Development and Fire Trends in Oak Woodlands of the Northwestern Sierra Nevada Foothills[1]

James G. Spero[2]

Abstract

Human development appears to present a larger threat to the long-term persistence of California's hardwood rangelands than fire in terms of likely ecological significance. This paper describes of the California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) projections of human development and fire occurrence and explores trends in the incidence of fire and development on woodland areas historically dominated by oak species. Previous FRAP work on fire probability on about 3 million acres of private lands in the northwestern Sierra Nevada foothills provides a small-scale model of comparison for these forecasts. FRAP's methods combine historical (1950-1990) block group housing density estimates based on the 1990 Census with decadal housing projections (2000-2040) derived from Department of Finance county population projections. County housing projections are allocated to 9.6 square mile grid cells based on their share of county housing growth between 1980 and 1990. The primary purpose is to produce estimates with a low level of error in the acreage that is projected to attain at least a dispersed level of residential land use. Overlaying development projections on a 1945-vintage vegetation map yields tables of vegetated acres developed from 1950 to 2040. In this analysis, developed areas are defined as having reached a housing density of at least one house per 20 acres and presumed to present a potential for ecological impact. Current and future "footprints" of development within the study area are compared to the expected amount of fire over time to provide a context for evaluating the ecological significance of development and fire in hardwood ecosystems. By 2040, an estimated 507,000 acres (22 percent of the ~2.3 million acres of 1945-era oak woodland in the study area) will be developed. This regional rate of development is higher than for all oak woodlands statewide, which show 16 percent development by 2040. In the study area, hardwoods burned on the average ~0.5 percent per year where development density was less than one house per 20 acres. In areas of higher development density, the rate of burning was about 0.2 percent. An estimated 411,812 acres will burn in the 2000-2040 period. Driving this estimate are area characteristics, such as predominating vegetation life form and developed/undeveloped status. Plausible reasons for reduced fire occurrence in developed areas include quicker detection, more fire suppression resources, improved access and fire safe development, and modified vegetation composition and structure that lessens fire hazard. Assuming 30 percent and 5 percent net mortality from development and fire, respectively, FRAP researchers estimate that by 2040, about 80,000 acres (about 4 percent of the vegetation extant in 2000) might be lost due to development (about 60,000 acres from development, about 20,000 acres from fire). Long-term ecological impacts are perhaps more permanent with development than with fire, however, both fire suppression and land development policies will help shape the future of quickly developing

---

[1] An abbreviated version of this paper was presented at the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape, October 22-25, 2001, San Diego, California.

[2] Fire Economist, Fire and Resource Assessment Program, California Department of Forestry and Fire Protection, 1920 20th Street, Sacramento, CA 95814 (e-mail: james_spero@fire.ca.gov)

foothill ecosystems. This analysis is a work in progress by the author and FRAP. Conclusions, data, and discussion are those of the author and FRAP.

Introduction

The land use impacts of population growth affect a number of responsibilities of the California Department of Forestry and Fire Protection (CDF). Expanded residential use of wildland changes the fire protection needs in terms of public safety, assets at risk, patterns of fire ignitions, and the deployment of new state and local fire service resources. Expanded residential use within forest and woodland areas also affects a variety of resource management activities, such as forest management, prescribed burning, and other forms of vegetation management and watershed protection activities. Changing residential use patterns also change the overall stresses on many wildlife species that depend on a matrix of reserved, managed, and developed land and water areas; local definitions of important open space; local and regional tax bases, and other factors.

To effectively assess trends and potential responses, it is useful to have a systematic approach towards projecting land use impacts of population growth. To help envision these resource management challenges, FRAP applies methods pioneered by Tim Duane for the Sierra Nevada Ecosystem Project (Duane 1996) to map the progression of development (housing density) from 1940 to 1990 across the entire State of California. Overlaying FRAP's map on a circa-1945 vegetation map allows FRAP researchers to map and plot trends in 20th Century development within grassland, shrub land, woodland, and conifer ecosystems. To generate a future scenario FRAP researchers generalize the progression of development map to 5,000-meter square grid cells. This second map contains allocations of Department of Finance (DOF) projections that are based on within-county housing count changes over the 1980-1990 period.

Tables of vegetated area developed by decade from 1950 to 2040 are created by combining vegetation overlay results from both progression of development maps (after adjustments to remove bias introduced by the change in scale).

For this paper, FRAP staff extract data pertaining to hardwood woodland types and report historical and projected development trends (1950-2040) both statewide and on the private ownership lands in a northwestern portion of the Sierra Nevada foothills. In the Sierra Nevada microcosm, estimates of fire occurrence in developed and undeveloped areas have already been produced.

Wildfire's role in hardwood ecology is unclear. Blue oak (*Quercus douglasii*), the most abundant hardwood forest type in California, has sapling populations that may be insufficient to maintain current stand densities (Bolsinger 1988, Muick and Bartolome 1987, Swiecki 1999). Although many species of native California oaks are relatively fire resistant, either due to innate low fuel conditions or to vegetative adaptation, fire may not play as much of a role in regeneration as once thought, neither enabling nor preventing regeneration (Bartolome and others 2002, Lang 1988). However, frequent fires can compromise re-sprouting from saplings and seedling advance regeneration. According to Swiecki: "A combination of frequent fires and annual livestock grazing would…be a prescription for eliminating blue oak regeneration." Even though in the past 50 years the amount of wildfire in this study area has been moderated by fire suppression and other factors resulting from rural development, prudence dictates continued awareness and concern about wildfire as a potential threat to hardwood resources.

The relationship between human development and fire is also complex. More people can logically mean an increase in the potential for ignitions, but FRAP's fire analysis shows that fire frequency based on area burned is lower in developed areas surrounding undeveloped wildland areas. FRAP researchers believe this is due to fire suppression and other factors such as roads, irrigation, and vegetation modification, that are a result of human development.

For the Sierra-specific analysis FRAP researchers apply estimates of mean annual wildfire occurrence to both developed and non-developed hardwood lands to 2040. Calculated fire rotation periods (expressed as percent area burned per year) for landscapes stratified to reflect different combinations of vegetation types and developed/undeveloped status evolved from a 48-year history of wildfires (coupled with vegetation and housing density information). Potential changes to oak woodlands arising from development are then inferred.

Methods

The statewide historical "Progression of Development" map (*fig.1*) is a consistent picture of development trends across all of California, depicting the location of developed and mixed urban/wildland interface within U.S. Census (1990) "split" census Block Groups by decade over the period 1940-1990. A block group is a cluster of census blocks within a census tract and contain between 600 and 3,000 people, with an optimum size of 1,500 people. Block Groups may be split along city and other administrative boundaries. The source of the historical housing counts is data from the 1990 Census "long form" survey question "Year Structure Built" for which respondents indicated the decade in which their home was built. Homes demolished and not rebuilt prior to the Census are not reflected in these data; therefore, there is some underestimation of housing density in earlier decades. Because impacts on wildlife habitat due to fragmentation by roads and other artifacts of rural development can occur even if very little acreage is directly converted to urban land uses (McBride and others 1996, Saving and Greenwood 2002, Scott 2000), this study uses a housing density threshold of one house per 20 acres to encompass potentially impacted rural residential lands as well as more densely settled areas. Beyond this threshold are constraints on ecosystem management, increased chances for habitat degradation, and increases in the potential for housing and other asset losses due to wildfire.

To create a map of future housing density this study uses the Share method (Smith and others 2001), also called the apportionment method (Pittenger 1976, White 1954). First, census block group housing counts are averaged to a uniform 9.65 square mile (5,000 m by 5,000 m) grid and then countywide DOF growth projections are allocated in the same proportions as observed in existing data for the period 1980-1990. At the block group scale, this simple model does not work well in highly urbanized areas because it does not explain a variety of site-specific factors, such as constraints on land availability, changing conditions in the building market, and urban growth policies. The spatial re-sampling tends to average housing counts in very small (i.e., highly urbanized) block groups, reducing the decade-to-decade variability in the data, and prediction errors fall to acceptable levels. Moreover, the resulting map (8,405 cells) still has enough spatial resolution for analysis at bioregional scales.

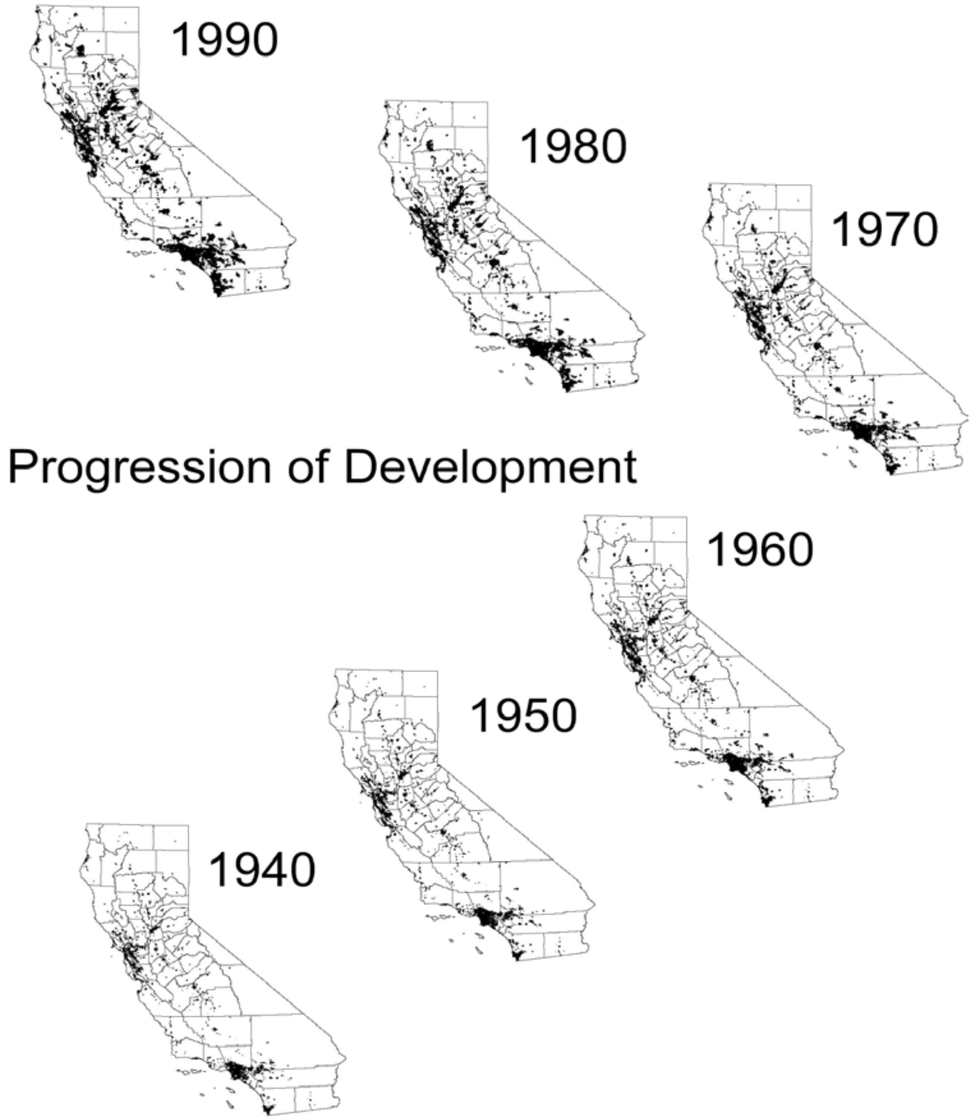

Figure 1—Maps of progression of development 1940-1990.

For the decades 2000, 2010, 2020, 2030, and 2040, this study converts DOF county population estimates to housing estimates using the 1990 countywide ratio of houses to people and apportions the new housing increments to each county's grid cells in the same proportions as in the 1980-1990 period. For example, to allocate projected county growth from 1990 to 2000 to a grid cell, this study multiplies that growth increment by the proportion of 1980-1990 growth captured by that grid cell (the growth factor), as in equation (1):

$$2000-1990i \approx \sum 2000-1990i \times \frac{1990-1980i}{\sum 1990-1980} \qquad (1)$$

The increment of growth in cell *i* during the decade 1990 to 2000 equals its historical expected share of county growth, i.e., the total county growth from 1990 to 2000 times the proportion of the 1980 to 1990 growth captured by cell *i*.

For example, if a grid cell that had 1,000 houses in 1990 had captured 0.25 percent of the 1980-1990 county growth, and the DOF-based projection for that county for 1990-2000 was 100,000 houses, then the year 2000 estimate for that grid cell would be 1,000+(0.0025*100,000)=1,250 houses.

To create the future housing density map (*fig. 2*) we apply 1980-1990 growth factors to DOF county growth expectations for between 2000 and 2010 and add the results to the cell's expected housing count for 2000. We repeat these steps iteratively for calculations of 2020, 2030, and 2040 housing counts always using the 1980-1990 growth factor.

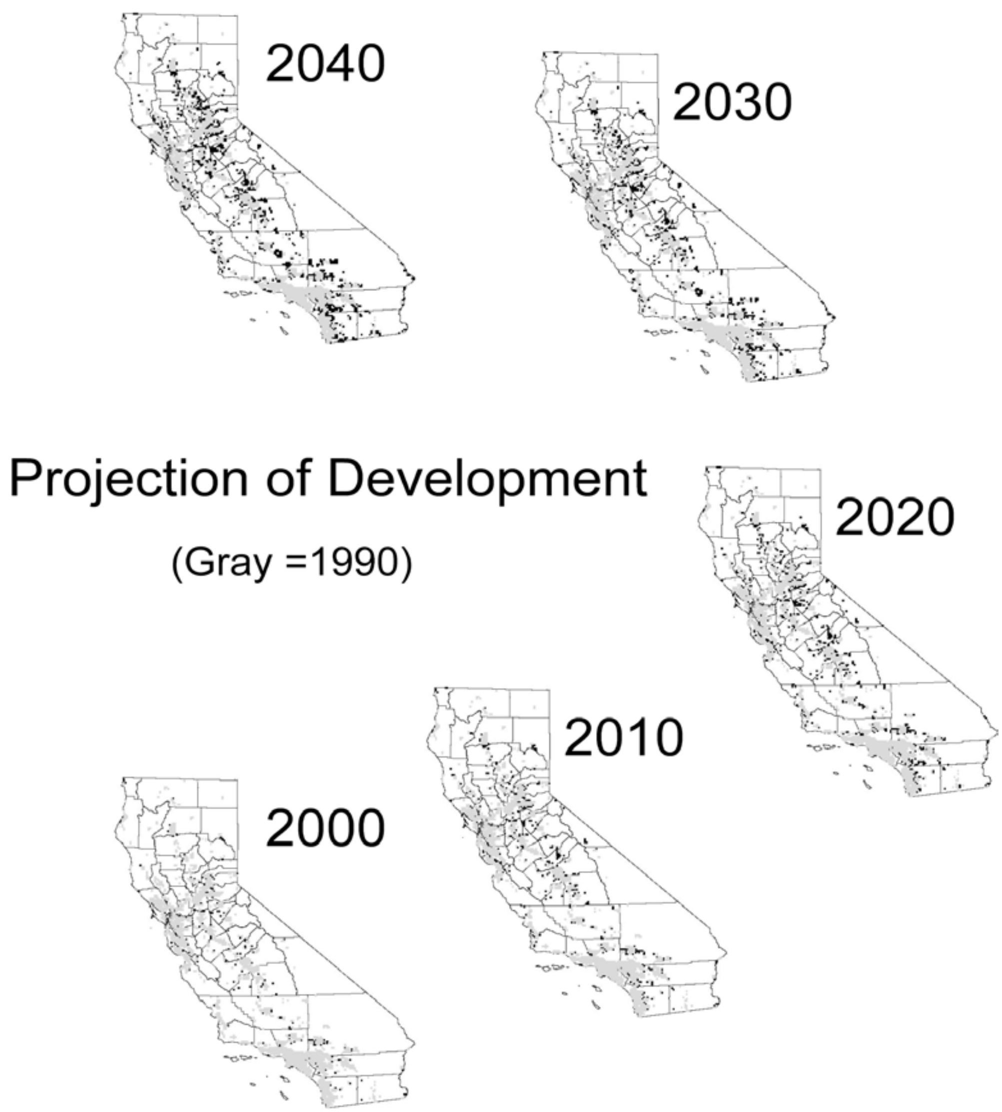

Figure 2—Maps of projection of development to 2040.

To test the accuracy of the growth factor variable, we implement the Share Model to split Block Group, Census Tract, and grid cell data using ordinary least squares regression techniques (*table 1*). The form of the model for creating a growth scenario for 1980 to 1990 (which is the most recent period that can be verified from the map data) is shown by equation (2):

$$1990-1980i \approx \sum 1990-1980i \times \frac{1980-1970i}{\sum 1980-1970} \quad (2)$$

Table 1—*Regression analysis results on fit of share model for predicting 1990 housing count.*

Map	R^2	P	N
Census Block Groups			
Original	0.17	<0.0001	27,146
Log Transform	0.44	<0.0001	
Census Tracts			
Original	0.32	<0.0001	9,218
Log Transform	0.71	<0.0001	
5000-meter Grid Cells			
Original	0.7	<0.0001	8,780
Log Transform	0.88	<0.0001	

Regressions compare the actual growth of housing from 1980 to 1990 in a map polygon or grid cell (the dependant variable) with housing counts calculated using the expected share as the independent variable. Because both dependant and independent variables are highly and positively skewed, FRAP researchers also examined logarithmic transformations.

Model fit (R^2) improves for tracts and 5,000-meter grid cells (*table 1*). In the non-log transformed grid cell model the expected share for 1990 explains 70 percent of the variation in actual housing increase in 1990. This result is quite adequate for the scale of analyses envisioned. The significant P values are not surprising because the coefficients measure the entire population (Studenmund and Cassidy 1987). These statistics indicate that areas with higher proportions of growth in the 1970-1980 period show greater absolute growth in the period 1980-1990. We could have also shown that the process is consistent when using different sets of decadal data. For example, 1970s growth is predicted by 1960s share; 1960s growth by 1950s share, and so on. Thus, the 1990 results are consistent with a general pattern in the data over time.

A histogram comparing actual and modeled data by housing density class shows a close correspondence (*fig. 3*). The classes, numbered 1-8 correspond to housing density ranges as follows: (1) Less than 1 housing unit per 160 acres, (2) 1/160 to

1/40 acres, (3) >1/40 to 1/20 acres, (4) >1/20 to 1/10 acres, (5) >1/10 to 1/5 acres, (6) >1/5 to 1 per acre, (7) >1 per acre to 5 per acre, (8) Greater than 5 per acre.

Figure 3—Frequency of grid cell counts (actual, predicted housing density class).

The Share Model is limited to areas with at least some history of growth; hence it does not predict the emergence of new growth centers. That is, grid cells with no growth from 1980-1990 will continue to remain static through time. FRAP researchers are considering how this model might be used in combination with a more detailed urban growth models such as CUF-II (Landis 1995), which reflect underlying development probability but are difficult to calibrate for rural areas.

By overlaying a vegetation map (Pacific Forest Trust 1997) that shows the location of forests, rangelands, and agricultural areas shortly after World War II on the progression of development maps, the area of each vegetation type falling under the footprint of development over time is estimated. The vegetation base map is from the Vegetation Type Map (VTM) Survey, conducted between 1929 and 1934 by the U.S. Forest and Range Experiment Station, Berkeley and updated in 1945. We call this map “Weislander” after A. E. Weislander, the Survey's director. The original Weislander maps were at a scale of approximately 1:64000. The four broad vegetation classifications—forest, range, agriculture, and barren—reflect the historical perspective towards potential land uses. *Figure 4* shows the Weislander vegetation classification Woodland-grass with the Sierra Bioregion and northwestern Sierra Nevada fire study area boundaries.

Because the Weislander vegetation map did not exclude urban areas (for example, the Weislander “Agriculture” label includes Urban and Industrial land uses) FRAP researchers subtract acres under the 1940-development footprint (at 1 house per 20 acres for consistency) to leave a base map of circa-1940 vegetation. Two Weislander overlays are needed to produce tables of 1945-era vegetation developed by decade: one using census block groups and the other using the 5,000-meter grid.

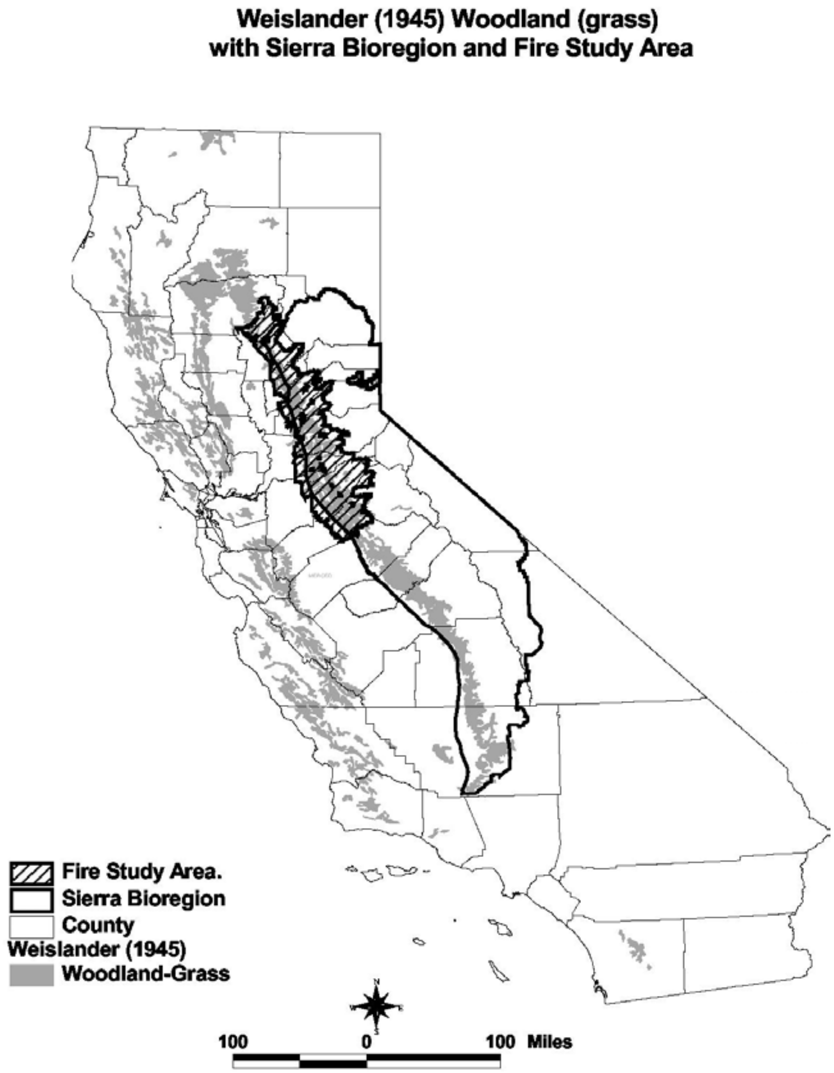

Figure 4—Map of Weislander Woodland-Grass vegetation, Sierra Bioregion, fire study area.

In constructing tables of development over time, the census block group/vegetation overlay provides the data for 1950 through 1990 while decades 2000 through 2040 are based on the 5,000-meter grid/vegetation overlay, with a calibration adjustment to correct for bias due to the change in scale. As mentioned earlier, the need for two different overlays arises because the two maps yield different results due to the effects of averaging. For example, the number of developed acres in 1990 (and earlier decades) differs between the two maps because small areas of high housing density measured at the block group level result in a developed label being placed on a grid cell of greater size. To deflate the grid-based results, we use a multiplier based on the ratio between the developed acres totals from the two maps for 1990. This multiplier adjusts developed acres for 2000, 2010, 2020, 2030, and 2040 and makes the grid-based results consistent with the 1990 and earlier data.

Intuitively, population gains mean that the agents of human-caused fires are more numerous, and it is logical to consider the possibility of an increase in the potential for more wildfire ignitions. The actual amount of fire depends on many factors such as weather, vegetation characteristics and conditions, topography, criminal activity (arson), and fire suppression. While infrequent "large" fires account for most of the area burned by wildfire (Strauss and others 1989, California Department of Forestry and Fire Protection 2000) most fires are stopped before they can become large and damaging. According to the CDF's Wildfire Activity Statistics for 2000, 26 fires listed as "large and damaging" burned 216,157 acres, or 73 percent of the total of 295,026 acres burned by 9,685 wildfires in all California wildland fire jurisdictions. The 26 fires represent a mere 0.3 percent of the total number of fires.

Our analysis of wildfire perimeter data on private ownership lands in the foothill areas of the Northwestern Sierra Nevada was needed to provide fire occurrence inputs for a model of fire effects on houses in El Dorado County (Greenwood 1999). In that model, the annual probability of burning an acre in a large fire is multiplied by the conditional probability of house loss and by the number of houses to produce estimates of expected house loss.

Available fire risk probability models produced for the Sierra Nevada Ecosystem (McKelvey and Busse 1996) were not designed for analysis of the predominantly lower elevations more characteristic of private lands. Therefore, FRAP researchers calculated mean annual fire rotation for various combinations of vegetation type (measured at the life-form level—conifer, mixed hardwood/conifer, hardwood, shrub, grass) and development status (developed – at least one house per 20 acres, undeveloped – less than one house per 20 acres). Results suggest that that wildfire protection and other factors have made a difference in fire occurrence rates in developed areas as compared to non-developed areas.

Computation of fire probability involves querying landscape attributes, linking burned areas to both a vegetation type and historical (decadal) housing density class consistent with the date of the fire (*table 2*). Earlier, FRAP used a related approach to map large fire probability in the Sierra Nevada bioregion (Sapsis and others 1996). For this analysis, however, FRAP researchers created landscape "strata" using FRAP's Arc/Info Geographic Information System (GIS)—polygons produced from the intersected boundaries of Widllife Habitat Relationships (WHR) vegetation data, census split Block Groups labeled with housing density for each decade from 1940 to 1990, and historical fire perimeters for the period 1950-1997. Most of the woodland vegetation data used in this analysis comes from 1997 imagery mapped by Pacific Meridian Resources (PMR) under contract with CDF and the USDA Forest Service. The fire perimeter data are for fires that burned at least 300 acres. Only areas that actually burned within the study area are calculated.

Table 2—*Housing density year to fire start year crosswalk.*

Fire year	Housing density year
1950-54	1950
1955-64	1960
1965-74	1970
1975-84	1980
1985-97	1990

Average fire probability for each stratum was calculated by computing the fire rotation period (FR). FR is the number of years required to burn an area equivalent to the size of that stratum. To calculate the FR, divide the average annual acres burned in stratum i into the total number of acres in the stratum, as shown in equation (3).

$$\text{FR (years)} = \text{Total Area of Stratum/Average Annual Acres Burned} \quad (3)$$

The reciprocal of FR (1/FR) is the average probability of an acre burning in any year, referred to henceforth as p(burn). Multiplying an area's size in acres by its p(burn) gives the average annual number of acres burned.

Results—Statewide, Northwestern Sierran Foothills

Development Trends

Since the 1940s, statewide development trends have shifted from a concentration on agricultural lands to rangelands and forests. Of the approximately 7.5 million acres of statewide private range classified as Woodland-Grass by Weislander (1945), 7 percent was developed at a density of one house per 20 acres or greater by 1990. By 2040, 16 percent of the 1945-era hardwood vegetation could experience this level of development (*fig. 5*). This net increase of 9 percent reflects acres newly developed.

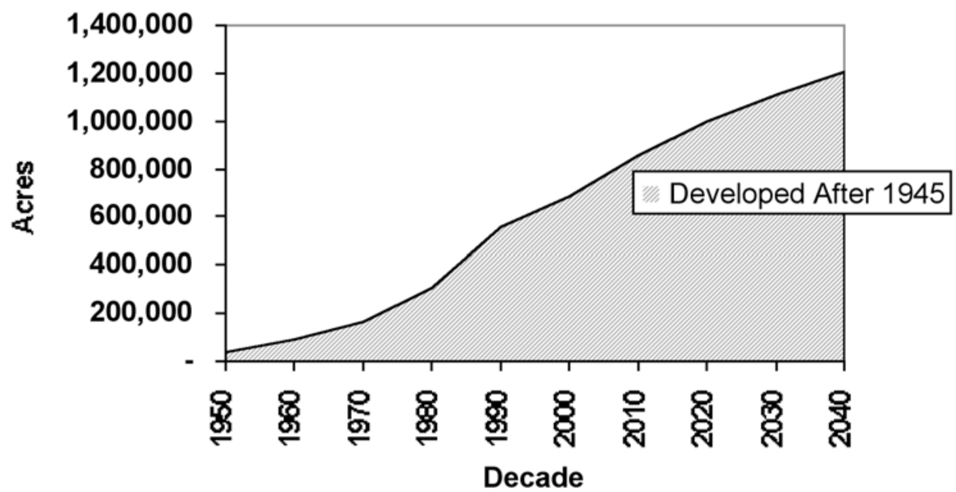

Figure 5—Development of private hardwood lands in California 1950-2040. In California, development will have occurred on 16 percent of the habitable 1945 Woodland-Grass land base by 2040. Undeveloped acres in 1945: 7,472,979.

These trends are more pronounced in the Northwestern Sierra foothills. The approximately 2.3 million acres of private land classified as Woodland-Grass by Weislander (1945), about 507,000 acres (22 percent) is expected to become developed by 2040 (*fig. 6*). Knowing that development is moving at a faster pace in the Sierra study area as compared to California hardwoods as a whole (a marginal increase of 6 percent) emphasizes heightened concern about impacts on important hardwood species.

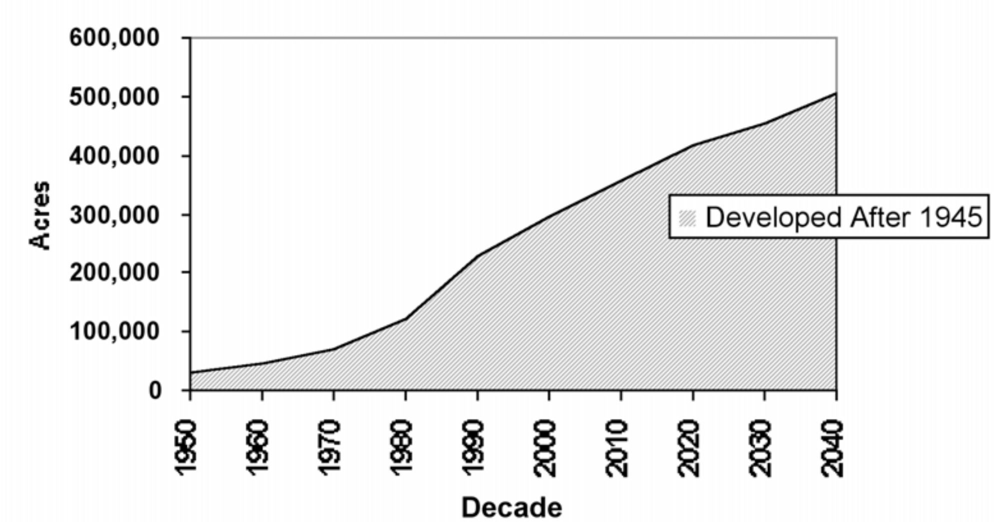

Figure 6—Development of private hardwood lands in the northwestern Sierra foothills fire study area 1950-2040. In the Sierra fire study area, development will have occurred on 22 percent of the habitable 1945 Woodland-Grass land base by 2040. Undeveloped acres in 1945: 2,287,753.

Fire Trends

Over the 48-year period from 1950 to 1997 a total of 529,824 acres burned in the roughly three million acre northwestern Sierra Nevada study area in all vegetation types (11,038 acres per year on the average or about 0.4 percent per year overall). Calculation from the Vegetation-only strata showed highest fire frequencies in the Shrub type (0.8 percent/year), followed by Hardwood and Grass (0.4 percent), Mixed Hardwood/Conifer (0.3 percent) and Conifer (0.1 percent). For Housing density-only strata, developed areas burned at 0.2 percent per year—half the 0.4 percent/year rate of burning in undeveloped areas. Combined, vegetation/housing density strata had substantially lower rates of burning in developed areas (with the exception of Conifer) than in undeveloped areas (*table 3*).

Table 3—*Fire rotation period (years) and annual wildfire probability [p(burn)] for vegetation strata by development status and overall.*

	Developed		Undeveloped		Any	
Vegetation type	**FR (yrs)**	**p(burn)**	**FR (yrs)**	**p(burn)**	**FR (yrs)**	**p(burn)**
Shrub	258	0.004	120	0.008	126	0.008
Hardwood	658	0.002	218	0.005	233	0.004
Grass	712	0.001	254	0.004	262	0.004
Mixed hardwood/conifer	802	0.001	312	0.003	333	0.003
Conifer	868	0.001	821	0.001	825	0.001

In the combined Hardwood/Developed stratum, annual wildfire probability was measured at 0.002 (0.2 percent per year) while for Hardwood/Undeveloped stratum it was 0.005 (0.5 percent). A one-tailed t-test on annual acres burned per 1,000 acres in both strata was significant (T=–2.14, P=0.0174). Overall, 172,080 acres burned in the 1950-1997 period.

Calculation of Weislander Woodland-grass acres burned in the 2000 to 2040 period (411,812) shows a decline over time. The number of acres in each land class (developed, undeveloped) is multiplied by its respective annual probability of burning and the products are summed (*table 4*).

Table 4—*Calculated burned area 2000-2040 for Sierra study area*

	Acres of woodland (grass)		x	p (burn)	= Burned area	
Year	Developed	Undeveloped	Dev (0.002)	Undev (0.005)	Per year	Decade
2000-10	294,591	1,993,163	589	9,966	10,555	105,550
2010-20	356,610	1,931,143	713	9,656	10,369	103,689
2020-30	418,629	1,869,124	837	9,346	10,183	101,829
2030-40	454,807	1,832,947	910	9,165	10,074	100,743
					Total area burned 2000-2040:	411,812
					40-year average:	10,295

Discussion

Future cumulative effects on habitat quality due to fire and development are difficult to predict. Because the predominant woodland species in this region (blue oak, interior live oak, canyon live oak) are all highly adapted to fire, development is much more likely to lead to persistent and cumulative impacts on oak woodlands. Urban development affects habitat adversely. Once you have smaller than 40-acre parcels with houses, driveways, fences, pets, etc., the chance of it functioning as habitat for a wide range of species diminishes rapidly (Shilling 2001).

Nevertheless, even low intensity fires can result in substantial oak woodland mortality. Swiecki and Bernhardt found that a relatively light grassfire that burned an oak stand in 1996 killed 6 percent of saplings and almost all saplings "less than 150 cm tall and/or with basal diameters of less than 5 cm were completely topkilled." They found that nearly a year after the fire, "post-fire shoot biomass was clearly much lower than prefire biomass for all but the smallest topkilled saplings" and also that "saplings were least likely to occur in plots that had experienced multiple fires over a five year period" (Swiecki and Bernhardt 1999). Long-term effects of fire on oak woodland persistence are still unknown, however.

The amount of fire is predicted to decline over time (*table 4*) due to increasing portions of land area reaching developed status and the associated lower fire occurrence rates for these areas. It is assumed that the relationship of ignitions, detection, and fire service response in the future will be similar to the historical period on which the fire occurrence study is based.

Only a fraction of all fires burn with enough intensity to kill trees, or to prevent regeneration (either alone or through interactions with post fire herbivory/grazing).

Nevertheless, hardwood mortality presumably negatively affects habitat quality for a variety of species. Assuming 5 percent net mortality from fire and 30 percent net mortality from development, losses from development (63,569 acres) would be more than three times the losses due to wildfire (20,590 acres) *(figs. 7 and 8)*. Is a total net loss of 84,160 acres of Sierran hardwoods ecologically important? After all, this is a mere 3.7 percent of the amount of total undeveloped 1945-era woodland (grass) remaining in 2000. We cannot offer prognostications of future vegetation spatial structures and patterns at a landscape scale to address such a question. A spatial simulation approach, in which both development and fire are treated as a vegetation disturbance regime, could very well shed some light. However, such analysis is beyond the scope of this paper.

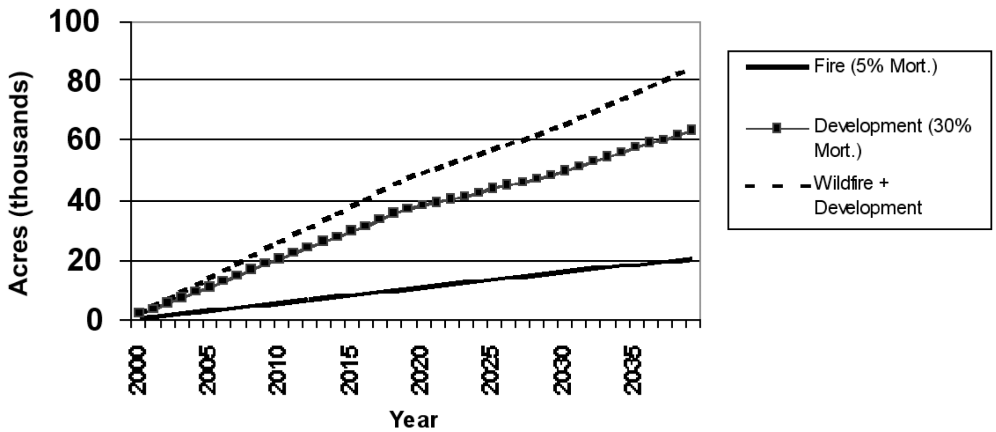

Figure 7—Potential acres of hardwood loss due to fire and development in the northwestern Sierra Nevada foothills 2000-2040.

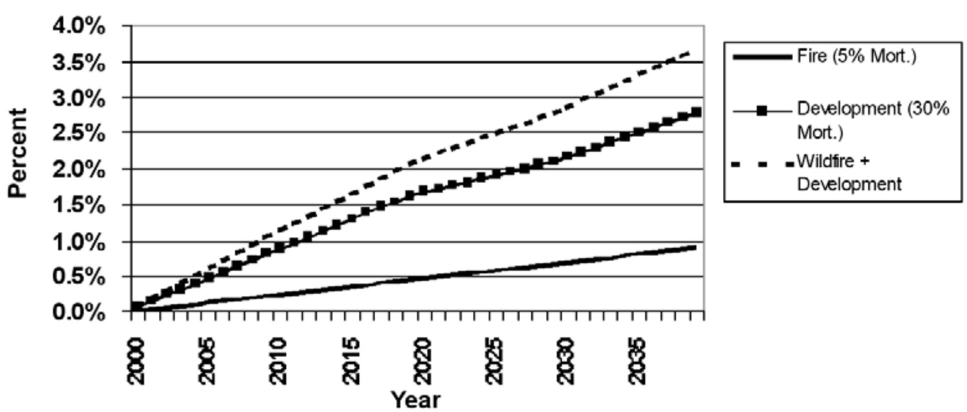

Figure 8—Potential percent hardwood loss due to fire and development in the northwestern Sierra Nevada foothills 2000-2040.

The advance of rural residential development is putting pressure on California's remaining hardwood resources, especially in the Sierra foothills. On these lands and perhaps elsewhere, development itself likely overshadows fire as an agent of impact and change within the dominant hardwood communities. These findings underscore both the need for thoughtful land development planning policies and practices at the local level, and the need to keep pace with development by meeting growing needs for fire prevention and suppression services.

References

Bartolome, J.W.; McClaran, M.P.; Allen-Diaz B.H.; Dunne, J.; Ford, L.D.; Standiford, R.B.; McDougald, N.K.; Fornero, L.C. [In press]. **Effects of fire and browsing on regeneration of blue oak.**

Bolsinger, C. 1988. **The hardwoods of California's timberlands, woodlands, and savannas.** Res. Bulletin. PNW-RB-148. Portland, OR: Pacific Northwest Research Station, Forest Service, U.S. Department of Agriculture; 148 p.

California Department of Forestry and Fire Protection. 2000. **Wildfire activity statistics**. Sacramento, CA.

Duane, Timothy P. 1996. **Human settlement, 1850-2040.** In: Sierra Nevada ecosystem project: final report to Congress, vol. II, assessments and scientific basis for management options. Davis, CA: Centers for Water and Wildland Resources, University of California, Davis; 235-360

Greenwood, G. 1999. **How will buildout affect wildfire losses in El Dorado County?** A Slide Presentation. Website Address: http://frap.cdf.ca.gov/projects/eldo_buildout /powerpoint/index.html.

Landis, J.D. 1995**. Imagining land use futures: applying the California futures model**. Journal of the American Planning Association 61: 438-457.

Lang, F. Jordan. 1988. **Oak regeneration assessment—a problem analysis**. (JSA 86-72.) Sacramento, CA: Jones & Stokes Associates, Inc. Prepared for: California Department of Forestry and Fire Protection, Forest and Rangeland Resources Assessment Program; 75 p.

McBride, J.R., Russell, W.; Kloss S. 1996. **Impact of human settlement on forest composition and structure.** In: Sierra Nevada ecosystem project: final report to Congress, vol. II, assessments and scientific basis for management options. Davis, CA: Centers for Water and Wildland Resources, University of California, Davis; 1193-1202.

McKelvey, K.S.; Busse, K.K. 1966**. Twentieth-century fire patterns on forest service lands.** In: Sierra Nevada ecosystem project: final report to Congress, vol. II, assessments and scientific basis for management options. Davis, CA: Centers for Water and Wildland Resources, University of California, Davis; 1119-1138.

Muick, P.C.; Bartolome, J.R. 1987. **An assessment of natural regeneration of oaks in California**. Prepared for: California Department of Forestry, Sacramento, CA; 126 p.

Pacific Forest Trust. 1997. **Weislander vegetation of 1945**. Arc/Info polygon coverage. Sacramento, CA: California Department of Forestry and Fire Protection.

Pittenger, D. 1976. **Projecting state and local populations**. Cambridge, MA: Ballinger.

Sapsis, D.; Bahro, B.; Spero, J.; Gabriel, J.; Jones, R.; Greenwood, G. 1996. **An assessment of current risks, fuels, and potential fire behavior in the Sierra Nevada**. In: Sierra Nevada ecosystem project: final report to Congress, vol III, assessments, commissioned reports, and background information. Davis, CA: Centers for Water and Wildland Resources, University of California, Davis; 759-786.

Saving, S.; Greenwood, G. [In press]. **Potential impacts of development on wildlands in El Dorado County California**. Sacramento, CA: Department of Forestry and Fire Protection.

Scott, Tom. 2000. **The effects of development on oak woodland wildlife: fragmentation of woodland habitats.** IHRMP Oak Fact Sheet. Website Address: http://danr.ucop.edu/ihrmp/oak45.htm.

Shilling, Fraser. Department of Environmental Science and Policy, University of California, Davis. [Personal Communication with James G. Spero]. 18 July 2001.

Smith, S.K.; Tayman, J.; Swanson, D. 2001. **State and local population projections**. New York: Kluwer Academic/Plenum Publishers; 426 p.

Spero, James G. [In press]. **Comparison of areas burned in developed and wildland areas in the northwestern Sierra Nevada foothills vegetation—wildland/developed strata**. Sacramento, CA: California Department of Forestry and Fire Protection.

Strauss, D.L.; Bednar, L.; Mees, R. 1989. **Do one percent of forest fires cause ninety-nine percent of the damage?** Forest Science 35: 319-328.

Studenmund, A.H.; Cassidy, Henry J. 1987. **Using econometrics—a practical guide**. Canada: Little, Brown and Company; 440 p.

Swiecki, T. J.; Bernhardt, E. **Understanding blue oak regeneration**. Fremontia 26(1): 19-26.

White, H. 1954. **Empirical study of the accuracy of selected methods of projecting state population.** Journal of the American Statistical Association 49: 480-498.