933,002
Plumas	551	1,277	1,957	8,794	102,640	175,610	133,459	636	440	922	9,566	21,993	16,432	7	9,208	300		483,792
Tuolumne	1,134	4,297	3,502															8,933
Total	8,653	83,326	187,691	290,766	204,504	374,589	406,269	163,834	85,426	96,433	166,198	182,457	148,293	120,069	22,584	128,919	259,195	2,929,206
California	36,232	491,708	763,021	823,811	733,307	523,378	551,059	272,762	422,649	225,196	501,634	758,427	376,788	272,249	320,085	265,783	498,492	7,836,581

Source: State Board of Equalization, 2000

Disease and pests

Many disease and pest agents, when combined with other stressors such as drought, over-watering, or over-dense stands, are associated with oak mortality. Long-standing fungi such as *Armillaria* and *Hypoxylon* are the most well known diseases. However, the emerging pest of greatest concern to hardwoods is *Phytophthora ramorum*, the fungi associated with the syndrome called Sudden Oak Death (SOD), currently prevalent in the northern central coast region of California.

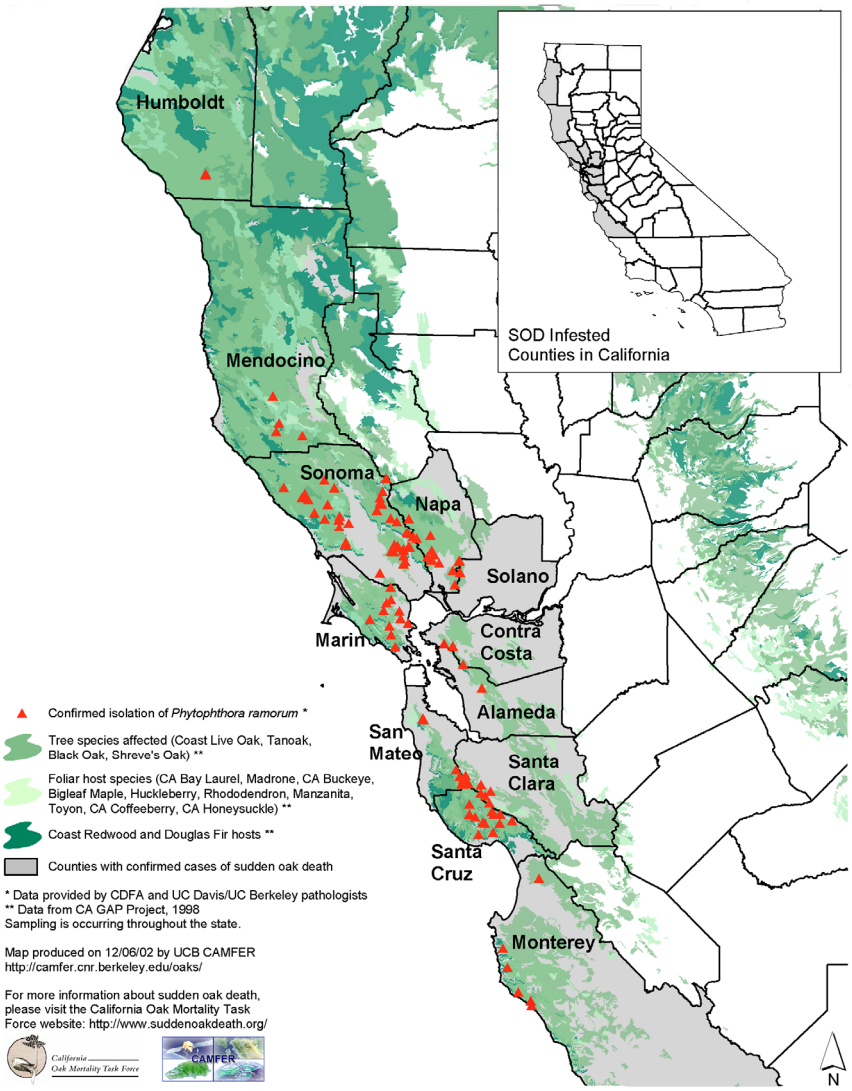
Sudden Oak Death (SOD)

Tens of thousands of tanoak *(Lithocarpus densiflorus*), coast live oak *(Quercus agrifoli*a), California black oak *(Quercus kelloggii*), Shreve oak *(Quercus parvula* var. *shrevei*), and madrone *(Arbutus menziesii*) have been killed by a newly identified species, *Phytophthora ramorum*, which causes SOD. The syndrome was first reported in 1995 in the central coast of California. The pathogen also infects rhododendron species, huckleberry *(Vaccinium ovatum*), bay laurel *(Umbellularia californica*), and California buckeye *(Aesculus californica*), but usually causes only leaf spot and twig dieback on these hosts. The host list is expected to increase as researchers at UC Davis and UC Berkeley continue their investigations of affected ecosystems. See the Assessment document Forest Pests and Diseases for further discussion.

The known distribution of Sudden Oak Death is expanding and as of December 2002 is found in 12 California counties.

The known distribution of SOD is expanding. In November 2001, there were 10 counties with SOD: Alameda, Marin, Mendocino, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma. As of December 6, 2002, two additional counties, Humboldt and Contra Costa, were found to have SOD bringing the total to 12 counties (Figure 14). The northernmost confirmed location of SOD in California is near Garberville in Humboldt County. The southernmost confirmed location is in Torrey Canyon, south of Pfeiffer Big Sur State Park in Monterey County. The location farthest inland is in Solano County. The disease is widespread in Marin and Santa Cruz counties within redwood forests with tanoak in the understory, and in mixed hardwood forests of oaks, bay, madrone, and other species. There are also nine isolated sites with confirmed SOD in Oregon.

Figure 14. Distribution of Sudden Oak Death (SOD) as of December 6, 2002



Source: California Oak Mortality Task Force, 2002

The California quarantine regulates the movement of all known host materials within and out of the known infested counties. That means that any movement of any host material (except acorns and seeds) must be done under permit from the local Agricultural Commissioner's office. To date, the regulations cover Marin, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, and Sonoma counties. The host list includes tanoak, coast live oak, black oak, Shreve oak, California bay laurel, madrone, rhododendron species (except azaleas), evergreen huckleberry, and *Viburnum*. Regulations will be amended to reflect the recent isolation of the pathogen from buckeye, and from tanoak in Mendocino County. As research and monitoring continue, the list of counties and hosts is likely to change.

The potential consequences of high levels of oak tree mortality from SOD are substantial. Visually, the oak landscape characteristic of much of California could be altered dramatically. There could also be significant impacts to many wildlife species that are dependent on coastal oak forests for food and shelter.

Ecological processes such as nutrient cycling, storage and release of water, and moderation of soil temperatures could also be affected. For more information, see the Home page of the California Oak Mortality Task Force.

Housing development projections in hardwood forest woodlands

Rural residential land development can affect the ecological function of hardwood land cover by reducing habitat extent and continuity, creating air quality impacts, increasing wildfire risk and creating conditions favorable for spreading invasive exotic species. To help identify future locations, FRAP uses housing development projections and vegetation data to assess the potential for development impacts on hardwoods from 2000-2040 (FRAP, 2003).

The goal of the projection of development map and analysis is to identify areas deemed "developed"; those that have reached a housing density of at least one house per 20 acres. This density is used as a lower boundary for the beginning of a rural residential land use pattern. Presumably, beyond this threshold development initiates progressive impacts on the ecological function of natural vegetation, constraints on ecosystem management, and increases in the potential for housing losses due to wildfire. However, within this footprint of development, opportunities still exist to design habitat corridors, best management practices, and favorable spatial layouts to sustain desired landscape functions.

Overlaying projected development on FRAP's current vegetation map allows for the computation of the approximate total hardwood land area as of 2000 that had a housing density less than one house per 20 acres. Sequential overlays of population density projections for the decades 2000-2040 indicate where densities will become greater than one house per 20 acres on land classified as hardwoods.

Seven of nine hardwood habitats are projected to lose at least 10 percent of the base 2000 acreage to development at a density of at least one house per 20 acres by 2040.

Seven out of nine hardwood habitats are projected to lose at least 10 percent of the base 2000 acreage to development at a density of at least one house per 20 acres by 2040 (Table 9). Montane Hardwood will have the largest projected decrease of about 294 thousand acres by 2040. Of greater concern are the Valley Foothill Riparian habitats that have a large proportional projected decrease (24 percent) between 2000 and 2040.

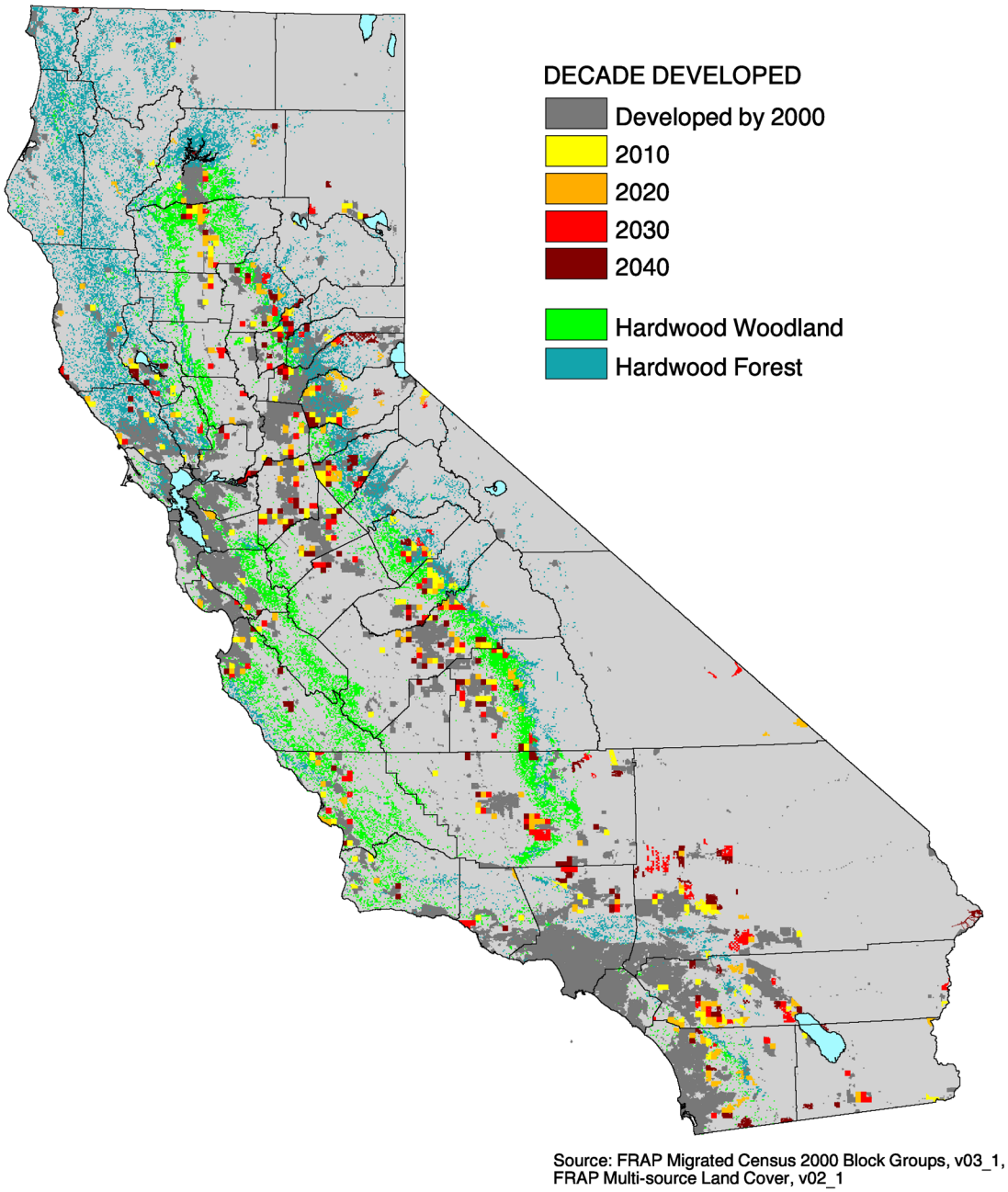
Table 9. Projected area and percentage of current private, undeveloped hardwood potentially impacted by new development* by decade to 2040 (thousand acres)

Land cover type	2000 undeveloped land base	Area developed at density of at least one housing unit per 20 acres				Total	Percentage loss 2000 to 2040
		2000-2010	2010-2020	2020-2030	2030-2040	2000-2040	
Aspen	2,236	15	0	0	0	15	1
Montane Hardwood	2,322,076	92,279	51,991	73,259	76,966	294,495	13
Montane Riparian	69,857	3,005	1,549	835	593	5,982	9
Blue Oak Woodland	2,168,710	88,595	58,438	53,760	70,484	271,277	13
Blue Oak-Foothill Pine	675,794	39,742	21,288	24,728	16,724	102,482	15
Coastal Oak Woodland	613,632	11,639	17,614	14,794	18,812	62,859	10
Eucalyptus	3,754	316	242	368	12	939	25
Valley Foothill Riparian	63,039	3,729	4,394	3,025	3,744	14,891	24
Valley Oak Woodland	104,639	2,555	598	4,329	3,133	10,616	10

**housing density of one or more units per 20 acres*
Source: FRAP, 2003; FRAP 2002c

Housing development patterns within a "developed" cell are highly variable. In other words, all cells do not represent complete, dense urbanization (Figure 15). Where the historical (pre-1990) residential land use thresholds were crossed long ago, higher densities may be found due to widespread continuous infill. A cell developed within the previous few decades may have only a small fraction of the total cell in residential land use, but at a density high enough to trigger the "developed" label.

Figure 15. Projected development* in relation to California's hardwood land cover



**Development means densities of one housing unit per 20 acres or greater*
Source: FRAP, 2003; FRAP 2002c

Impacts of development in El Dorado County: Regional and Statewide models of development do well at demonstrating coarse trends across broad areas and highlighting locations of concern. However, their simplicity and scale do not allow for site-specific modeling. Spatial models with highly detailed, fine-grained datasets are required for evaluating impacts of development on ecological, economic, or social systems at the local level. Such highly detailed models also enable stakeholders to more easily relate the data portrayed on maps to their perception of the landscape in which they live (Landis, 1994, 1995, 1998a and 1998b; Johnston and de la Barra, 2000; Johnston and Shabazian, 2001; U.S. Environmental Protection Agency, 2000). Most site-specific models of development focus on dense urban development (1-2 acre parcels or smaller). Furthermore, in order to guide development probabilistically and incrementally over time, these models use economic formulas of land values and empirically derived "attractors" of development such as proximity to existing infrastructure (roads, sewer, water, etc.). However, in rural areas (5-40 acre parcels) these factors are not the primary drivers behind development decisions (Johnston and Shabazian, 2001). Therefore, CDF/FRAP has developed a large-scale, highly detailed model capable of predicting potential rural "ranchette" development patterns at the local level in order to assess impacts on natural systems.

Forty-three percent of the privately owned land in El Dorado County is zoned to be developed at the 5-40 acre parcel size range.

As shown in FRAP's statewide progression of development modeling, the population in California's Sierra Nevada foothills has increased dramatically over the past 20 years and is projected to continue increasing at a similar rate over the next 40. Since the eastern half of these Sierra Nevada counties above 4,951.5 feet is predominantly national forest, the vast majority of the additional population will reside in the lower elevation foothills, a region dominated by hardwood woodlands with relatively sparse tree cover. Unlike other regions in California that have experienced rapid growth primarily in high density development, the trend in the Sierra Nevada foothills has been a mix of high density and low density, rural ranchette style expansion with large areas developed, or planned for development, in the 5-40 acre parcel size range. El Dorado County's 1996 Adopted General Plan, for example, called for 23 percent of the county (43 percent of the privately owned land) to be developed at this density.

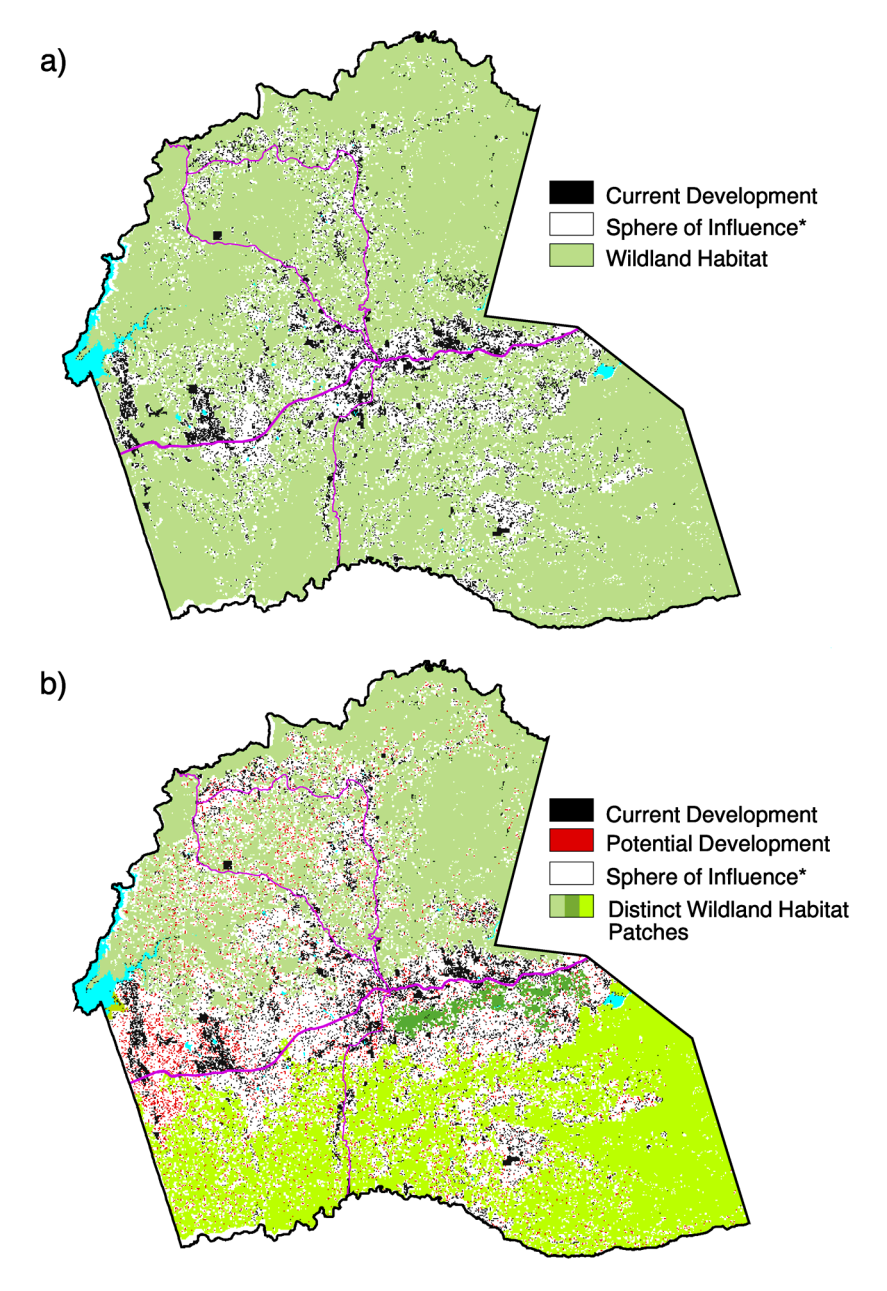
The switch from historically large parcel (low to moderate intensity agriculture, primarily ranches) to small parcel (high intensity urban and rural residential land use) promises great change to the natural ecosystems of the foothills region (Greenwood et al., 1993; Duane, 1996). These 5 to 40-acre ranchettes will likely contain the majority of naturally functioning, hardwood woodland landscapes in the near future.

FRAP's highly detailed resolution development model allows assessment of the implications of a variety of development scenarios. FRAP has used this model to conduct a detailed policy analysis of El Dorado County's 1996 Adopted General Plan, examining a variety of land use policies and their relative impacts on two major areas of concern—hardwood woodland habitat quality (characterized by extent, fragmentation, and configuration) and economic costs and losses due to wildfire.

The population of El Dorado County, a predominantly rural county stretching from the valley floor east of Sacramento to southern Lake Tahoe, has increased 82 percent since 1980—from 85,812 in 1980 to 156,299 in 2000 (U.S. Census Bureau, 2002a and 2002b). The California Department of Finance (2001) projects the population will continue increasing to 252,900 residents by 2020. To begin to understand the ramifications of such dramatic population growth, it is necessary to construct a spatial estimate of their current settlement pattern. Using the urban classifications from hardwood mapping (Pacific Meridian Resources, 1994) and information on parcel occupancy/vacancy from the 1996 County Assessor's dataset, we constructed a "footprint of current development" or the location of current human settlement was created (Figure 16a).

To measure future settlement growth, FRAP developed a potential footprint of future development for various General Plan policy scenarios (e.g., uncontrolled versus 'smart' growth, strict versus loose environmental land use policy, conservative versus generous water availability, and other similar combinations). This map simulation was guided by restrictions that limit where development can occur (e.g., high slope, setbacks from streams, areas meeting the oak canopy retention standard, public ownership and easements, and existing development) (Figure 16b).

Figure 16. Current and potential footprint of current development



**Natural hardwood land cover types influenced by development*
Source: Saving and Greenwood, 2002

In the last step of the model, the footprint of future development was overlain onto the hardwoods land cover data and was used to create a buffer around the newly developed areas. Natural land cover types falling outside this "sphere of influence" and in connected patches greater than 100 hectares were considered wildland habitat (i.e., undisturbed habitat). Natural land cover types within this buffer zone are considered urban habitat. These areas are subject to regular, sometimes intense disturbances from impacts such as wildland fuels reduction, non-native landscaping, noise, and domestic animals. Land cover types outside the buffer but in patches smaller than 100 hectares are considered marginal habitat. Species may utilize marginal habitat for movement and cover, but generally these patches are too small to sustain wildlife populations. In El

Dorado County, under the existing General Plan policy scenario, future development converted only four percent of the existing oak canopy to an urban use (i.e., trees removed and structures built in their place). However, nearly 40 percent of the oak woodlands were converted from wildland habitat to urban or marginal habitat (see Figure 16b). In other words, areas that once functioned under a fairly natural state, and are thus presumed to provide high quality habitat for species, become degraded either due to proximity to urban land uses or by isolation from larger patches of contiguous wildland habitat. More noticeable, however, is the splitting of the county's dominant contiguous wildland habitat into distinct northern and southern patches along the Highway 50 corridor (Saving and Greenwood, 2002). For complete information, see El Dorado County Buildout.

Hardwood Woodland sustainability and regeneration

A key factor in sustaining Hardwood Woodlands is the ability of species to regenerate. Regeneration is defined as the means by which a stand of trees maintains its structure and density by recruiting new saplings into the tree overstory to replace mature trees lost to mortality. An assessment of the success or failure of Hardwood Woodland regeneration typically examines the desired stand structure, rate of mortality in mature tree size classes, and the rate of seedling, sapling, and tree recruitment to the stand over time.

Regeneration is a dynamic process, in which periodic or only sporadic recruitment may be sufficient to balance mortality and thus maintain stand structure over the long term. A lack of seedling reproduction and recruitment during one or several years in a stand does not necessarily constitute regeneration failure in that stand (Lang, 1988).

There has long been recognition that some species within Hardwood Woodlands are not regenerating well and researchers have examined a variety of possible causes. Sudworth (1908) (fide Standiford et al., 1997) noted apparent poor natural regeneration of several oak species, particularly blue oak. The introduction of exotic non-native grasses in hardwood woodland understory, rodent herbivory, and grazing by livestock were considered by Griffin (1977) as factors responsible for a lack of oak seedlings. Lack of precipitation as well as season and intensity of livestock grazing can also affect seedling survival. Grazing, when implemented at specific levels, can reduce competing vegetation and improve oak seedling survival. Limited precipitation is also a factor. Seasons and level of livestock can increase seedling survival when competing grasses are reduced (Muick and Bartolome, 1987). Allen-Diaz and Bartolome (1992) (fide Standiford et al., 1997) evaluated natural regeneration in blue oak stands in north coastal California and concluded that blue oak as a species in this area had a successful strategy for seedling establishment. However, they were unable to determine the factors that prevented seedlings from moving into the sapling size class. Fire and sheep grazing were eliminated as factors responsible for recruitment failure.

Studies affirmed regeneration problems in a number of areas occupied by blue oak, valley oak, and Engelmann oak.

The natural regeneration of Hardwood Woodlands and the influence of environmental variables has been a topic of focused research from the late 1980s. This has been an important area of research for the Integrated Harwood Range Management Program (IHRMP, 2000). At least two studies have quantified the presence or absence of oak seedlings and saplings on plots located throughout

California (Muick and Bartolome, 1987; Bolsinger, 1988). Although these studies are based on a relatively low number of plots across a variety of environments in the State, both studies affirmed regeneration problems that make oak sustainability an issue for blue oak, valley oak and Engelmann oak. More recent research has focused extensively on the natural regeneration of blue, coast live, and valley oaks because these species are frequently considered to have low or inadequate levels of regeneration in certain areas of California. For these species, the thrust of regeneration research has been competition with annual grasses for limited water availability, acorn and seedling consumption by browsing wildlife and domestic livestock, changing levels of fire frequency and intensity, and influence of existing tree canopy density on seedling establishment and survival.

Standiford et al. (1997) examined the factors influencing the probability of oak seedling and sapling regeneration in southern Sierra Nevada Hardwood Woodlands. Their study found that tree cover was positively correlated with the probability of seedling and sapling regeneration. Grazing influences were negatively correlated with blue oak seedlings, while no correlation was found with saplings in this particular study area. Solar radiation levels as derived from site slope and aspect were significant influences on black, interior live, and canyon live oak seedlings. Elevation was positively correlated with blue oak seedling presence.

It is noteworthy that the five oak species (valley, Engelmann, coast live, interior live, and blue oak) that are frequently the subject of regeneration studies can reproduce from both acorns and from root or stem sprouting. Younger age classes of all of these species resprout vigorously when cut, broken, burned, or browsed by livestock or wildlife. Valley and blue oak may lose sprouting vigor as they grow larger while interior live oak, coast live oak, and Engelmann oak continue to sprout vigorously in older age classes after fire or cutting (Lang, 1988).

Management guidelines have been developed for hardwood species within hardwood woodlands by the Integrated Hardwood Range Management Program. These guides help landowners, managers, and professional planners of hardwood rangeland resources develop management plans and other initiatives that maintain the sustainability of hardwood woodland ecological value as well as the profitability of individual properties. In addition, most local governments have policies that relate to these lands (IHRMP, 2001a, 2001b, and 2001c). See the Assessment document Legal Framework for a detailed discussion.

Hardwood forest sustainability and regeneration

The dominant type on Hardwood Forests is Montane Hardwood. Within Montane Hardwoods, California black oak (*Quercus kelloggii*) is one of the most prevalent species. It is also key to wildlife habitat, especially deer. The continued abilities of black oak to sustain regeneration and to provide forest structure are the key elements to the

Black oak, Yosemite National Park.

sustainability of montane forest ecosystems. They are also indicators of the status of hardwood forests.

California black oak is the most widely distributed hardwood in the State (see Figure 17), occurs on approximately 4.3 million acres outside of national forest lands, and occurs on approximately 8.6 million acres Statewide (Bolsinger, 1988). The species exceeds all other California oaks in volume, distribution, and altitudinal range (McDonald, 1990). California black oak is found from the basin of the McKenzie River in western Oregon southward through the Coast Ranges and principally along the western slopes of the Sierra Nevada to the Cuyamaca Mountains in southern California. A few stands of the species are found on the east side of the Sierra Nevada. It is typically found where ponderosa pine also grows (McDonald and Sundahl, 1967). California black oak is most abundant and attains its largest size in the Sierra Nevada (Figure 17). Extensive stands are also found in eastern Mendocino and Humboldt counties of the north Coast Range (McDonald, 1997).

Figure 17. Distribution of California black oak (*Quercus kelloggii*)

Source: McDonald, 1997

Wildlife habitat relationships and regeneration

The value and importance of hardwoods to wildlife in general is well documented, and numerous species are potentially affected by a reduction in hardwood densities. A review of the California WHR System for the Montane Hardwood/Conifer type, which supports significant amounts of California black oak, showed a total of 164 terrestrial vertebrate species finding moderate or high habitat capability for breeding, feeding, and/or cover requirements (eight amphibian, 12 reptile, 94 bird, and 50 mammal species). However, for most species utilizing forested habitats with a black oak component, data is insufficient to consistently link population response to changing black oak density.

California black oak can regenerate by way of stump sprouting or germination of acorns. California black oak is shade intolerant and a vigorously sprouting species. It generally occurs in even-aged stands where intensive fire or logging is the principal means of stand replacement (McDonald, 1969). Because fire incidence throughout its natural range is high, nearly all California black oak trees originated from sprouts. Consequently most California black oak stands are even-aged. The size and vigor of the parent tree determines the number of sprouts and their height and crown spread.

Probably the most important single soil variable that limits the presence of California black oak is adequate drainage. Increasing clay content in the surface soil usually means a decreasing incidence of black oak. In general, black oak grows best on medium- to coarse-textured, deep, and well-drained soils (McDonald, 1997).

Wildlife food sources

Acorns from California black oak are valuable foodstuffs because of the large amounts produced, their high caloric content, and extended period of availability. For species that are primarily dependent on this food source, the size and well-being of their populations can hinge on the size and availability of that year's acorn crop. Yet, annual acorn production by California black oak, as is the case with other oak species, is variable by nature, average to good crops for this species are produced, in general, every three to four years.

California black oaks on a good forest site begin to produce acorns in moderate quantities (20 pounds) at about 80 years of age (generally a 13 inch bole and 26 foot crown diameter). A California black oak on a good forest site with a bole diameter of 32 inches and crown diameter of 52 feet produces 140 pounds of acorns. The age at which acorn production begins to decline is uncertain; however, it appears to occur after 200 years of age (McDonald, 1969).

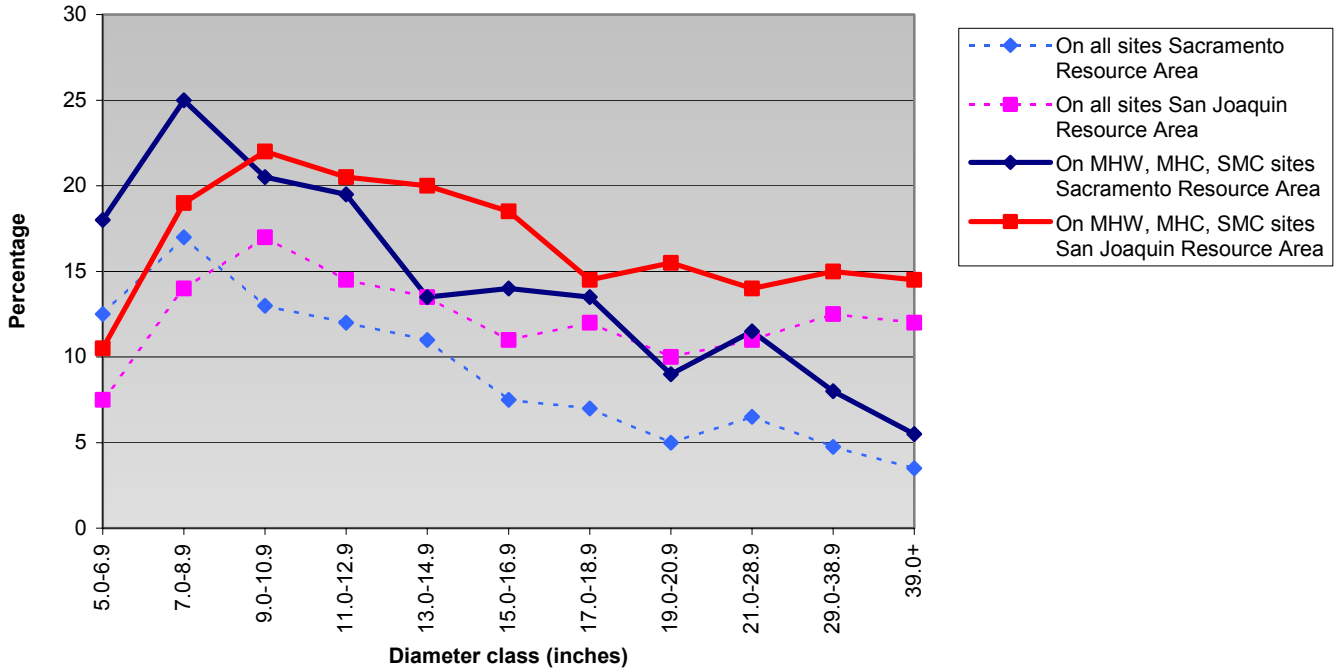
Acorns from most oak species, when available, are an important food source for deer and a variety of studies in different areas of the State have investigated the importance of acorns and foliage from California black oak and other oak species. Seedling and sapling stages of this tree species are also a frequently used source of leaves and stems as browse. For example, reproductive rates were positively associated with a high acorn diet among the North Kings Deer Herd. During good acorn production years, mean ovulation and fetal rates were higher for both adult does and yearlings (Bertram and Ashcraft, 1983). Acorns comprise as much as 50 percent of the November and December diet in this area (Garrison, 1992).

Black oak inventory

In May 2002, CDF/FRAP analyzed the distribution of black oak within three forest types: Sierra Mixed Conifer (SMC), Montane Hardwood/Conifer (MHC), and Montane Hardwood (MHW). Plot level data from the USFS Forest Inventory and Analysis (FIA) Program on private lands within the Sierra Nevada mountains and within these three forest types were examined. Results of the FIA show that black oak is quite abundant in the forest types most likely to have this species. Black oak accounts for approximately 15 percent of the total tree basal area for all tree species in the Sierra Mixed Conifer, Montane Hardwood/Conifer, and Montane Hardwood forest types. On average, black oak basal area for Sierran mixed conifer sites was 20 square feet per acre. Black oak basal area in the combined Montane Hardwood/conifer and Montane Hardwood types was 35 square feet per acre. Much of the black oak basal area is found in smaller size classes (Figure 18). These results suggest that black oak is generally abundant, but is predominately found in trees of small size. Specific management actions will be needed to maintain current black oak stocking and to promote the development of existing stands into larger tree sizes and the associated ecological benefits trees of this size provide.

Black oak is found to have abundant stocking levels, but most stocking is found in smaller size trees.

Figure 18. California black oak as a percentage of diameter class total basal area on timberlands types outside of national forests, Sacramento and San Joaquin Resource Areas



Source: compiled by FRAP from FIA1997a; FIA 1997b

Management guidelines

The California Forest Practice Act regulates commercial timber harvesting on non-federal lands. Although several rules provide for certain levels of hardwood retention, economic and other regulatory considerations ultimately shape hardwood extent and quality on the landscape. For example, as intensive timber management activities move increasingly to upland sites in deference to environmental protections for other more sensitive areas, high quality conifer sites can be expected to have the largest reduction in hardwood basal area. Over time, hardwoods like black oak are shifted to less productive conifer sites (Merenlender et al., 1996). In addition, recent changes to the Forest Practice Rules concerning the achievement of Maximum Sustained Production (MSP) of high quality timber products may increase the likelihood of conifer retention and management over the retention of California black oak and other hardwood species. Where ownership or management unit-wide sustained yield or other programmatic planning efforts have not been completed, stocking and basal area requirements must be met with conifer species. California black oak may be selectively removed in order to calculate a higher MSP based on conifers.

Management of California's hardwood forests for the benefit of wildlife and other values has been advocated for many years, but no comprehensive management perspective and few guidelines specific to California black oak have emerged. The ability of these and other guidelines to provide wildlife habitat values remains largely untested (Garrison et al., 1998).

In 1989, DFG proposed interim management guidelines for oak species in areas of high importance to wildlife on hardwood forestlands (DFG, 1989). These retention guidelines recommend basal area retention of 25 square feet per acre in Montane Hardwood and Montane Hardwood/Conifer habitats. These basal area recommendations increase to 35 square feet per acre on areas of recognized importance to wildlife such as critical deer wintering range. More recently, DFG has expressed concern that adequate hardwoods may not be retained in sufficient quantities to meet the needs of wildlife following timber harvest in the Sierra Nevada. In response, the California State Board of Forestry and Fire Protection adopted rule language for retaining hardwoods in sufficient quality and quantity and in appropriate locations to provide functional habitat for wildlife species associated with hardwoods (California State Board of Forestry and Fire Protection, 2002).

The USFS retention standards range from 10 to 80 square feet per acre depending on the wildlife management objective. Also, the committee affiliated with the IHRMP provided recommendations for hardwood retention guideline development on California's north coast. This group did not recommend specific quantitative retention guidelines but identified areas of additional research needs, important habitat types, and criteria and approaches that should be considered when developing retention guidelines in their region (Merenlender et al., 1996).

Concluding observations

Hardwood Woodlands and Forests represent some of the most biologically rich natural resources in California. Conversion and development pressures are land uses that affect these areas. With just over 73 percent in private ownership (83 percent of Hardwood woodland is in private ownership) and most in non-reserve management classes, these pressures will likely continue.

Certain Hardwood Woodland and Forest types are more susceptible to intense land uses. Valley Oak Woodland and Valley Foothill Riparian are particularly vulnerable to development because of their low abundance, little reserve status and adjacency to intensively developed land uses. Blue Oak Woodland, Blue Oak-Foothill Pine, and Coastal Oak Woodland also have development pressures, but cover far larger areas.

If projections based on past land use and management hold true, pressures will intensify. FRAP estimates that seven of nine hardwood habitats will lose at least 10 percent of their 1990 base acreage to development at a density of at least one house per 20 acres by 2040.

Several tools will play critical roles in conserving California's Hardwood Woodlands and Forests. Acquisition strategies for reserves and stewardship incentives for the management landscape will guide protection of critical habitat and ensure sustainability of existing Hardwood Woodland and Forests and associated land uses. Consideration for compensation of private landowners who maintain lands to provide valuable ecosystem services will likely be part of the conservation strategies. Finally, for these strategies to be adaptable and successful, monitoring will need to have a major emphasis. At small and large scales, monitoring will help to direct management practices and conservation strategies.

Acquisition and enhanced reserve strategies may play important roles in increasing the protection of key habitat areas. However, the sheer size of Hardwood Woodland and Forest in private ownership demonstrates that strategies to help maintain a viable working landscape, such as incentives or conservation easements, may be even more important.

Glossary

basal area: The cross sectional area of a tree at breast height (4.5 ft above ground).

bole: The trunk of a tree, below the lowest branch.

browse: To feed on leaves, young shoots, and other vegetation.

California Wildlife Habitat Relationship: California Wildlife Habitat Relationship is a state-of-the-art classification system for California's wildlife. CWHR contains life history, management, and habitat relationships information on 675 species of amphibians, reptiles, birds, and mammals known to occur in the State. CWHR products are available for purchase by anyone interested in understanding, conserving, and managing California's wildlife.

CDF: California Department of Forestry and Fire Protection.

CEQA: California Environmental Quality Act.

crown: The part of a tree or shrub above the level of the lowest branch.

CWHR: See **California Wildlife Habitat Relationship**.

even-aged: A forest stand or forest type in which relatively small (10-20 year) age differences exist between individual trees. Even-aged stands are often the result of fire, or a harvesting method such as clearcutting or the shelterwood method; Forest stand where more than 70 percent of the tree stocking falls within three adjacent, decadal, age classes.

FIA: See **Forest Inventory and Analysis**.

forb: A broad-leaved herb other than a grass, especially one growing in a field, prairie, or meadow.

Forest Inventory and Analysis: Forest land and timberland statistics reported by the Pacific Resource Inventory, Monitoring and Evaluation program (PRIME) of PNW. Every decade, PRIME conducts the Forest Inventory and Analysis, which is a national mandate authorized by the Forest and Rangeland Renewable Resource Research Act of 1978. The FIA is a plot-based survey and statistical analysis with representative field based plots of all forest lands outside the National Forest System.

FRAP: Fire and Resource Assessment Program.

FRAPVeg: Fire and Resource Assessment Program Vegetation Habitat Classification and Mapping Project, multi-source vegetation data.

Geographic Information System: A computer based system used to store and manipulate geographical (spatial) information.

GIS: See **Geographic Information System**.

IHRMP: Integrated Hardwood Range Management Program.

LCMMP: California Land Cover Mapping and Monitoring Program.

MSP: Maximum Sustained Production.

nutrient cycling: The exchange or transformation of elements among the living and nonliving components of an ecosystem.

overstory: The larger, taller trees that occupy a forest area and shade young trees, hardwoods, brush, and other deciduous varieties growing beneath the larger trees (i.e., understory).

silviculture: Generally, the science and art of cultivating (such as with growing and tending) forest crops, based on the knowledge of silvics. More explicitly, silviculture is the theory and practice of controlling the establishment, composition, constitution, and growth of forests.

SOD: Sudden Oak Death.

understory: The trees and other woody species growing under a relatively continuous cover of branches and foliage formed by the overstory trees.

USFS: U.S. Forest Service.

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