

Engelmann
Oak-Ecology
& Management



The Distribution of Engelmann Oak (*Quercus engelmannii*) in California¹

Thomas A. Scott²

Abstract: Engelmann oaks (*Quercus engelmannii*) only occur in the foothills of San Diego (93 pct of extant stands), Riverside (6 pct), Orange (0.5 pct), and Los Angeles (<0.1 pct) counties, covering the smallest range of any oak species in California. The overall distribution of the species covers approximately 31,500 hectares of woodlands, although they are subdominant (contributing <50 pct of canopy area) to coast live oak (*Quercus agrifolia*) over about 52 pct of that area. Individual stands across the species range were mapped at 1:24,000 scale into a geographic information system (using 1:20,000 scale aerial photographs). Stands were separated into 6 classes of Engelmann oak canopy dominance: (one) 0 to 5 pct of canopy area; (two) >5 to ≤25 pct; (three) >25 to ≤50 pct; (four) >50 to ≤75 pct; (five) >75 to ≤95 pct; and (six) >95 to ≤100 pct. All areas were field checked for accuracy in boundary and canopy classification. There are approximately 7,300 ha of woodlands in categories five and six; 14,000 ha in categories three and four; and 9,200 ha in categories one and two. Combining these data with USGS Digital Elevation Models suggests that Engelmann oaks are most concentrated on 0° to 10° slopes with southwestern aspects between the elevations of 700 m to 1250 m above sea level. They tend to occur at higher elevations and slightly steeper slopes (5° to 10°) than coast live oaks, but there are no differences in the distribution of the two species relative to slope-aspect. The largest landholder of Engelmann oak stands is the Cleveland National Forest (24 pct of all stands), followed by Spanish Land Grants (29 pct; unbroken large land holdings), Native Americans (7 pct; on Indian Reservations), and the US Marine Corps (6 pct; Camp Pendleton). A large number of small private parcels control the remaining 31 pct of Engelmann oak stands.

This study was undertaken to define the distribution of the Engelmann oak (*Quercus engelmannii*). It is the first step in conserving and managing this oak resource in a rapidly urbanizing part of California. Wieslander and Jensen (1946) mapped part of the Engelmann oak range in the 1940's; if it were not for the rapid conversion of wildland habitats and the increased interest in woodland, these maps probably would have been sufficient to typify the species distribution. The U.S. Forest Service maps (Anderson 1969) are more up to date and at a finer

scale than the Wieslander maps, but still did not provide the data for private lands outside the Cleveland National Forest. Bolsinger (1986) provided the best estimates of Engelmann oak area, but these data were neither location specific nor retrievable by geographic unit.

The goals of this paper are threefold: (1) to define the extent of Engelmann oak woodlands, (2) to make broadscale predictions on the occurrence of the species relative to topographic features, and (3) to outline the ownership, administration, and management control of Engelmann oak woodlands.

METHODS

Photographic Imagery

I used 1980 color imagery at 1:20,000 scale to map the woodlands. Areas with rapidly changing (urbanizing) landscapes in the northern half of the species range were mapped with 1989 color infrared imagery at 1:20,000. Engelmann oak woodlands in the aerial photographs were traced onto 46 USGS 7.5 minute topographic maps using a zoom transfer scope or drawn directly onto maps using stereoscopic glasses and stereo-paired photographs. Engelmann oaks in aerial photographs were separated from other trees by: (1) the open canopy and growth form of *Q. engelmannii* and (2) lighter green color of *Q. engelmannii* in infrared imagery. Oak woodlands that did not contain Engelmann oaks (i.e., pure stands of coast live oak) were not mapped.

Woodland Mapping

Polygon boundaries were drawn by connecting the canopies of oaks on woodland perimeters; woodland areas with less than 10 mature oaks per hectare (10 to 30 pct canopy cover) were not mapped. When woodlands were interdigitated with or bisected by other vegetation, I followed two conventions: (1) if the distance between two canopies exceeded 75 m, the space between was not mapped as woodland, and (2) stands smaller than 0.5 ha were not mapped unless they occurred in isolated areas (greater than 3 km from nearest stand) or they occurred along the edge of the species range. We used the GIS ARC/INFO to calculate the area and perimeter of each polygon.

¹Presented at the Symposium on California's Oak Woodlands and Hardwood Rangeland, October 30 - November 1, 1990, University of California, Davis.

²Natural Resource Specialist, Integrated Hardwoods Management Program, Department of Forestry and Resource Management, University of California, Berkeley, and Assistant Adjunct Professor, Department of Earth Sciences, University of California, Riverside.

Categorization of Woodlands

A releve method was used to classify woodlands containing Engelmann oaks into six categories of species dominance. The dominance of Engelmann oak within polygons was ranked into six categories: (one) 0 to 5 pct of canopy area was Engelmann oaks; (two) >5 to ≤25 pct; (three) >25 to ≤50 pct; (four) >50 to ≤75 pct; (five) >75 to ≤95 pct; and (six) >95 to ≤100 pct. A specific woodland was subdivided into separate polygons only when a clear division could be drawn between two dominance categories. I did not attempt to separate woodland areas into canopy cover-density classes (oak canopy area/total area), because this categorization clouded comparison between live and Engelmann oak. Categorization of the woodlands was done in the field during the spring and summer months of 1987 through 1989. Stands of hybrid *Quercus engelmannii* x *dumosa* and *Q. engelmannii* x *cornellius-mullerii* were not mapped unless they contained single stemmed trees with predominantly Engelmann oak leaf and bark characteristics (Scott 1990).

Overall Topographic Distribution of Woodlands

Engelmann oak woodland polygons were overlaid onto topography to calculate the distribution of woodland areas among elevation, slope, and aspect. Categories of dominance were maintained so the relative distribution of live oak and Engelmann oak dominated woodlands could be calculated for each of the variables. I used Digital Elevation Models (DEMs) created from United States Geological Survey (USGS) data files for twenty-five 7.5-minute quadrangle data. These data were available for approximately 70 pct of the distribution of *Q. engelmannii*, but did not cover some stands in the southern and eastern portion of the species distribution. The DEM data were divided in the following manner to maximize computer efficiency: (1) elevation was divided into 25 m intervals; (2) slope data was divided into 5° intervals; (3) slope-aspect data was divided into 45° intervals. The Very Important Points (VIP) program of the GIS ARCO/INFO was needed to reduce the number of points in the DEM data set.

Land-Use Boundaries

The distribution of Engelmann oak woodlands was overlaid onto a coverage of the boundaries and county, state, and federally administered lands (take from USGS quadrangle maps and County of San Diego base maps). These categories were used to divide woodland areas into private, county, state, and federal holdings. Federally owned parcels smaller than 2.5 km² (1 mi²) were not mapped.

Deviations from Random Distributions

I compared the observed topographic distribution of woodlands against random distributions in nine of the 46 quadrangles where Engelmann oaks occur (figure 1). Because the computer time required to calculate DEM data limited the number of quadrangles that could be used, I selected nine representative quadrangles: three from the northern end, four from the central portion, and two from the southern end of the Engelmann oak distribution. DEM data were calculated for the entire surface of each quadrangle and the frequency distributions of elevation, slope, and aspect were calculated to describe the available landscape in the sampled area. I then measured the deviation in the observed woodland elevation, woodland slope, and woodland aspect from the distributions that would be expected if woodlands were randomly distributed across the nine quadrangles.

Statistical Analyses

The majority of data presented in this paper are derived from GIS map polygons. In nearly all cases the spatial areas (measured in hectares) of these polygons have been grouped in categories and their summed values among these categories were then compared against an expected (random) distribution. At present, there are no statistical techniques for calculating the significance of the differences in two distributions of summed (rather than enumerated) categorical data. Although the tests used here represent trends, they cannot be compared to standard tests of statistical significance. To be conservative, I used average woodland polygon size (15 hectares) as the operational geographic (sample) unit (Crovello 1981) rather than my unit of measurement, which was the hectare. Summed data in categories were divided by this geographic unit to approximate sample size for estimating the appropriate critical values in Kolmogorov-Smirnov comparisons (P_{est}) summed values within cells were divided by the geographic unit to approximate the frequency values for Chi-square comparisons.

RESULTS

Overall Distribution of Woodlands

I recorded 31,512 ha of woodland containing Engelmann oaks in 2,150 GIS polygons. These stands were concentrated in the cis-montane foothills of San Diego and southwestern Riverside counties (figure 1) (for general description of distribution see Scott 1990). The western edge of the species range averages

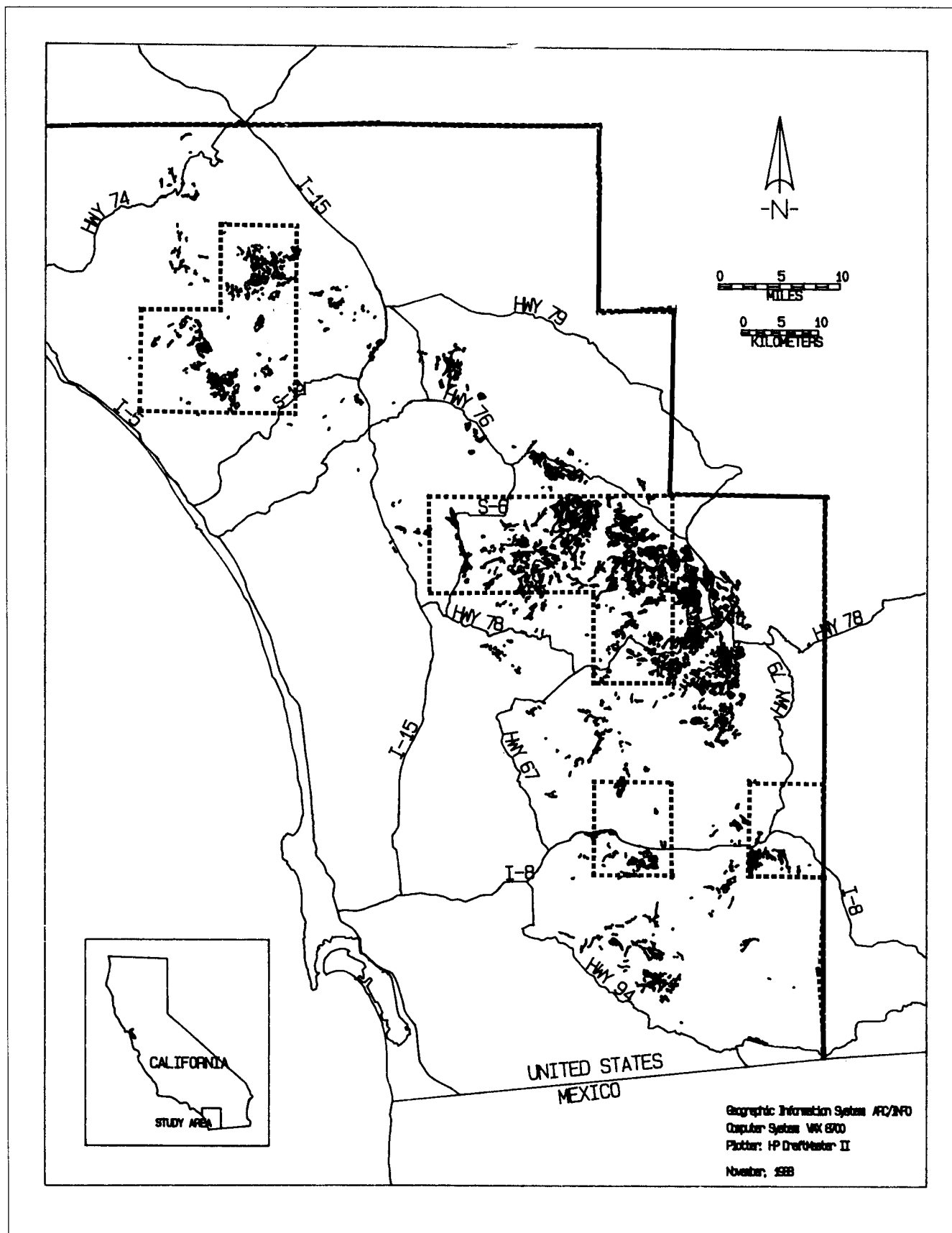


Figure 1—The geographic distribution of Engelmann oak (*Quercus engelmannii*). The dark line represents USGS quadrangles where topographic data was collected on woodlands; the dashed line outlines quadrangles where topographic data was collected for both woodland and landscape.

22.0 ± 1.6 km (13.7 ± 1 mi) (measured on 50 polygons at 2.5 km north/south intervals) from the coastline; the species range comes within 7 km (4.5 mi) of the coast at Camp Pendleton (north end of the range) but is 30 km (19 mi) from the coast at the Mexican border. The east-west width of the species range is 20 km (12.5 mi) at the Mexican border and reaches a maximum width of 40 km (25 mi) between the cities of Escondido and Julian (33° 7' latitude); north of this latitude the range splits into a narrow western (20 km; 12.5 mi) band in the Santa Ana Mountains and a diffuse pattern of small (0.2 to 1 ha) stands across the Perris Plain and the foothills of the San Jacinto Mountains. I found only scattered Engelmann oaks south of the Mexican Border and north of California State Highway 74. The proportion of USGS (7.5 minute) quadrangle area covered by Engelmann oaks varied from 2 pct of quadrangles at the western fringe of the species distribution to 29 pct of quadrangles in the center of the species distribution. Engelmann oak woodland area averaged 8.1 ± 7.6 (SD) pct of quadrangle area in the 18 contiguous quadrangles where the majority of the species distribution occurred.

Distribution Among Woodland Types

Only 1.6 pct of the woodland area was classified as pure stands of Engelmann oak woodland (category six) (table 1). A slight majority of woodlands (52 pct) occurred in stands where Engelmann oaks were subdominant to live oak. There were no strong patterns of spatial segregation among the different categories of woodlands other than the elevational differences (see beyond).

Polygon Size and Shape

Polygons averaged 15.9 ± 49 ha, with a wide range of averages among woodland categories (table 2). The high variance to mean ratios in all six woodland categories indicates that the pattern of a few large woodlands and a large number of small woodland stands is consistent across all categories of Engelmann oak woodlands. Woodlands in categories four and five had the largest average woodland areas, measuring 20.3 ± 53 ha and 20.1 ± 76 ha, respectively. Pure stands of Engelmann oaks averaged 9.1 ± 18 ha. About 22 pct of the woodlands had area/perimeter ratios of less than 0.125, which approximates the ratio for a linear or strongly interdigitated woodland.

Elevational Range

Engelmann oaks in the sample quadrangles ranged from 50 m (160 ft) to 1,375 m (4500 ft) (a.s.l.), with 60 pct of woodland area occurring between 475 m (1,640 ft) to 1075 m (4,000 ft) (a.s.l.). The distribution was bimodal, with peaks occurring at 600 m (1,950 ft) and 1075 m (3,500 ft) (figure 2).

The elevational distribution of Engelmann oak deviated strongly from the elevational distribution of the nine sample quadrangles. In general, there were more hectares of Engelmann oak woodland between 700 m (2,300 ft) and 1,275 m (4,200 ft) than would be predicted by random distribution (Kolmogorov-Smimov test; $P_{est} < 0.01$) (figure 3) across the nine quadrangles; conversely, there were fewer hectares of woodland above and below this range than would have been predicted.

Woodlands dominated by Engelmann oak showed a strong tendency to occur at higher elevations than woodlands dominated

Table 1—Total area of Engelmann oak woodland in hectares.

CATEGORY ¹	PRIVATE PARCEL ²	LAND GRANT	NATION FOREST	INDIAN RESERV	MILITARY BASE	STATE/ COUNTY	TOTAL
SOLITARY TREES	2354	937	1441	378	145	20	5273
SCATTERED GROUPS	2003	440	1025	275	254	5	4001
SUB-DOMINANT	2140	2624	1244	426	190	2	6626
CO-DOMINANT	2137	2062	1546	939	657		7341
DOMINANT	2254	1939	2088	140	269		6690
PURE STAND	141	258	38	41	2		481
TOTAL	11029	8260	7382	2198	1516	27	30412

¹The ratio of Engelmann oak (*Quercus engelmannii*) canopy area to coast live oak (*Quercus agrifolia*) canopy area within these 6 woodland categories are; Scattered trees, 0 to 0.05; Scattered groups, >0.05 to ≤0.25; Sub-dominant, >0.25 to ≤0.5, Co-dominant, >0.5 to ≤0.75, Dominant, >0.75 to ≤0.95; Pure stands, >0.95 to 1.00.

²Includes Nature Conservancy property.

Table 2—The mean and standard deviation of woodlands (polygons) containing Engelmann oaks.

CATEGORY ¹	PRIVATE PARCEL ²	LAND GRANT	NATION FOREST	INDIAN RESERV	MILITARY BASE	STATE/ COUNTY	TOTAL
SOLITARY TREES	10.80 ³	12.49	18.71	12.59	8.51	4.60	12.49
	8.63	27.46	55.90	20.22	12.24	4.70	30.42
SCATTERED GROUPS	11.64	8.62	16.27	14.45	11.04		12.18
	18.13	13.36	34.34	19.15	18.32		29.44
SUB-DOMINANT	13.38	24.76	13.82	9.90	10.54		15.89
	20.94	99.61≤	18.89	12.53	11.80		53.08
CO-DOMINANT	16.31	32.21	15.01	22.91	28.56		20.28
	27.14	99.32	34.73	54.31	38.49		3.16
DOMINANT	14.09	26.57	31.64	10.77	12.79		20.09
	27.26	83.55	139.72	10.05	22.92		76.50
PURE STAND	6.72	12.89	7.63	6.87	2.32		9.07
	8.64	26.83	10.83	8.43	0.00		18.15

¹The ratio of Engelmann oak (*Quercus engelmannii*) canopy area to coast live oak (*Quercus agrifolia*) canopy area within these 6 woodland categories are: Scattered trees, 0 to 0.05; Scattered groups, >0.05 to ≤0.25; Sub-dominant, >0.25 to ≤0.5; Co-dominant, >0.5 to ≤0.75; Dominant, >0.75 to ≤0.95; Pure stands, >0.95 to 1.00.

²Includes Nature Conservancy property.

³Data are presented as mean (top) and standard deviation (bottom) for each category and land-use type.

by live oak (figure 4). Over 45 pct of live oak dominated woodlands occurred below 525 m (1,700 ft), while only 5 pct of Engelmann oak dominated woodlands occurred below this area. These two types of woodlands have similar patterns of distribution above 1,150 m (3,900 ft); only 4 pct of live oak dominated woodlands and 6 pct of Engelmann oak woodlands occur above this elevation.

Slopes

Approximately 62 pct of Engelmann oak woodlands occur on slopes of less than 10° inclination, and approximately 94 pct occur on slopes of less than 20° inclination (figure 5). The Chi-

square comparison (test for contingency; $P_{\text{est}} < 0.01$, 3 d.f.) suggests that more woodlands occurred in areas with 0° to 10° slope than would be predicted by a random distribution across slope categories; approximately 68 pct of the woodlands occurred on slopes of 0° to 10°, while only 54 pct of the landscape area had slopes of less than 10°.

Slope-Aspect

Engelmann oaks occurred throughout slope-aspect categories, but showed a trend towards southwestern aspects (225° to

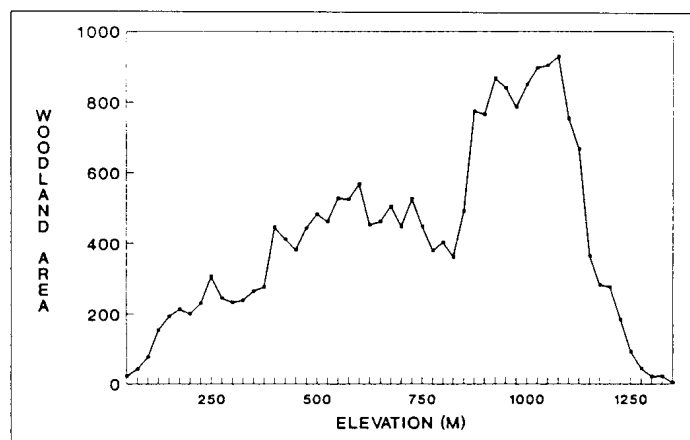


Figure 2—The elevational distribution of Engelmann oak woodland area.

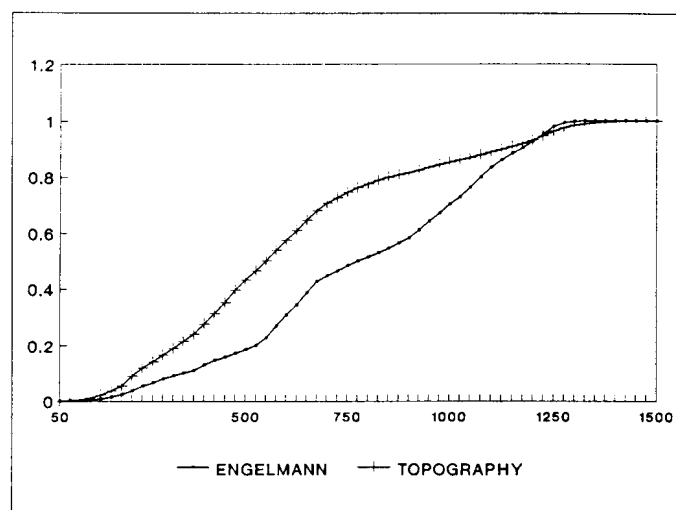


Figure 3—Cumulative frequency (0 to 1.0) of Engelmann oak woodland area (.) and landscape area (+) across elevation (m).

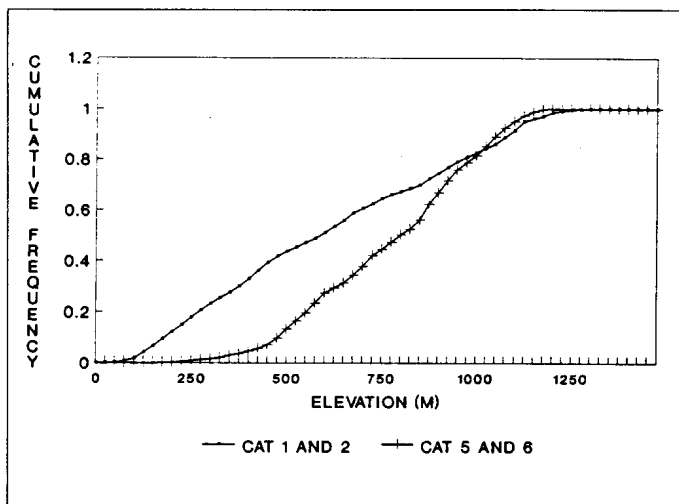


Figure 4—Cumulative frequency (0 to 1.0) of coast live oak (*Quercus agrifolia*) dominated woodland area (category 1 and 2) and Engelmann oak (*Quercus engelmannii*) dominated woodland area (category 5 and 6) across elevation (m).

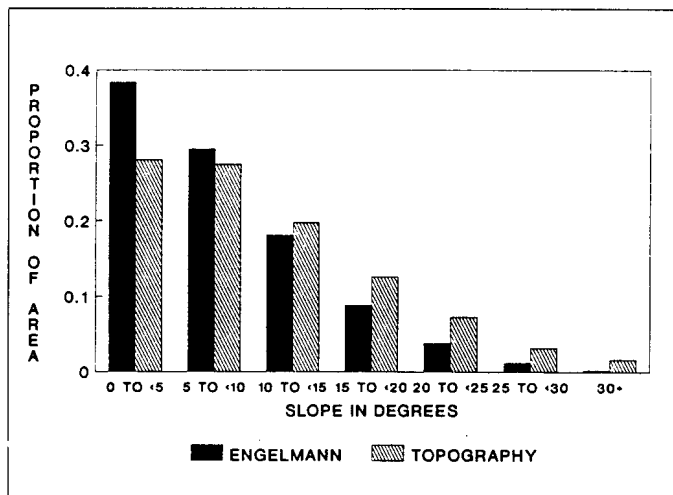


Figure 5—The proportion of Engelmann oak woodlands area (ENGELMANN) and landscape area (TOPOGRAPHY) among 5° slope categories.

315° azimuth) (figure 6). The distribution of Engelmann oak woodlands among slope-aspect categories deviated from what would be predicted by random distribution across the nine quadrangles (Chi-square test for contingency; $P_{est} < 0.05$, 5 d.f.). Even though the difference was consistent in direction, Engelmann oak woodland area varied no more than 6 pct from the area that would be predicted by distribution of slope-aspects in the sample nine quadrangles. The distribution of woodland categories is equivocal and suggests no pattern between Engelmann oak dominated and live oak dominated woodlands (figure 7).

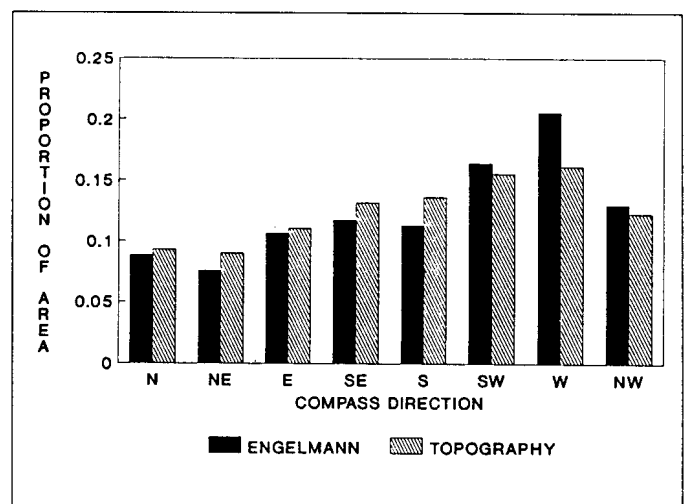


Figure 6—The proportion of Engelmann oak woodland area (ENGELMANN) and landscape area (TOPOGRAPHY) among 45° compass divisions.

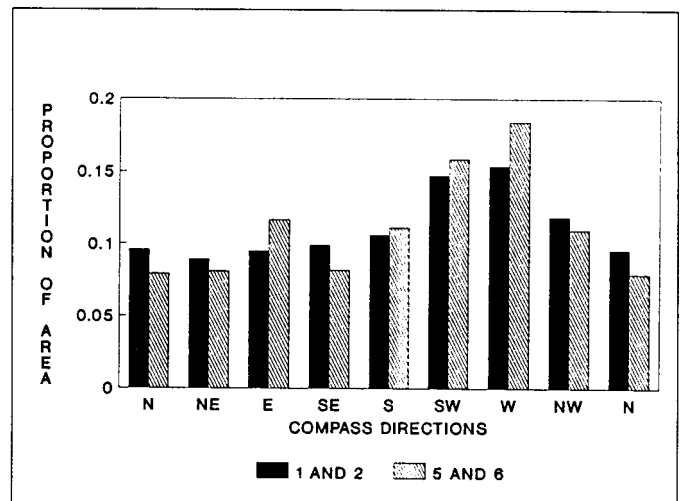


Figure 7—The proportion of coast live oak (*Quercus agrifolia*) dominated woodland area (category 1 and 2) and Engelmann oak (*Quercus engelmannii*) dominated woodland area (Category 5 and 6) among 45° compass divisions.

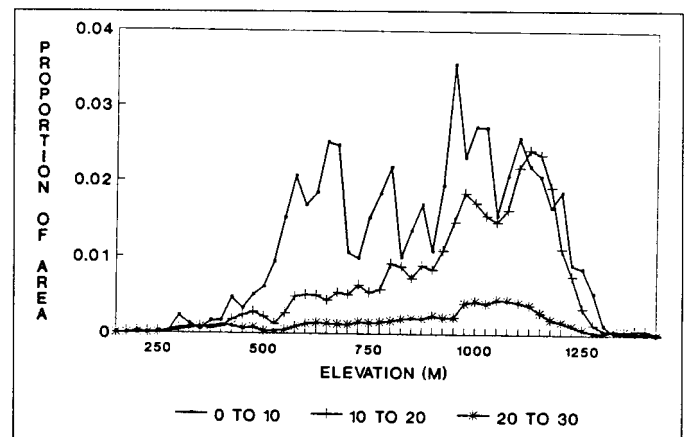


Figure 8—The elevational distribution of landscape area among slope categories: 0 to $\leq 10^\circ$ (•); $> 10^\circ$ to $\leq 20^\circ$ (+); and $> 20^\circ$ to $\leq 30^\circ$ (*). intervals and elevation.

Confounding Effect of Slope on Elevational and Aspect Data

The area within specific slope categories was not evenly distributed across elevational categories. A recalculation of elevation distribution, corrected for slope area within each elevation category (figure 8), suggests that variable pattern in elevation may be attributable in part to the availability of 0° to 10° slopes (figure 9). No differences were found when the aspect analysis was run on data grouped by slope category: aspect distributions were not significantly different among 10° slope intervals (0° to ≤10°; 10° to ≤20°; and 20° to ≤30°).

Aspect and Elevation

The distribution of woodlands among aspect categories showed no gradients across topographic elevation. Instead, the tendency of woodlands to occur on south facing slopes was relatively uniform from 50 m to 1250 m of elevation (figure 10), and did not vary significantly from what would be predicted by the elevational distribution of aspects in the landscape. This relationship did not change when the data was re-analyzed using only slopes greater than 10°.

Distribution Among Counties and Ownerships

Approximately 93.5 pct of Engelmann oak woodland areas occur in San Diego; approximately 6.0 pct occur in Riverside County and 0.4 pct occur in Orange County. The extant woodland areas in Los Angeles County account for less than 0.1 pct

of the species distribution. Less than 0.5 pct of Engelmann oak woodland areas occur in any incorporated cities (only Poway and Escondido).

The Cleveland National Forest controls the largest area of Engelmann oak woodlands (table 1). However, the largest proportion (57 pct) of the species distribution falls under the administration and land-use planning of the County of San Diego as private lands (including land grants). Approximately 60.5 pct of the Engelmann oak dominated woodlands (categories four, five, and six) are administered by the County, while the National Forest administers approximately 25.7 pct. The remaining lands are administered primarily by Native Americans (7.7 pct; Indian Reservations) and the U.S. Marine Corps (6.4 pct; Camp Pendleton).

The largest polygon areas occurred in category five woodlands on the National Forest (31.6 ± 139 ha) and category four woodlands on Land Grants (32 ± 99 ha). Category four woodlands were larger, on average, than category five woodlands in all land-use types except for the National Forest lands. Pure stands had the largest average area (12.9 ± 26 ha) on Land Grants.

DISCUSSION

Geographic Distribution

The area covered by Engelmann oaks is the smallest reported for any species of oak tree in California. The estimate of 15,000 ha (36,900 ac) is relatively close to Bolsinger's (1987) estimate of 39,000 ac of Engelmann oak woodlands; the 9 pct

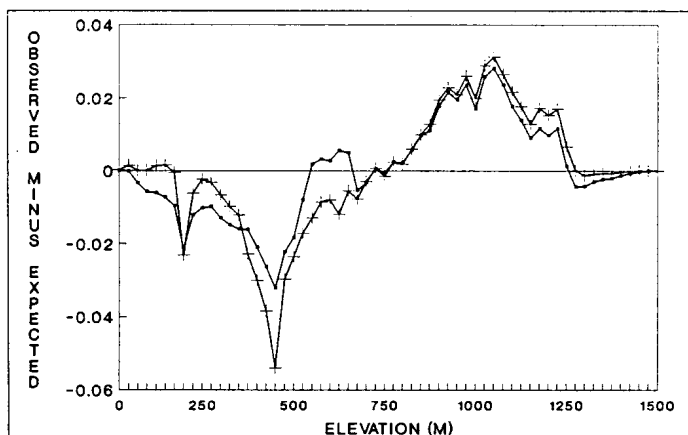


Figure 9—The difference between the distribution of Engelmann oak (*Quercus engelmannii*) woodlands and the distribution expected if these woodlands were randomly distributed across the landscape. The points (.) denote the distribution differences at 25 m elevation intervals; the crosses (+) denote the differences when the expected distribution is adjusted to include only areas with slopes < 10°.

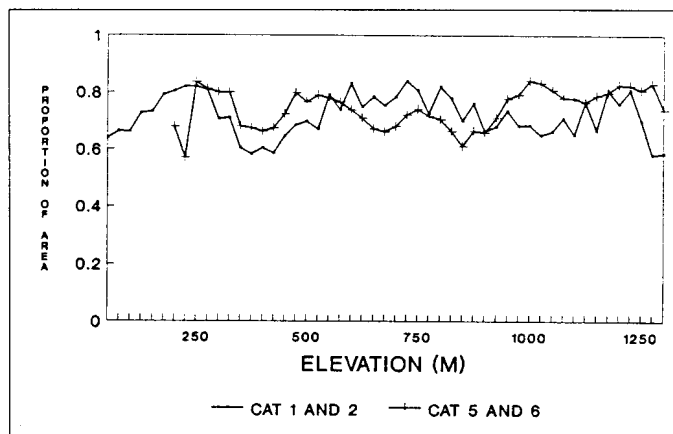


Figure 10—The proportion of oak woodland area on south facing (90° to 270° azimuth): coast live oak (*Quercus agrifolia*) dominated woodland area (category 1 and 2)(.); and Engelmann oak (*Quercus engelmannii*) dominated woodland area (Category 5 and 6) (+).

difference is attributable to methods used to divide Engelmann and live oak woodlands and to methods of mapping. The results of this study do not significantly alter his conclusions, but indicate a greater intergradation of Engelmann oak and live oak than could be detected at the statewide scale that Bolsinger was required to use.

Engelmann oak woodlands occupy a small portion of the overall range of the species; in general, stands are widely scattered and often small in area. The only regions where they contribute over 10 pct to vegetation cover-types are the Santa Rosa Plateau in Riverside County, and mountain region of San Diego County from Palomar Mountain to Cuyamaca Peak. A quarter of Engelmann oak woodland area occurs as linear or interdigitated woodlands. These areas, found on the western edge of the species distribution, are typically dominated by live oaks. The small average size of Engelmann oak woodlands, their scattered distribution, and the linearity of woodland polygons suggests that these stands are strongly effected by adjacent conditions and human activities, perhaps more so than the larger tracts of oak woodlands in western Sierra Nevada Mountains and central Coast Ranges.

Topographic Distribution

Engelmann oaks are most concentrated on low angle slopes, on southwestern aspects, and between elevations of 700 m and 1,250 m. While these data provide a general model of Engelmann oak occurrence, the variance in woodland distribution across elevation and aspect suggest other factors strongly influence the species distribution.

Engelmann oak woodlands occurred primarily in areas of less than 10° slope. Although Engelmann dominated woodlands tend to occur on steeper slopes than live oak dominated woodlands, the majority of both types of woodlands occur on slopes of less than 10°.

The upper elevational limit of Engelmann oak woodlands was far more abrupt than would have been predicted by the landscape. Temperature decreases (both average annual and daily minimum) and rainfall increases (annual precipitation) are the primary climatic condition associated with elevational increase in southern California mountains (Major 1988); it appears that 1275 m of altitude produces low enough temperatures to severely reduce Engelmann oak establishment and persistence.

The lower elevational limit of Engelmann oak distribution is far less abrupt, but appears to be tied to precipitation. A comparison of woodland occurrence to estimates of rainfall distribution (California Department of Water Resources, 1980) suggests that Engelmann oaks are concentrated in areas with over 45 cm (18 in) of annual precipitation and are nearly absent from areas with less than 35 cm (14 in). Rainfall in the region is controlled in part by orographic conditions (unpublished data³).

It appears that the elevations where rainfall typically exceeds 35 cm (350 m) approximate the elevations where Engelmann oak concentrations occur (400 m). The two depressions located in the lower elevations of figure 9 represent large areas of valley where rain shadows may alter precipitation more than elevation (Major 1988).

Engelmann oak woodlands showed a slight tendency to occur on south facing slopes through its elevational range, in part reflecting the slightly southern orientation of aspects across the landscape. The data indicates that Engelmann oak woodlands were not concentrated on either south-facing slopes at high elevations or on north-facing slopes at lower elevations. It appears that either (1) the species tends to occur on south facing slopes; however, light and temperature are contributing rather than critical elevation factors in the species distribution; or (2) the low angle slopes do not provide sufficiently different light and temperature conditions to change the aspect distribution of Engelmann oak stands at high and low elevations.

Distribution of Woodlands Among Land-Use Types

The U.S. Forest Service has the largest tracts of Engelmann oak woodlands under one management, and provides the best opportunity for comprehensive planning for the conservation and management of the species. Land Grants, particularly those which have not been divided into subunits, provide the next largest group of undivided woodland areas. In some cases, these large tracts of lands will remain as buffers, separating Forest Service lands from urbanizing areas. In other cases, the pressures and incentives to develop large tracts of private lands suggests that some Engelmann oak woodlands may have to be protected through land purchase and donation to conservation agencies.

At present, very little of the distribution of the Engelmann oak is protected in parks or preserves. Cuyamaca Rancho State Park has approximately 0.1 pct of the species distribution. The Nature Conservancy and the County of Riverside are attempting to acquire the Santa Rosa Plateau, which contains approximately 5 pct of all Engelmann oak woodlands. U.S. Marine Corps and Native American lands provide de facto nature preserves because of their low levels of land development. However, these areas should not be considered as preserves because their charters and management goals do not necessarily protect woodlands.

The greatest challenge in Engelmann oak conservation occurs in the small parcels which share 36 pct of all Engelmann oak woodlands. Maintenance of community woodlands through the management actions of individual landowners will require a combination of education and creative policies by the counties of San Diego and Riverside. Most woodlands occur on slopes of less than 10°, and are likely to be developed as the population of southern California expands into foothill areas.

³Unpublished data on file, Geography Research Library, Department of Earth Sciences, University of California, Riverside, CA 92521.

ACKNOWLEDGMENTS

This work was funded by the Integrated Hardwood Range Management Program. Elaina Misquez and Arle Montalvo helped with the mapping; Barbara Pitzer helped with field surveys. Elaina Misquez created the GIS overlays; Keith Palmer, Jean Power, and Mathew Rossano helped to create the DEMs. Thomas Oberbauer let me use his vegetation maps of San Diego County as a starting point in woodland mapping. Thomas White provided Forest Service maps and photographs.

REFERENCES

- Anderson, G. 1969. Soil-vegetation and timber stand maps by the U.S. Forest Service. 1969. Berkeley, CA: California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; (FS 177A-3 to 190c-2).
- Bolsinger, C.L. 1987. Major findings of a statewide resource assessment in California. In: Proceedings on the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 291-297.
- California Department of Water Resources. 1980. California Rainfall Survey, 1849-1979. Sacramento, California.
- Crovello, T.J. 1981. Quantitative biogeography: an overview. *Taxon* 30(3): 563-575.
- Scott, T.A. 1990. Conserving California's rarest oak, *Quercus engelmannii*. *Fremontia* 18(3): 26-29.
- Major, J. 1988. California climate in relation to vegetation. In: Barbour, M.G.; Major, J. 1979. *Terrestrial vegetation of California*. New York: Wiley and Sons; 11-74.
- Wieslander, A.E.; Jensen, H.A. 1946. Forest area, timber volume, and vegetation types in California; Forest Service Release No. 4; Berkeley, CA: California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 66 p.