Monitoring Land Cover Changes in California

California Land Cover Mapping and Monitoring Program

South Coast Project Area

Cycle II

July 2007

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Abstract

The California Land Cover Mapping and Monitoring Program (LCMMP) uses Landsat Thematic Mapper (TM) satellite imagery to map vegetation and land cover change within five-year time intervals. Monitoring data created by the LCMMP quantify changes in California's landscape and provide necessary information for regional assessment across jurisdictional boundaries. These data, developed at a low cost of approximately $0.01 per acre, provide consistent, high quality information to manage, assess and protect California's diverse vegetation resources. This data can inform mangers as to whether landscape management plans and policies are accomplishing their intended purposes. Land cover monitoring information is a key source of information for consultation when starting land management plan revision, preparing wildlife conservation assessments, and developing fire and vegetation policies.

This report focuses on land cover change from 1997 through 2005 in the South Coast project area, which is one of five project areas in the state. The South Coast area spans ~17 million acres and includes all or part of Los Angeles, Monterey, Kings, Kern, San Benito, San Luis Obispo, Riverside, Orange, Imperial, Ventura, San Bernardino, Riverside, San Diego and Santa Barbara counties. The project area extent encompasses the four southern California national forests, the Los Padres, Angeles, San Bernardino and Cleveland. This report assesses vegetation cover changes on 17 million acres within hardwood, conifer, shrub/chaparral and grass/forb vegetation types. Changes in vegetation cover are assigned to categorical increase and decrease classes while the causes of cover changes are determined by GIS analysis, resource professionals, aerial photography and ancillary data layers. Summary tables and maps provide numerical and graphical estimates of land cover change by lifeform type, Wildlife Habitat Relationships System (WHR) type, CALVEG type (Forest Service lands only), ownership and cause. For more information about the LCMMP, or to download data and maps, visit our web page at: http://www.fs.fed.us/r5/spf/fhp/fhm/landcover/.

EXECUTIVE SUMMARY

Conditions in the South Coast Project Area in the time period 1997 to 2002 resulted in a change in canopy cover over 1.4% or 236,000 acres. Decreases across vegetation types occured on approximately 193,000 acres or 1.1% of the project area, and increases on approximately 43,000 acres or 0.25% of the project area. Fire was the primary cause for change in vegetation cover. Development, pests, agricultural conversion and unidentified causes accounted for the remainder of the change detected.

Decrease in Vegetation Cover

- Decreases in conifer accounted for about 23,500 acres of the total decrease in vegetation within the project area.
- Decreases in vegetation cover affected approximately 29,000 acres and 115,000 acres of hardwood and shrub/chaparral, respectively.
- Fire was the primary cause of change in both the conifer and the hardwood vegetation types, affecting about 19,000 acres and 15,000 acres, respectively.
- There was no harvesting in the project area.

Increase in Vegetation Cover

- Increases in conifer accounted for approximately 600 acres of the total increase in vegetation in the project area.
- An increase in shrub/chaparral cover was detected on approximately 36,000 acres.
- Regrowth was the primary cause for increase in both conifer and shrub/chaparral types, affecting about 500 acres and 33,000 acres, respectively.

Conifer Highlights

- Decreases in conifer were present in every county analyzed.
- Increases in conifer were found in Los Angeles, Monterey, Riverside, San Bernardino, San Diego and San Luis Obispo counties.
- At the National Forest Level, the San Bernardino National Forest showed the most decrease in conifer, affecting approximately 12,500 acres.

National Forest Highlights

- Fire was the predominant cause of vegetation change on all forests, affecting approximately 76,600 acres.
- Regrowth of vegetation was most evident on the Los Padres National Forest. This was post-fire regeneration from fires that occurred from 1992-1996.
- An additional change detection for the San Bernardino National Forest detected 72,000 acres of vegetation cover decrease from 2003-2005 (21,000 acres of decrease in vegetation cover were detected from 1997-2002 on the San Bernardino).

INTRODUCTION

The California Land Cover Mapping and Monitoring Program (LCMMP) began as a collaboration between the USDA Forest Service-Forest Health Protection (FHP) and the California Department of Forestry and Fire Protection (CDF) staffs to create seamless vegetation monitoring data across all ownerships within the Forest and Rangelands of California (Figure 1). The vegetation change data is developed from Landsat Thematic Mapper (TM) with a revisitation schedule of five years. In addition to the land cover change data, cause of change is also determined through fieldwork, aerial photo interpretation and Geographic Information Systems (GIS) analyses. Monitoring data created by the LCMMP estimates changes in California's landscape and provide necessary information for regional assessment across jurisdictional boundaries. These data provide consistent land cover monitoring information to resource managers and analysts. Through monitoring using remote sensing and GIS technologies, agencies and counties have a way to assess and protect California's diverse vegetation resources at a low per acre cost (approximately 1 cent per acre).

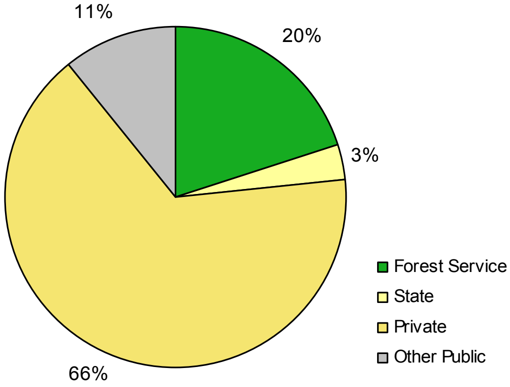
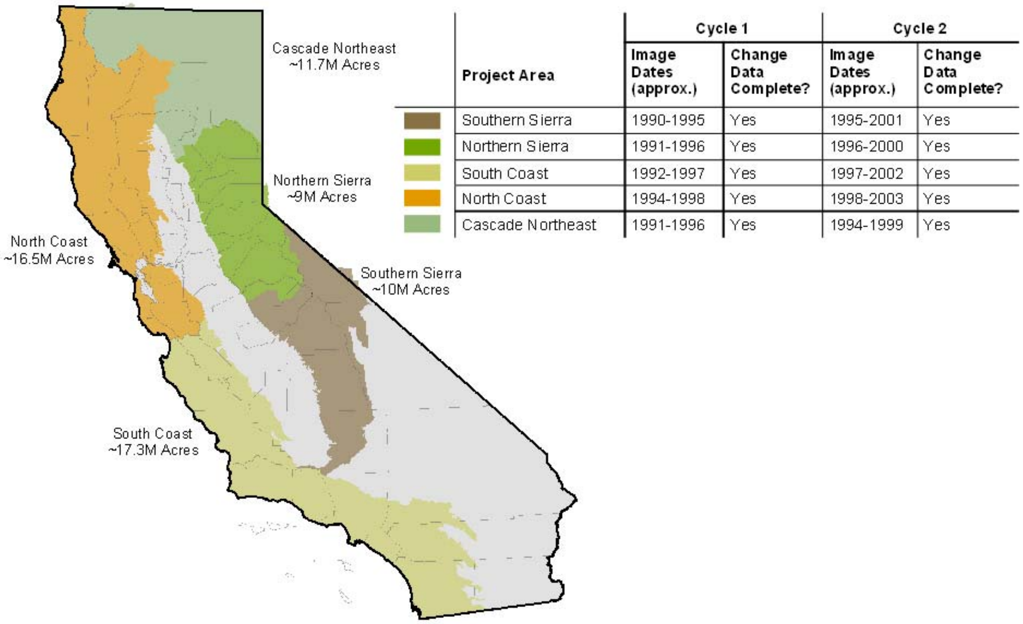


Figure 1. Land ownership distribution in the south coast project area.



		Cycle 1		Cycle 2	
	Project Area	Image Dates (approx.)	Change Data Complete?	Image Dates (approx.)	Change Data Complete?
🟫	Southern Sierra	1990-1995	Yes	1995-2001	Yes
🟩	Northern Sierra	1991-1996	Yes	1996-2000	Yes
🟨	South Coast	1992-1997	Yes	1997-2002	Yes
🟧	North Coast	1994-1998	Yes	1998-2003	Yes
🟩	Cascade Northeast	1991-1996	Yes	1994-1999	Yes

Figure 2. Location and extent of project areas with monitoring schedule.

Monitoring of land cover change occurs in one of five project areas (Figure 2). Analysis is complete for all project areas for two statewide cycles and three cycles for southern California. Land cover monitoring datasets and reports can be downloaded from the FHP web site at http://www.fs.fed.us/r5/spf/fhp/fhm/landcover/geodatabase.shtml.

The Forest Service (FS) manages most of the resource activities within the national forests, such as timber management, recreation, forest health programs, fire protection and grazing allotments. CDF is responsible for providing fire protection on most private and state lands, regulating timber harvests on private lands and monitoring resource conditions across all wildlands in the area. The LCMMP monitoring information provides a single consistent source of current landscape level and site-specific change to the FS and CDF as well as other federal agencies (e.g., Fish and Wildlife Service, National Park Service, Bureau of Land Management), state agencies (Fish and Game, Parks and Recreation, State Water Resources Control Board), county governments, city governments and other interested parties. The South Coast project area spans ~17 million acres, including large portions Los Angeles, Ventura, San Bernardino, Riverside, San Diego, Monterey, San Luis Obispo and Santa Barbara counties. The project area extent encompasses the four southern California National Forests, the Los Padres, Angeles, San Bernardino and Cleveland (Table 1). Other federal, state and privately owned lands that fall within the project area extent are assessed during all processing phases (Figure 3).

The South Coast project area spans ecoregion sections (the highest hierarchical unit at the subregion level) 261A, 261B, M262A and M262B (figure 3), covering an area of ~70188 km^2 (17,343,950 acres). The climate can be characterized as Mediterrenean with mild wet winters and dry summers. Mountain ranges (Transverse and Peninsular Ranges) and maritime influences shape the climate and plant distributions in these ecoregions, particularly in section 261B. Precipitation in this project area ranges from 6 to 40 inches. Drought years are not uncommon for southern California, particularly in the southern extents of 261B and M262B. Mean annual temperature ranges from 61 to 65 ^{o}F (16 to 18 ^{o}C). Summer daytime temperatures are often modified by morning fog and sea breezes. The growing season lasts 250 to 360 days.

Figure 3. SCCDP2 project area and ecoregion boundaries.

Natural Vegetation

Vegetation in the South Coast project area is dominated by mixed chaparral and coastal scrub communities. Chaparral and scrub communities are found at lower elevations (below 6,000 feet), while forested communities , which are typical of those found on drier sites of the Sierra Nevada, are found primarily at higher elevations above 6,000 feet. Dominant tree species of the forest communities include Bigcone Douglas-fir (*Pseudotsuga macrocarpa*), Jeffrey Pine (*Pinus jeffreyi*), Coulter Pine (*Pinus coulteri*), Singleleaf Pinyon Pine (*Pinus monophylla*), Western Juniper (*Juniperus occidentalis*), White Fir (*Abies concolor*), and Lodgepole Pine (*Pinus contorta*), and mixed hardwoods comprised predominately of oak species. Shrub communities are dominated by mixed chaparral and scrub species. Representative species include California sagebrush (*Artemesia californica*), Chamise (*Adenostoma fasciculatum*), Eastwood Manzanita (*Arctostaphylos glandulosa*) and Birch-leaf Mountain Mahogany (*Cercocarpus betuloides*).

Disturbance Regimes

Fire

Fire plays a significant role in the disturbance regime of the South Coast project area, with many plant species adapted to fire or dependent on fire for regeneration. Since the early 1900s, the natural fire regimes have been significantly altered through fire suppression and the subsequent changes in vegetation structure, resulting in an increase in ladder fuels and a higher risk of stand-replacing fires, especially in conifer forests. (Franklin et al. 2005). In some areas of the South Coast region, especially in the coastal scrub and lower elevation chaparral, fire frequency has increased, while the average size of fires has decreased (Franklin et al., 2005). This may be due to an increase in human-caused fires, especially at the expanding wildland-urban interface, where suppression efforts also keep the fires relatively small (Franklin et al., 2005). The increased fire frequency may also increase the likelihood of invasive grasses and forbs becoming established, altering fuels, which may in turn act to further increase fire frequency (Keeley, 2001).

Insects

Insects also play an important role in the disturbance regime. Historically, bark beetles have acted as disturbance agents throughout forests of California, playing an important role in forest succession and dynamics. Large outbreaks are known to have occurred prior to European settlement, but were constrained by a more heterogeneous landscape that limited the outbreaks' duration and area. Changes in the landscape, especially those caused by fire suppression, have created a more homogeneous forested landscape that contributes to larger outbreaks seen today. In 2003, severe tree mortality events caused by epidemic levels of *Dendroctonus, Scolytus and Ips* beetle species were exacerbated by prolonged drought, overly dense forests and stress from pollutants such as ozone**.** The outbreak affected over 500,000 acres in Southern California. Although average ozone concentrations in Southern California have declined from 350 ppb (parts per billion) in 1975 to below 100 ppb currently, ozone pollution still represents a significant threat to the region's forest health.

In order to identify and track mortality on and adjacent to the San Bernardino National Forest (BDF), change detection data from Cycle II (1997-2002) for the South Coast project area, change detection data from 2001-2003, and aerial survey data were combined to develop a cumulative mortality layer for the entire project area (CDF-FRAP, Ecosystem Planning and FHP cooperative study). The mortality layer was used to stratify plot location by level of mortality and vegetation type for re-measurement of the plots. Volume estimates were calculated for dead trees and used to aide CDF in prioritizing their resources for harvesting. Within the project extent, approximately 13% of all conifer trees died between 2001 and 2004. This estimate represents approximately 21% (~127 million cubic feet) of the total conifer forest biomass with larger trees (DBH $\geq$ 21 inches) accounting for about 80% of the total dead biomass.

The total volume loss for all tree species is estimated to be 137 million cubic feet. Plot re-measurement revealed that Coulter and Ponderosa pine (*Pinus coulteri and P. ponderosa*) were the most heavily impacted conifer species, particularly in size classes ≥ 21 inches DBH. For more information on this analysis, see http://www.fs.fed.us/r5/rsl/projects/inventory/invdata/socalmort. To further assess the impacts of the 2003 beetle outbreak, an additional change detection cycle was processed by FHP revealing a decrease in conifer canopy cover affecting over 20,000 acres between September 2003 and August 2005.

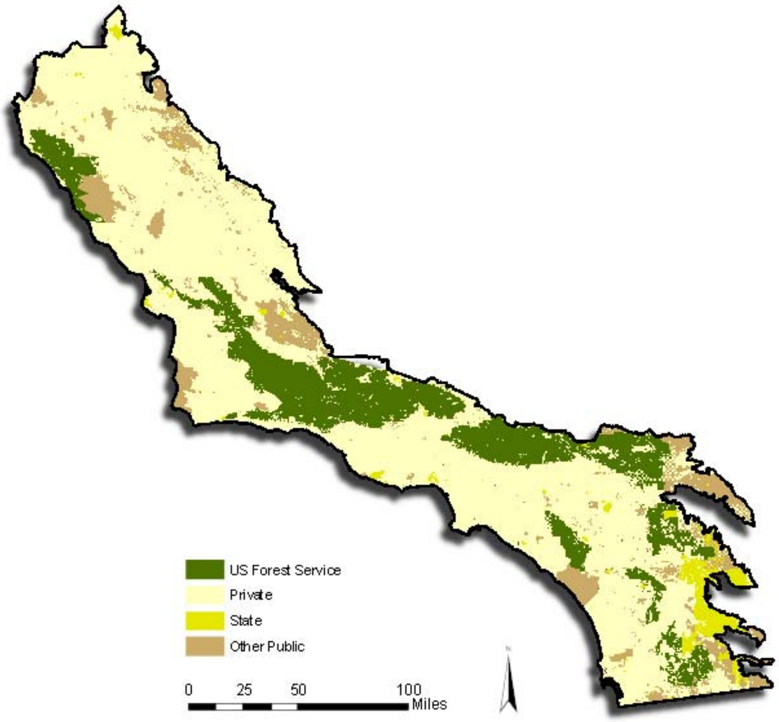


Figure 4. South Coast Project Area and corresponding land ownership.

Table 1. Acres of Each County Analyzed by Private and Public Ownership

County	Private	Public	Total Acres in County	% of County Analyzed
Imperial	13,204	78,766	2,868,483	3
Kern	916,617	384,468	5,223,231	25
Los Angeles	1,665,292	786,048	2,615,328	94
Monterey	1,412,994	604,469	2,120,174	95
Orange	398,210	76,921	511,480	93
Riverside	1,193,951	804,059	4,672,261	43
San Benito	687,187	131,120	889,395	92
San Bernardino	1,587,532	1,954,545	12,866,979	28
San Diego	1,299,393	1,142,517	2,712,246	90
San Luis Obispo	1,651,993	372,751	2,124,785	95
Santa Barbara	871,678	763,601	1,759,195	93
Ventura	577,636	601,074	1,188,255	99

CHANGE DETECTION MONITORING METHODS

Introduction

The Region 5 Land Cover Mapping and Monitoring Program (LCMMP) uses Landsat imagery (MSS, TM, and ETM+) and change detection techniques to assess changes in landcover over 5-year intervals. The change detection process relies on the difference in reflectance between the time 1 and time 2 image where landcover has changed during the time interval that the two images were collected. Processing for estimating canopy cover change is accomplished in five primary steps: image preprocessing, GIS database building, change detection processing, thresholding and labeling/editing (figure 4). These steps are followed by accuracy assessment, cause collection and field verification.

Pre-preprocessing

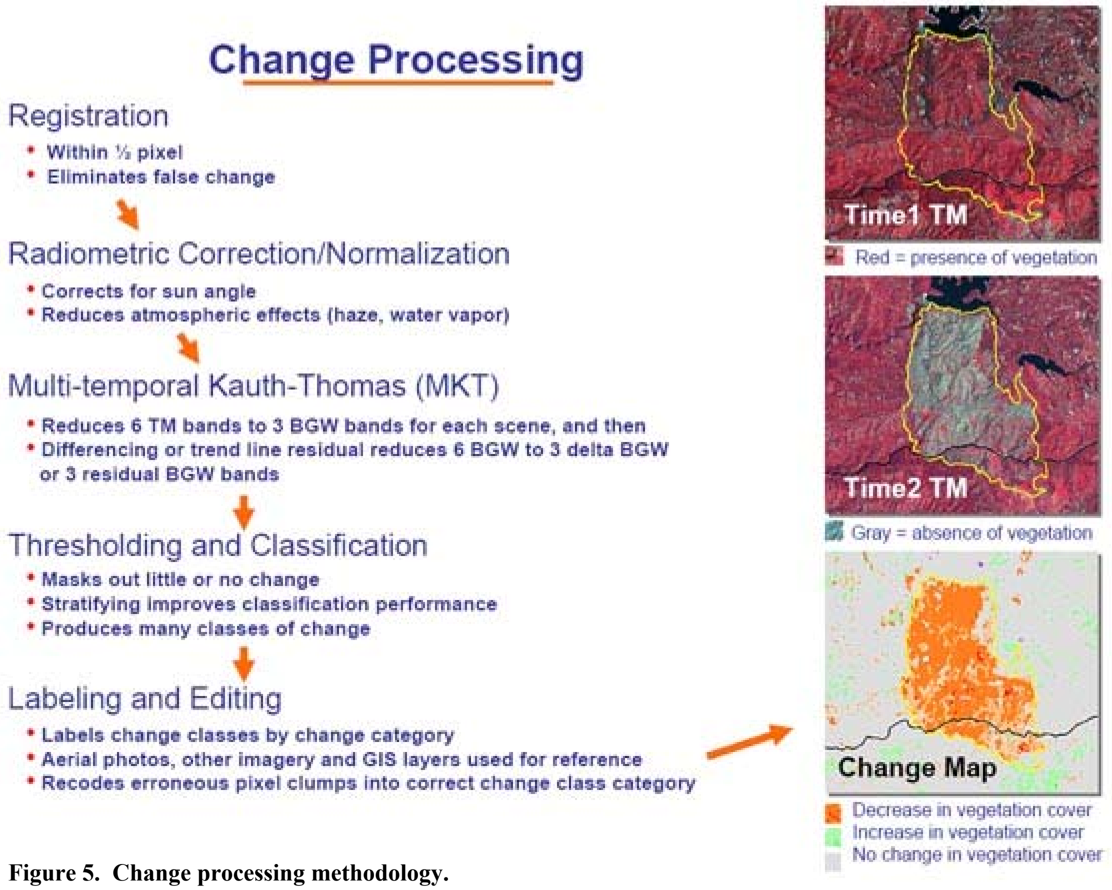
Terrain corrected image pairs are acquired and coregistered using a nearest neighbor resampling method to maintain the spectral information. A maximum RMSE of 0.5 pixels is required to minimize or eliminate false change. The image pairs are then radiometrically and atmospherically corrected to at-sensor reflectance. Lastly, the time 2 image is normalized to the time 1 image using an empirical line calibration approach (Schott et al., 1988).

GIS Database Building

GIS database building includes assembling data from multiple sources into a single vegetation layer. This process involves gathering data predominately from the Cooperative Vegetation Mapping Program (USDA-Forest Service, Region 5); however, data from the GAP Project and CDF are used for areas of Region 5 that have not been mapped by the Forest Service RSL. The WHR classification system is used for the final vegetation coverage. Vegetation layers not in this classification system, such as CALVEG (USDA-Forest Service Regional Ecology Group, 1981), are crosswalked to the WHR classification.

Change Detection Processing

Change detection processing begins by applying the Kauth-Thomas (KT) transformation to both dates of co-registered imagery (Kauth and Thomas, 1976). This transformation uses model coefficients to produce three orthogonal axes: brightness, greenness, and wetness (BGW) (Crist and Cicone, 1984). Brightness identifies variation in reflectance, greenness is related to the amount of green vegetation present in the pixel, and wetness correlates to canopy and soil moisture. The regression line between B, G, and W is computed and an image based on the residuals is used for developing thresholds (personal communication, Richard Walker, PhD.-California Department of Forestry and Fire Protection). Using the residuals image helps reduce some of the seasonal variation during the thresholding process.



Change Processing

Registration
- Within ½ pixel
- Eliminates false change

Radiometric Correction/Normalization
- Corrects for sun angle
- Reduces atmospheric effects (haze, water vapor)

Multi-temporal Kauth-Thomas (MKT)
- Reduces 6 TM bands to 3 BGW bands for each scene, and then
- Differencing or trend line residual reduces 6 BGW to 3 delta BGW or 3 residual BGW bands

Thresholding and Classification
- Masks out little or no change
- Stratifying improves classification performance
- Produces many classes of change

Labeling and Editing
- Labels change classes by change category
- Aerial photos, other imagery and GIS layers used for reference
- Recodes erroneous pixel clumps into correct change class category

Figure 5. Change processing methodology.

Thresholding, Stratification, and Classification
Thresholding of the BGW residuals is applied in a model to create a little or no change mask. Additionally, very bright features (e.g. snow, ice, rock, etc.), agricultural, urban, water, clouds, and smoke are masked out in both times. The non-masked areas are then subdivided or stratified. A model based on the BGW residuals and vegetation lifeform (e.g., conifer, hardwood and shrub) produces a GIS layer of potential increase or decrease of vegetation cover for each lifeform. An unsupervised and supervised classification is performed for each individual potential change-lifeform area resulting in pixel groups of similar levels of brightness, greenness and wetness resulting in a change image. These change images are mosaicked into one change image for the TM scene.

Change Labeling
Change labeling converts the change image to a change map that identifies decreases and increases in vegetation cover (see Change Classes section below). These groupings are assigned to one of nine change classes. Image appearance, photo interpretation, vegetation data, digital elevation models, bispectral plots (e.g., greenness vs. wetness) and other ancillary GIS layers aid in assigning the change classes. Refinement of the classes proceeds systematically across the entire project area.

Training and Accuracy
A stratified random sample of the change image is performed to measure selected points for quantifying canopy cover change. Digital orthophoto quads are used for the time 1 estimates and digital imagery is used for the time 2 estimates for canopy cover classification. The percent canopy estimates are then used

to label the classes into change categories. A portion of the randomly selected sites are used for accuracy assessment. An error matrix is constructed to assess the accuracy of the final classified change map.

Cause Collection

Once the final change map is complete, an attempt is made to verify cause on all change areas. Causes of change are verified through GIS analysis, fieldwork, photo interpretation and interpretation by land managers, landowners and other stakeholders. The GIS analysis uses the CDF forest practices database, FS stand record system, FACTS database and statewide fire history layer to attribute changes caused by harvests, regeneration and wildfires. Aerial detection survey data (see http://www.fs.fed.us/r5/spf/fhp/fhm/aerial/index.shtml) are also used to help identify pest-related changes. Areas without a causal agent identified become the focus of further field efforts and aerial photo interpretation. FS resource managers interpret change maps by applying local knowledge and fieldwork to identify sources of change on Forest Service lands. Similarly, University of California (UC) Integrated Hardwood Rangeland Management Program (IHRMP) personnel consult private landowners to verify causes of change in hardwood rangelands. Despite all of these efforts, complete cause verification is not always possible due to the large number of change areas, insufficient information and inaccessible lands (see Appendix B for more information on cause verification).

Field Verification

A portion of the randomly selected sites are set aside for field verification. Field crews run transects through the polygon of change and measure canopy cover with a densiometer. Canopy cover measurements are then compared against in-house estimates to calibrate the estimates from photo interpretation.

Vegetation Data

Existing vegetation (EVeg) data (USDA-FS Ecosystem Planning) are used to determine which lifeform types are experiencing changes in canopy cover. “Lifeforms” are general land cover categories, such as conifer and hardwood. The Wildlife Habitat Relationships System (WHR) and the Classification and Assessment of Visible Ecological Groupings system (CALVEG) are used to summarize change on the landscape (see Appendix A for more details on vegetation data).

Because many vegetation layers exist for different parts of the project area, the best available vegetation data are collected and combined into one seamless data layer. Vegetation layers not containing a WHR classification (Mayer and Laudenslayer, 1988) are given a WHR classification based on the information in that layer. LCMMP vegetation data are used for the entire project area, and contain lifeform, WHR and CALVEG type. See Appendix A for vegetation data sources.

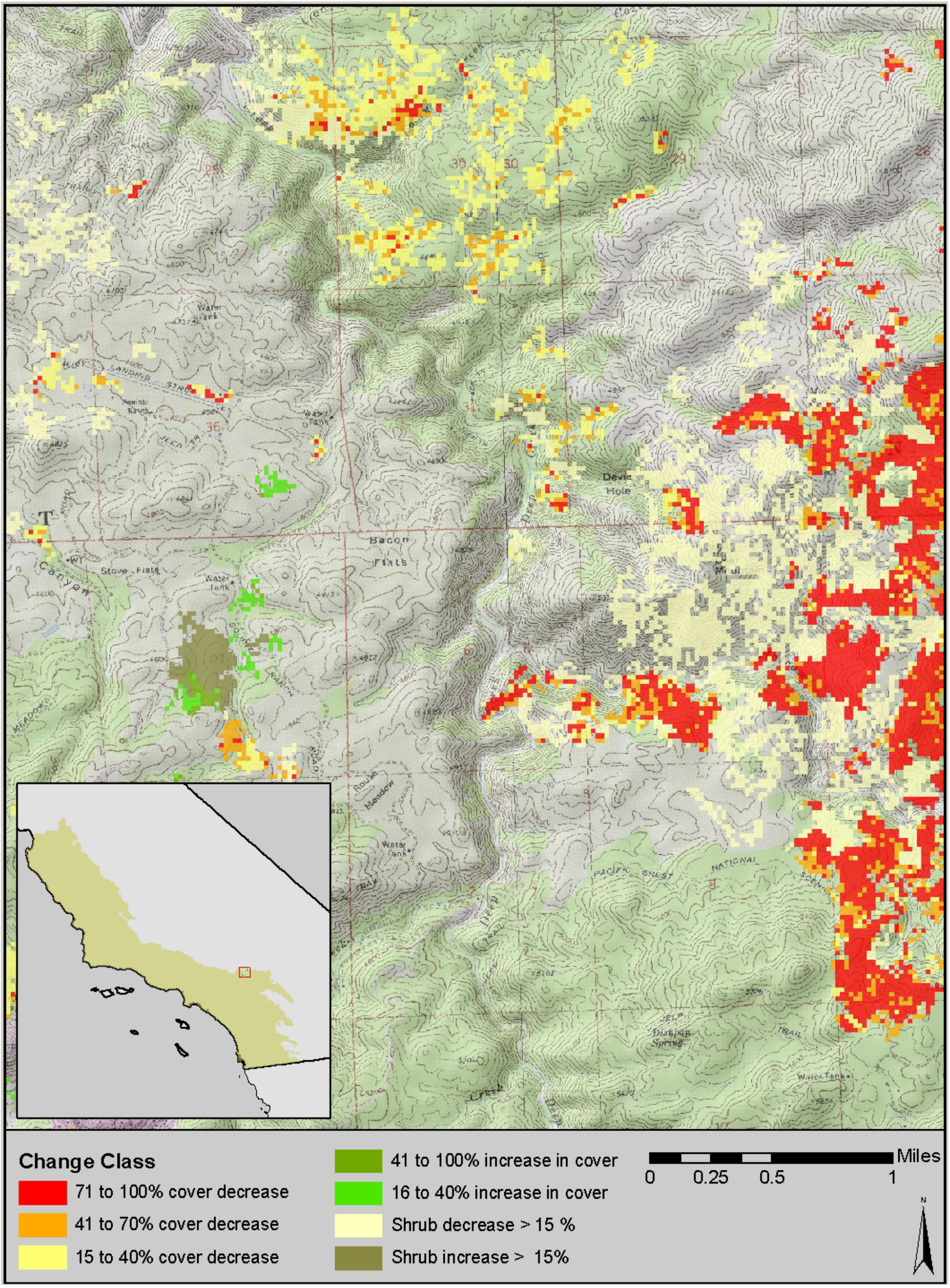


Figure 6. Portion of change map showing vegetation change in the South Coast study area, with inset locator map.

INTERPRETING RESULTS

Change Classes

Mapped vegetation change indicates areas that have undergone some form of vegetation decrease or increase between image dates (refer to Figure 1a in Appendix A for exact dates). For hardwood and conifer cover loss, change classes are broken down into three categories: -71 to -100% CC (71 to 100% decrease in canopy cover), -41 to -70% CC and -16 to -40% CC. For hardwood and conifer cover gain, change classes are broken down into two categories: +16 to +40% CC and +41 to +100% CC (figure 5). In the shrub/chaparral and grass/forb vegetation types, the change classes are quantified as a decrease or increase in vegetation cover of 16% or greater. The little to no change class indicates that change within the existing vegetation is either nonexistent or too subtle to detect. Table 2 describes the different change classes.

Multiple change classes are created to represent relative levels of canopy cover change (Table 2). In the text and tables of the main report, however, changes are generalized and denoted simply as an "increase" or "decrease" in canopy cover. To see details on each change class, see the tables in Appendix G.

Table 2. Change Classes and Corresponding Description

CHANGE CLASS	DESCRIPTION
-71 to -100% CC	71 to 100% decrease in cover
-41 to -70% CC	41 to 70% decrease in cover
-16 to -40% CC	16 to 40% decrease in cover
+15 to -15% CC (Little or No Change)	Little or no change in cover
+16 to +40% CC	16 to 40% increase in cover
+41 to +100% CC	41 to 100% increase in cover
Shrub/Grass Decrease > 15%	16 to 100% decrease in shrub and/or grass
Shrub/Grass Increase > 15%	16 to 100% increase in shrub and/or grass
Cloud or Cloud Shadow	Cloud or cloud shadow (prevents change assessment)

Change values are reported in two ways: by area, or acres of change, and by proportion. A particular value in acres, such as 15,000 acres, indicates that 15,000 acres have undergone a vegetation change of 16% or more. Proportion refers to the amount of land undergoing a change relative to the total area of that particular vegetation type. For example, if 1.3% of montane hardwood experienced a decrease in canopy cover, then 1.3% of the montane hardwood analyzed in the project area experienced a canopy cover change of 16% or more.

A detected vegetation cover increase, particularly a small increase, does not necessarily represent a gain in canopy or extent of a specific vegetation type. In some cases it represents understory regrowth or seasonal variation. The hardwood and shrub/chaparral types with low canopy cover are particularly sensitive to this phenomenon due to the presence of understory grasses and forbs within these types. Conversely, once vegetation fully covers a site, a change may not be detected even though biomass is increasing or stand structure is changing.

Results are particularly difficult to interpret for brushland types. Land uses that cause type conversion from brushlands (e.g., development) are most likely to result in detectable levels of vegetation change. Disturbances that do not result in type conversion (e.g., changes in grazing or low intensity fires) may escape detection. For example, figure 7 shows two fires that burned chaparral-dominated areas in 1997. The monitoring process detected change in the northernmost fire, but not in the southernmost, possibly because the area in the southernmost fire had burned and regrown prior to the second image date, causing the monitoring process to effectively "miss it" due to timing. Complex interactions between many factors such as site quality, vegetation composition and structure and fire intensity determine conditions at the two monitoring dates, and thus whether or not a change can be detected. Additional research is needed to explore potential improvements in the methodology for monitoring brushlands and changes due to seasonality.

Interpreting Cause

When interpreting results by cause, it is important to note that some ancillary data sources are more complete than others. Change caused by wildfire is verified using the FS and CDF perimeter data layer. Other sources of change are often more difficult to verify as data is unavailable and exhaustive fieldwork to identify all changes is impractical.

Cause is usually identified in three ways. First, ancillary data layers (e.g., FS plantation database, state fire history database, etc.) are used to identify cause. Second, regional experts familiar with a particular area are asked to identify causes of change. And lastly, photo interpretation is used to identify causes of vegetation change. Some error in cause attribution is expected as ground experts may make errors, ancillary data layers may not be perfect and photo interpreters may not be 100% correct.

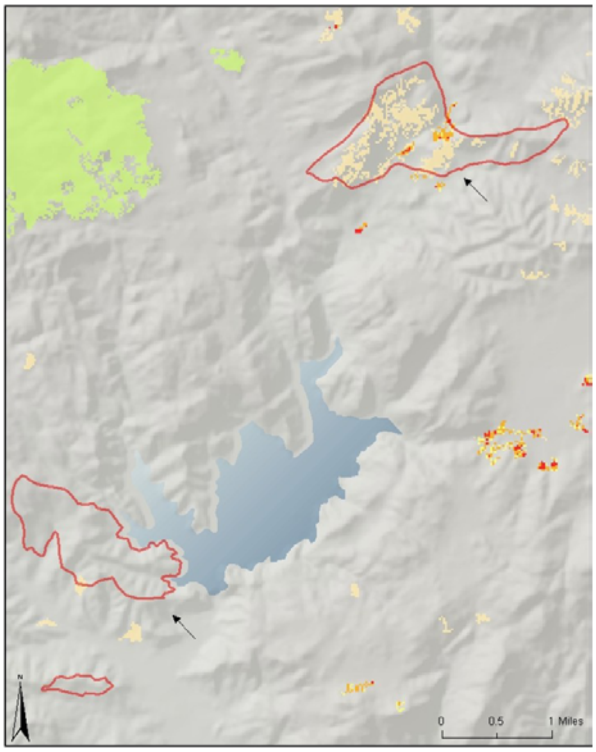


Figure 7. Comparison of two fires that burned in chaparral dominated areas.

Vegetation mapping errors may also contribute to change/cause combinations that seem unrealistic or inconsistent. This could be due to the attribution errors mentioned in the previous paragraph, or this could be due to errors in the input vegetation data. In this case, it is likely that harvest is the identified cause of change according to data layers or ground experts, but because the input vegetation shows the area as shrub/chaparral, the area is classified as a shrub/chaparral decrease due to harvest.

Many causes are extremely difficult to verify, particularly causes that affect only small areas, such as development. However, just because a particular cause may have little or no affected area, it does not necessarily follow that this cause was not important. The unverified cause acreage could belong to any of the categories mentioned in this report, such as harvest or development. But the unverified cause could also be due to other causal agents, such as landslides, local mortality or management activity; therefore, acres listed for the various causes represent a minimum acreage of change.

Calculating a "net" change by simply comparing acres of decrease and increase does not necessarily provide a full and accurate portrait of change. Vegetation decreases are usually quick and dramatic, such as those caused by fire, harvest, and development, while increases in vegetation are often more gradual (particularly for hardwood and conifer), and may not increase at the minimum change class of at least 16% during a five year period. A decrease in large trees or other mature vegetation types will be followed by decades of net regrowth, although only the first five to ten years will have sufficient change in cover to register as an increase. Some decreases in vegetation, such as development and conversion to agriculture, are permanent losses to that particular vegetation. Comparing vegetation that is permanently lost or removed to vegetation that has temporarily increased mixes two different processes.

RESULTS: ENTIRE PROJECT AREA

All Vegetation

Changes in vegetation cover in the South Coast project area affected all vegetation types and occurred on all ownerships across the region. Change occurred on approximately 237,000 acres within the South Coast project area, with most of this change occurring on land covered by shrub/chaparral vegetation, followed by grass/forb, hardwood and conifer. Across all cover types, vegetation loss was greater than growth. On national forest land, most of the change occurred on the Los Padres National Forest, in Monterey County.

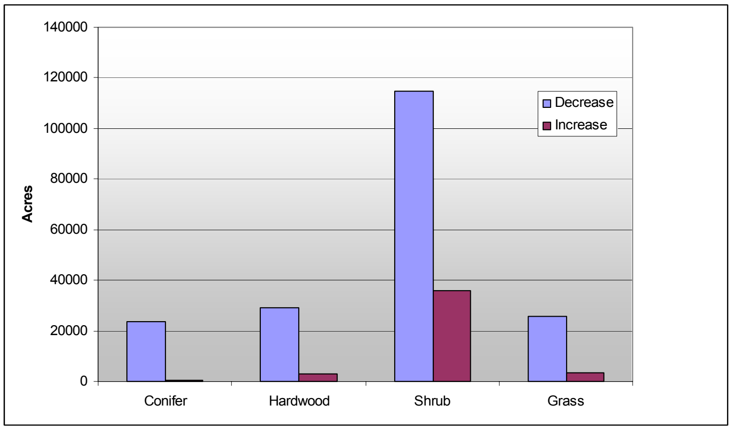


Figure 8. Acres of vegetation change by lifeform

Within areas where a cause of vegetation change was determined, fire was the primary agent of change, affecting approximately 115,000 acres, followed by vegetation regrowth (35,000 acres) (post-fire and harvest). Change due to development occurred on approximately 10,000 acres.

Conifers

The conifer lifeform encompasses about 1.2 million acres in the South Coast Project Area. The dominant WHR types are Jeffrey pine, montane hardwood-conifer, pinyon-juniper, and Sierran mixed conifer, which comprise about 91% of the area. Pinyon-juniper covers about 30% of the conifer area, while Sierran mixed conifer covers 26%, Jeffrey pine covers 21% and montane hardwood-conifer covers 14%. The remaining 9% of the conifer area is covered with ponderosa pine (5.1%), juniper (1.4%), redwood (0.9%), closed cone pine-cypress (0.8%), sub-alpine conifer (0.7%), Douglas fir (0.1%), and white fir (< 0.1%).

Canopy cover decrease occurred on approximately 23,500 acres, while increases in canopy cover were detected on only 600 acres. Within the conifer lifeform, the vegetation types that underwent the most change were pinyon-juniper and montane hardwood-conifer. Fire was the primary cause for the decreases in canopy cover (76% of the conifer change). Regrowth from post-fire regeneration was detected primarily on the montane hardwood-conifer WHR type (Table 4). These changes in conifer cover are similar to those found in the first cycle, though decreases in canopy cover were highest in the montane hardwood-conifer type in the first cycle. Overall, changes in conifer canopy cover were detected in roughly two percent of the total conifer area on the landscape.

Table 3. Acres of Conifer Change by WHR Type

WHR Type	Decrease	% total cover	Increase	% total cover	Total Change
Closed Cone Pine-cypress	1,992	13.3	58	0.4	2,050
Douglas Fir	4	0.4	0	0	4
Eastside Pine	1,776	3.9	4	0.01	1,780
Jeffrey Pine	488	0.6	12	0.01	499
Juniper	1,538	1.0	3	0.002	1,541
Montane Hardwood-Conifer	5,702	2.4	486	0.2	6,188
Pinyon-Juniper	10,486	2.6	27	0.007	10,513
Ponderosa Pine	87	1.4	1	0.02	88
Redwood	20	0.13	13	0.09	33
Sierran Mixed Conifer	1,396	0.79	2	0.001	1,399
White Fir	5	0.25	0	0	5
Total	**23,494**	**2.0**	**606**	**0.05**	**24,100**

Table 4. Acres of Conifer Change by Cause and WHR Type

WHR Type	Fire	Mortality	Regrowth	Other	No Cause Assessed	Total
Juniper	703	0	0	0	838	1,541
Closed Cone Pine-cypress	1,813	0	56	0	662	2,531
Douglas Fir	4	0	0	0	0	4
Eastside Pine	1,669	0	2	22	86	1,780
Jeffrey Pine	328	124	0	0	48	499
Montane Hardwood-Conifer	4,109	87	386	0	1,605	6,188
Pinyon-Juniper	8,801	0	6	0	1,706	10,513
Ponderosa Pine	76	0	1	0	11	88
Redwood	14	3	13	0	32	62
Sierran Mixed Conifer	1,108	31	0	0	259	1,399
White Fir	0	1	0	0	4	5
Total	**18,624**	**246**	**463**	**22**	**5253**	**24,610**

Most of the change in canopy cover in the conifer lifeform occurred in San Bernardino County, accounting for over half of the conifer canopy cover decrease. The greatest amount of increase in conifer canopy cover was detected in Monterey County (Table 5).

Table 5. Acres of Conifer Change by County

County	Decrease	% total cover	Increase	% total cover	Total
Kern	8	0.001	0	0	8
Los Angeles	1,651	0.15	10	0.00	1,662
Monterey	1,357	0.12	362	0.03	1,718
Orange	298	0.03	0	0	298
Riverside	2,253	0.20	7	0.00	2,260
San Benito	0	0	0	0	0
San Bernardino	13,236	1.18	75	0.01	13,310
San Diego	2,867	0.25	151	0.01	3,018
San Luis Obispo	3	0.00	0	0	3
Santa Barbara	409	0.04	0	0	409
Ventura	1,412	0.13	0	0	1,412
Total	**23,494**	**2.0**	**606**	**0.05**	**24,100**

Where cause was determined, fire was the primary agent of change in all counties. Mortality was detected in only three counties (Monterey, Riverside and San Diego) (Table 6).

Table 6. Acres of Conifer Change by Cause and County

County	Fire	Mortality	Regrowth	Other	No Cause Assessed	Total
Kern	0	0	0	0	8	8
Los Angeles	1,525	0	7	0	129	1,662
Monterey	1,308	13	358	0	528	2,207
Orange	288	0	0	0	10	298
Riverside	913	48	0	0	1,299	2,260
San Benito	0	0	0	0	0	0
San Bernardino	11,111	0	42	22	2,134	13,310
San Diego	2,172	185	56	0	605	3,018
San Luis Obispo	3	0	0	0	0	3
Santa Barbara	259	0	0	0	171	430
Ventura	1,044	0	0	0	368	1,412
Total	**18,624**	**246**	**463**	**22**	**5,253**	**24,610**

The majority of change in conifer canopy cover (both decrease and increase) occurred on Forest Service land, which was where the most of the fires during this time period occurred (Table 7). Where cause could be determined, fire was also the primary cause of change on private land, though most of the change on private land could not be attributed to a specific cause (Table 8). Most of the private land where fire occurred during the second cycle is land adjacent to National Forest land.

Table 7. Acres of Conifer Change by Owner

Owner	Decrease	% total cover	Increase	% total cover	Total
FS	17,370	1.54	270	0.02	17,640
Other Public	3,827	0.34	165	0.01	3,991
Private	2,297	0.2	171	0.02	2,468
Total	**23,494**	**2.0**	**606**	**0.05**	**24,100**

Table 8. Acres of Conifer Change by Cause and Owner

Owner	Fire	Mortality	Regrowth	Other	No Cause Assessed	Total
FS	15,721	186	245	11	1,478	17,640
Other Public	1,948	21	159	0	2,061	4,189
Private	955	39	59	12	1,715	2,781
Total	**18,624**	**246**	**463**	**22**	**5,253**	**24,610**

Hardwoods

Within the project area, hardwood vegetation types total approximately 2.2 million acres. Blue oak and blue oak/foothill pine encompass about 49% of this area, while coastal oak woodlands cover about 35%, and montane hardwood about 13%. Where cause was determined, Coastal Oak Woodland and Montane Hardwood types underwent the most change, with the primary cause of change being fire.

Table 9. Acres of Hardwood Cover Change by WHR Type

WHR Type	Decrease in CC	% total cover	Increase in CC	% total cover	Total
Blue Oak-Foothill Pine	162	0.06	8	0.00	170
Blue Oak Woodland	1,222	0.19	43	0.02	1,265
Coastal Oak Woodland	14,536	1.7	1,349	0.16	15,885
Desert Riparian	11	0.71	1	0.06	12
Eucalyptus	298	4.93	18	0.30	317
Joshua Tree	1,398	4.39	0	0.00	1,398
Montane Hardwood	8,259	3.45	532	0.19	8,791
Montane Riparian	844	2.05	545	1.32	1,389
Valley Oak Woodland	92	0.32	35	0.00	127
Valley Foothill Riparian	2,183	3.54	405	0.06	2,588
Total	**29,005**	**1.32**	**2,937**	**0.13**	**31,943**

Table 10. Acres of Hardwood Cover Change by Cause and WHR Type

WHR Type	Fire	Development	Mortality	Regrowth	Other	No Cause Assessed	Grand Total
BlueOak-Foothill Pine	73	0	0	7	1	90	170
Blue Oak Woodland	756	0	0	18	10	618	1,402
Coastal Oak Woodland	6,496	53	0	844	3	9,600	16,996
Desert Riparian	0	0	0	0	0	12	12
Eucalyptus	28	1	0	0	0	302	332
Joshua Tree	119	0	0	0	0	1,279	1,398
Montane Hardwood	6,636	0	32	467	0	1,657	8,791
Montane Riparian	562	2	0	56	0	868	1,487
Valley Oak Woodland	1	0	0	0	0	126	127
Valley Foothill Riparian	520	27	15	7	0	2,018	2,588
Total	**15,190**	**83**	**47**	**1,398**	**14**	**16,570**	**33,303**

Most change in hardwood cover occurred in San Diego and Monterey Counties. Increases in hardwood canopy cover were also greatest in Monterey County (Table 11). In all counties except for San Luis Obispo, fire was the primary agent of change.

Table 11. Acres of Hardwood Cover Change by County

County	Decrease in CC	%	Increase in CC	%	Total
Kern	1	0.00	0	0.000	1
Los Angeles	1,584	0.07	410	0.019	1,994
Merced	32	0.00	0	0.000	32
Monterey	7,880	0.36	1,334	0.060	9,214
Orange	578	0.03	81	0.004	659
Riverside	2,354	0.11	44	0.002	2,397
San Benito	150	0.01	10	0.000	161
San Bernardino	1,972	0.09	32	0.001	2,004
San Diego	9,557	0.43	147	0.007	9,703
San Luis Obispo	671	0.03	55	0.002	726
Santa Barbara	2,299	0.10	22	0.001	2,320
Ventura	1,928	0.09	803	0.036	2,731
Total	**29,005**	**1.32**	**2,937**	**0.133**	**31,943**

Table 12. Acres of Hardwood Change by Cause and County

County	Fire	Development	Mortality	Regrowth	Other	No Cause Assessed	Total
Kern	0	0	0	0	0	1	1
Los Angeles	1,034	13	0	285	0	678	2,010
Merced	32	0	0	0	0	0	32
Monterey	6,491	2	7	974	12	2,587	10,073
Orange	181	26	0	2	0	450	659
Riverside	397	18	0	2	0	1,981	2,397
San Benito	65	0	0	7	0	89	161
San Bernardino	892	0	0	2	0	1,110	2,004
San Diego	2,651	25	40	28	0	6,960	9,703
San Luis Obispo	0	0	0	23	2	700	726
Santa Barbara	1,863	0	0	17	0	926	2,807
Ventura	1,583	0	0	59	0	1,090	2,731
Total	**15,190**	**83**	**47**	**1,398**	**14**	**16,570**	**33,303**

Most of the decrease in hardwood canopy cover occurred on private land, slightly more than that detected on Forest Service land (Table 13). This is an increase in the amount of decline relative to the first cycle. Where cause could be assessed, fire was the primary disturbance agent on all ownerships, while change due to development and mortality occurred primarily on private land (Table 14). The cause for most of the change on private land could not be determined, due to insufficient data.

Table 13. Acres of Hardwood Cover Change by Owner

Owner	Decrease	%	Increase	%	Total
USFS	12,163	42	974	33	13,137
Other Public	3,823	13	614	21	4,437
Private	13,019	45	1,349	46	14,368
Total	**29,005**	**100**	**2,937**	**100**	**31,943**

Table 14. Acres of Hardwood Cover Change by Cause and Owner

Owner	Fire	Development	Mortality	Regrowth	Other	No Cause Assessed	Total
USFS	10,838	2	4	922	0	1,372	13,137
Other Public	1,281	0	19	338	0	3,325	4,963
Private	3,071	81	24	138	14	11,873	15,202
Total	**15,190**	**83**	**47**	**1,398**	**0**	**16,570**	**33,289**

Shrub/Chaparral

The shrub/chaparral lifeform encompasses about 9.8 million acres, which covers more area than any other lifeform in the project area. The major shrub/chaparral WHR types in the project area are desert scrub (24%), montane chaparral (19%), chamise-redshank chaparral (7%), mixed chaparral (7%) and alkali scrub (6%), together covering 64% of the shrub/chaparral in the project area. Undetermined WHR types compose 32% of the shrub/chaparral lifeform. The remaining 4% is composed of coastal scrub (3%), sagebrush (0.6%), desert succulent scrub (0.2%), alpine dwarf shrub (< 0.1%) and desert wash (< 0.1%).

The shrub/chaparral lifeforms affected most by change were mixed chaparral, coastal scrub and chamise-redshank chaparral (table 15). Decrease in cover was greater than increase for all lifeforms. Where cause was assessed, fire was the primary cause of change (table 16). Regrowth was also highest for mixed chaparral.

Table 15. Acres of Shrub/Chaparral Cover Change by WHR Type

WHR Type	Decrease	% total cover	Increase	% total cover	Total
Alkali Desert Scrub	359	0.01	3	0.00	365
Chamise - Redshank Chaparral	16,904	0.25	6,364	0.09	29,718
Coastal Scrub	27,079	0.40	7,110	0.10	53,630
Desert Scrub	2,741	0.04	26	0.00	3,069
Desert Succulent Scrub	1	0.00	0	0.00	1
Desert Wash	163	0.00	82	0.00	327
Mixed Chaparral	65,045	0.96	22,158	0.33	109,802
Montane Chaparral	1,438	0.02	29	0.00	1,495
Sagebrush	478	0.01	5	0.00	489
Unknown Shrub Type	461	0.01	12	0.00	485
Total	114,668	**1.69**	**35,788**	**0.53**	**150,456**

Table 16. Acres of Shrub/Chaparral Cover Change by Cause and WHR Type

WHR Type	Fire	Development	Regrowth	Other	No Cause Assessed	Total
Alkali Desert Scrub	0	0	0	0	362	362
Unknown Shrub Type	4	1	0	6	462	473
Chamise - Redshank Chaparral	13,914	88	6,131	8	3,170	23,311
Coastal Scrub	11,261	2,721	5,740	945	19,688	40,354
Desert Scrub	1,450	117	5	0	1,334	2,905
Desert Succulent Scrub	1	0	0	0	0	1
Desert Wash	1	13	0	0	231	245
Mixed Chaparral	51,590	1,096	21,038	242	13,458	87,424
Montane Chaparral	1,310	0	5	0	151	1,466
Sagebrush	203	4	2	0	274	483
Total	**79,735**	**4,038**	**32,922**	**1,200**	**39,129**	**157,024**

Approximately two-thirds of the decrease in shrub/chapparal cover occurred in three counties: San Diego, Ventura and Los Angeles (table 17). San Luis Obispo County had the most increase in cover, followed by San Diego and Los Angeles Counties. Change due to fire was also concentrated in the same counties that had the most decrease in vegetation cover (table 18).

Table 17. Acres of Shrub/Chaparral Change by County

County	Decrease	% total cover	Increase	% total cover	Total
Fresno	39	0.00	0	0.00	39
Imperial	10	0.00	13	0.00	22
Kern	382	0.01	0	0.00	382
Kings	110	0.00	0	0.00	110
Los Angeles	17,455	0.26	6,606	0.10	24,060
Monterey	2,241	0.03	5,585	0.08	7,826
Orange	3,339	0.05	285	0.00	3,624
Riverside	9,373	0.14	211	0.00	9,583
San Benito	117	0.00	24	0.00	141
San Bernardino	11,565	0.17	175	0.00	11,740
San Diego	35,922	0.53	10,846	0.16	46,769
San Luis Obispo	791	0.01	11,180	0.17	11,971
Santa Barbara	10,517	0.16	642	0.01	11,159
Ventura	22,807	0.34	222	0.00	23,029
Total	**114,668**	**1.69**	**35,788**	**0.53**	**150,456**

Table 18. Acres of Shrub/Chaparral Change by Cause and County

County	Fire	Development	Regrowth	Other	No Cause Assessed	Total
Fresno	39	0	0	0	0	39
Imperial	0	0	0	0	22	22
Kern	0	0	0	0	382	382
Kings	0	0	0	0	110	110
Los Angeles	12,585	896	6,330	0	5,451	25,262
Monterey	966	0	4,858	110	2,901	8,835
Orange	1,297	224	168	0	2,142	3,831
Riverside	4,766	940	138	1,008	2,731	9,583
San Benito	80	0	10	0	51	141
San Bernardino	8,220	90	76	7	3,347	11,740
San Diego	22,838	1,856	9,541	70	12,464	46,769
San Luis Obispo	4	0	11,105	6	855	11,971
Santa Barbara	8,167	0	584	0	6,558	15,309
Ventura	20,772	31	111	0	2,114	23,029
Total	**79,735**	**4,038**	**32,922**	**1,200**	**39,129**	**157,024**

While most change in shrub/chaparral cover occurred on Forest Service land, a higher proportion of change in this cover type occurred on private land, relative to conifer and hardwood change, which occurred primarily on Forest Service land (table 19). Where cause could be determined, changes due to fire and regrowth were detected primarily on Forest Service land, while development occurred almost entirely on private land (table 20).

Table 19. Acres of Shrub/Chaparral Change by Owner

Owner	Decrease in Cover	Increase in Cover	Total
Forest Service	54,673	20,201	74,874
Other Public	14,017	8,493	22,510
Private	45,978	7,094	53,072
Total	**114,668**	**35,788**	**150,456**

Table 20. Acres of Shrub/Chaparral Change by Cause and Owner

Owner	Fire	Development	Regrowth	Other	No Cause Assessed	Total
USFS	49,809	1	19,804	0	5,260	74,874
Other Public	9,998	10	7,440	22	9,039	26,508
Private	19,927	4,027	5,679	1,178	24,831	55,642
Total	**79,735**	**4,038**	**32,922**	**1,200**	**39,129**	**157,024**

Grass/Forb and Non-Forested Other

The majority of change in these cover types occurred in San Diego, Riverside and Los Angeles Counties (Table 21). Of the areas where cause was determined, development was the primary cause for change in cover.

Table 21. Acres of Grass/Forb and NFO Change by Cause and County

COUNTY	Fire	Development	Regrowth	Other	No Cause Assessed	Total
Fresno	31	0	0	0	32	63
Kern	0	0	0	0	1,025	1,025
Kings	0	0	0	0	8	8
Los Angeles	91	291	45	0	3,293	3,720
Merced	33	0	0	0	122	155
Monterey	27	193	14	165	681	1,080
Orange	47	1,197	182	0	2,302	3,727
Riverside	627	1,130	40	506	2,691	4,993
San Benito	0	37	0	202	72	312
San Bernardino	115	272	5	0	1,625	2,017
San Diego	51	3,017	55	0	4,472	7,595
San Luis Obispo	0	76	6	1,046	1,107	2,236
Santa Barbara	23	0	7	0	3,405	3,435
Ventura	595	43	17	0	1,750	2,405
Total	**1,640**	**6,256**	**371**	**1,919**	**22,586**	**32,773**

Table 22. Acres of Grass/Forb and NFO Change by Cause and Owner

Owner	Fire	Development	Regrowth	Other	No Cause Assessed	Total
USFS	248	0	46	0	147	440
Other Public	439	24	35	0	2,291	2,789
Private	953	6,232	291	1,919	20,148	29,543
Total	**1,640**	**6,256**	**371**	**1,919**	**22,586**	**32,773**

FOREST SERVICE LAND

Changes on National Forest Service land occurred primarily on the Los Padres National Forest, and decreases in canopy cover were greater than increases on all forests (Table 24). Where cause could be determined, fire was the primary cause of change on all national forests (Table 25).

Table 24. Acres of Change of All Vegetation by National Forest

Forest	Decrease	Increase	Total
Angeles National Forest	12,533	5,762	18,296
Cleveland National Forest	12,636	1,013	13,649
Los Padres National Forest	38,010	14,402	51,413
San Bernardino National Forest	21,390	345	21,735
Total	**84,570**	**21,522**	**106,092**

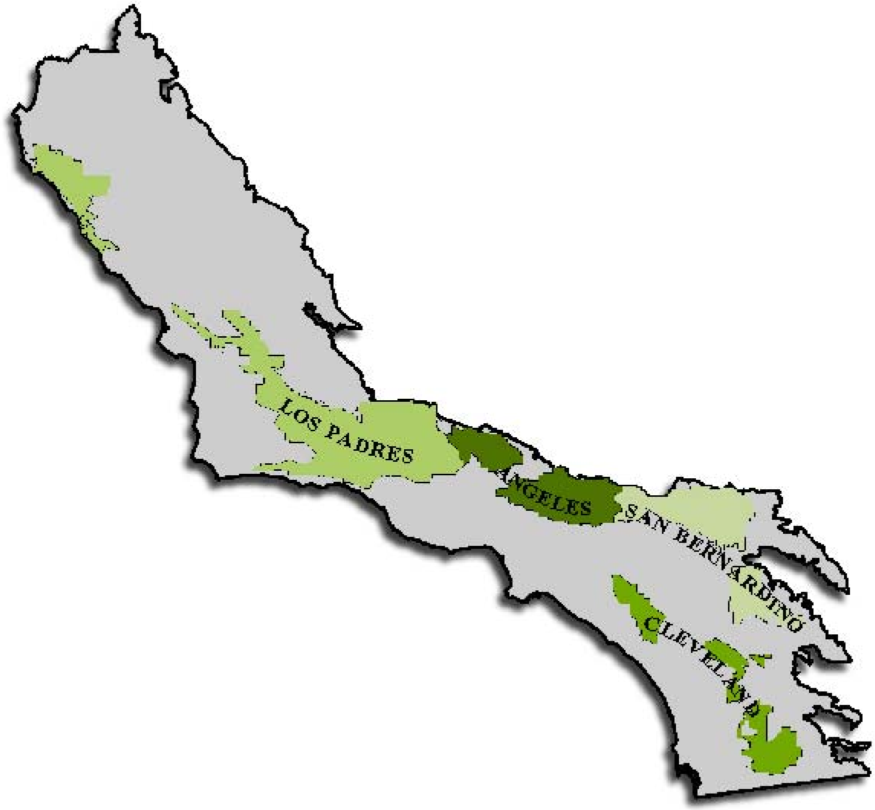


Figure 9. National forest land in the south coast project area

Table 25. Acres of Change of All Vegetation by Cause and National Forest

Forest	Fire	Development	Mortality	Regrowth	Other	No Cause Assessed	Total
Angeles	11,964	1	0	5,557	0	773	18,296
Cleveland	10,666	2	142	923	0	1,916	13,649
Los Padres	35,476	0	0	14,311	0	2,625	52,413
San Bernardino	18,509	0	48	225	11	2,942	21,735
Total	76,615	3	190	21,016	11	8,257	106,092

Conifers

Change in conifer canopy cover occurred primarily on the San Bernardino National Forest, which accounted for 71% of the change in conifer cover on National Forest Land within the study area. The Calveg types most affected on the San Bernardino were the singleleaf pinyon pine, the eastside pine, and the mixed conifer-pine alliance. With the exception of the Cleveland, decreases in vegetation cover within the singleleaf pinyon pine alliance were detected on all forests in the study area.

Table 26. Acres of Conifer Canopy Cover Change by National Forest and CALVEG Type

Forest	CALVEG**	Decrease	Increase	Total
Angeles	DM	358	6	365
	MF	17	1	17
	MP	154	0	154
	PJ	660	0	660
	Other*	145	3	148
	Total	1,334	10	1,344
Cleveland	DM	442	0	442
	JP	142	7	150
	MF	0	0	0
	PC	133	0	133
	Other*	43	0	43
	Total	760	8	767
Los Padres	JP	275	0	275
	PC	734	161	895
	PJ	378	0	378
	Other*	1,393	37	1,431
	Total	2,780	198	2,979
San Bernardino	DM	177	0	177
	EP	1,776	5	1,781
	JP	8	4	12
	MF	313	0	313
	MP	1,007	0	1,007
	PJ	7,898	5	7,903
	Other*	1,318	39	1,358
	Total	**12,496**	**54**	**12,550**
All Forests		**17,370**	**270**	**17,640**

*CALVEG types composing less than 5% of the conifer lifeform in the particular forest are combined into this category.
** See Appendix F for CALVEG code descriptions.

Fire is the primary cause of change on all of the National Forest land within the study area. Fire occurred primarily on the San Bernardino National Forest, affecting over 11,000 acres, occurring on singleleaf pinyon pine and eastside pine CALVEG types. Change due to regrowth occurred primarily on the Los Padres National Forest, within the coulter pine CALVEG type. On the San Bernardino National Forest, 27 acres of regrowth within the coulter pine CALVEG type was detected. Change due to mortality affected approximately 120 acres of Jeffrey pine on the Cleveland National Forest.

Table 27. Acres of Conifer Change by Cause, National Forest and CALVEG Type

Forest	CALVEG**	Fire	Mortality	Regrowth	Other	No Cause Assessed	Total
Angeles	DM	350	0	6	0	8	365
	MF	17	0	0	0	1	17
	MP	153	0	0	0	0	154
	PJ	651	0	0	0	9	660
	Other*	143	0	1	0	4	148
	Total	**1,315**	**0**	**7**	0	**23**	**1,344**
Cleveland	DM	432	0	0	0	10	442
	JP	7	120	0	0	22	150
	MF	0	0	0	0	0	0
	PC	104	14	0	0	15	133
	Other*	36	3	0	0	3	43
	Total	**579**	**138**	0	0	**50**	**767**
Los Padres	JP	268	0	0	0	7	275
	PC	712	0	160	0	22	895
	PJ	35	0	0	0	342	378
	Other*	1,365	0	35	0	30	1,431
	Total	**2,381**	**0**	**195**	0	**402**	**2,979**
San Bernardino	DM	125	0	0	0	52	177
	EP	1,757	0	5	11	8	1,781
	JP	0	0	0	0	12	12
	PC	608	16	27	0	246	898
	MF	176	31	0	0	105	313
	MP	739	0	0	0	268	1,007
	PJ	7,850	0	5	0	48	7,903
	Other*	190	1	5	0	264	460
	Total	**11,446**	**48**	**42**	**11**	**1,003**	**12,550**
All Forests		**15,721**	**186**	**245**	**11**	**1,478**	**17,640**

*CALVEG types composing less than 5% of the conifer lifeform in the particular forest are combined into this category.
** See Appendix F for CALVEG code descriptions.

Hardwoods

The majority of hardwood vegetation affected by change was found on the Los Padres National Forest, followed by the Cleveland, San Bernardino and Angeles (table 28). On the Los Padres, most of the decrease in vegetation cover occurred in the coast live oak CALVEG type. Decreases in vegetation cover for this vegetation type also occurred on the other national forests within the project area, but to a much smaller extent. This was due to the fact that the majority of fires during this time period occurred on the Los Padres.

As with other vegetation types and ownerships, where cause was assessed, fire was the primary agent of change on hardwood forests in the south coast project area (table 29).

Table 28. Acres of Hardwood Canopy Cover Change by National Forest and CALVEG Type

Forest	CALVEG**	Decrease	Increase	Total
Angeles	QA	167	51	217
	QC	573	134	707
	Other*	224	56	279
	Total	963	240	1,203
Cleveland	QA	594	1	595
	QK	48	4	52
	Other*	1,115	0	1,116
	Total	1,758	4	1,763
Los Padres	QA	3,675	399	4,074
	QC	810	1	811
	QD	90	8	97
	Other*	3,722	314	4,037
	Total	8,297	722	9,019
San Bernardino	QA	36	2	39
	QK	169	0	169
	QC	686	3	690
	Other*	254	1	256
	Total	1,146	7	1,153
All Forests		**12,164**	**974**	**13,138**

*CALVEG types composing less than 5% of the hardwood lifeform in the particular forest are combined into this category.
** See Appendix F for CALVEG code descriptions.

Table 29. Acres of Hardwood Canopy Cover Change by Cause, National Forest and CALVEG Type.

Forest	CALVEG**	Fire	Development	Mortality	Regrowth	No Cause Assessed	Total
Angeles	QA	157	0	0	47	13	217
	QC	532	0	0	127	48	707
	Other*	200	0	0	41	38	279
	Total	890	0	0	215	99	1,203
Cleveland	QA	391	2	0	0	202	595
	QK	36	0	0	0	16	52
	Other*	777	0	4	0	335	1,116
	Total	1,203	2	4	0	553	1,763
Los Padres	QA	3,489	0	0	397	188	4,074
	QC	774	0	0	0	37	811
	QD	88	0	0	8	2	97
	Other*	3,653	0	0	302	82	4,037
	Total	8,004	0	0	707	308	9,019
San Bernardino	QA	6	0	0	0	33	39
	QC	516	0	0	0	174	690
	QK	55	0	0	0	114	169
	Other*	165	0	0	0	91	256
	Total	741	0	0	0	412	1,153
All Forests		**10,838**	**2**	**4**	**922**	**1,372**	**13,138**

*CALVEG types composing less than 5% of the hardwood lifeform in the particular forest are combined into this category. ** See Appendix F for CALVEG code descriptions.

Shrub/Chapparal

Change in shrub/chapparal vegetation types affected approximately 75,000 acres on national forest land. Decreases in vegetation cover were greater than increases on all forests. The majority of change occurred on the Los Padres national forest, with most of the change affecting the lower montane mixed chaparral vegetation type. Increases in shrub/chappraral vegetation were also detected on all national forests in the study area.

Table 30. Acres of Shrub/Chapparal Cover Change by National Forest and CALVEG Type

Forest	CALVEG**	Decrease	Increase	Total
Angeles	CA	2,857	780	3,637
	CQ	6,034	2,933	8,967
	CZ	12	0	12
	Other*	1,301	1,778	3,079
	Total	**10,204**	**5,490**	**15,694**
Cleveland	CA	2,470	137	2,607
	CD	1,576	566	2,143
	CR	96	91	187
	CQ	5,056	34	5,089
	CS	357	22	379
	Other*	518	135	652
	Total	**10,073**	**985**	**11,058**
Los Padres	CA	4,456	4,637	9,093
	CQ	17,417	7,123	24,540
	SB	502	20	522
	SS	2,338	152	2,489
	Other*	1,990	1,526	3,516
	Total	**26,703**	**13,458**	**40,161**
San Bernardino	CA	578	1	579
	CQ	2,120	144	2,264
	CR	44	67	110
	CS	925	14	939
	CX	172	5	177
	CZ	2,297	12	2,309
	SB	4	0	4
	Other*	1,553	27	1,580
	Total	**7,693**	**269**	**7,962**
All Forests		**54,673**	**20,202**	**74,875**

*CALVEG types composing less than 5% of the shrub/chapparal lifeform in the particular forest are combined into this category.

** See Appendix F for CALVEG code descriptions.

Table 31. Acres of Shrub/Chaparral Change by Cause, National Forest and CALVEG Type

Forest	CALVEG**	Fire	Development	Regrowth	No Cause Assessed	Total
Angeles	CA	2,765	0	760	112	3,637
	CQ	5,769	0	2,813	385	8,967
	CZ	0	0	0	12	12
	Other*	1,198	1	1,742	138	3,079
	Total	**9,732**	**1**	**5,315**	**647**	**15,694**
Cleveland	CA	2,112	0	131	363	2,607
	CD	1,221	0	563	359	2,143
	CR	79	0	80	29	187
	CQ	4,688	0	12	390	5,089
	CS	353	0	1	25	379
	Other*	414	0	129	109	652
	Total	**8,867**	**0**	**915**	**1,275**	**11,058**
Los Padres	CA	4,291	0	4,635	167	9,093
	CQ	16,383	0	7,085	1,072	24,540
	SB	367	0	20	135	522
	SS	2,069	0	143	277	2,489
	Other*	1,795	0	1,510	211	3,516
	Total	**24,906**	**0**	**13,393**	**1,862**	**40,161**
San Bernardino	CA	447	0	0	132	579
	CQ	1,399	0	86	778	2,264
	CR	38	0	67	6	110
	CS	798	0	11	131	939
	CX	167	0	5	5	177
	CZ	2,206	0	10	92	2,309
	SB	3	0	0	1	4
	Other*	1,246	0	2	332	1,580
All Forests	**Total**	**6,305**	**0**	**181**	**1,477**	**7,962**

*CALVEG types composing less than 5% of the shrub/chaparral lifeform in the particular forest are combined into this category.

** See Appendix F for CALVEG code descriptions.

South Coast Change Detection 1997-2005: San Bernardino National Forest

Summary of Change for the San Bernardino National Forest, 1997-2005

From 1997 to 2005, change in vegetation cover was detected on over 155,000 acres across all vegetation types on the San Bernardino National Forest. From 1997-2003, changes in vegetation cover were detected on over 21,000 acres, with loss of vegetation cover accounting for 98% of the change. From 2003-2005, change was detected on over 130,000 acres, of which 72,000 acres was due to decreases in vegetation cover (Figure 11). From 1997 to 2005, over 94,000 acres of vegetation cover loss was detected on the San Bernardino. Fire was the primary cause of vegetation loss for the entire time period from 1997-2005, followed by mortality. The bark beetle outbreak of 2003 on the San Bernardino accounted for most of the mortality on the San Bernardino for this time period.

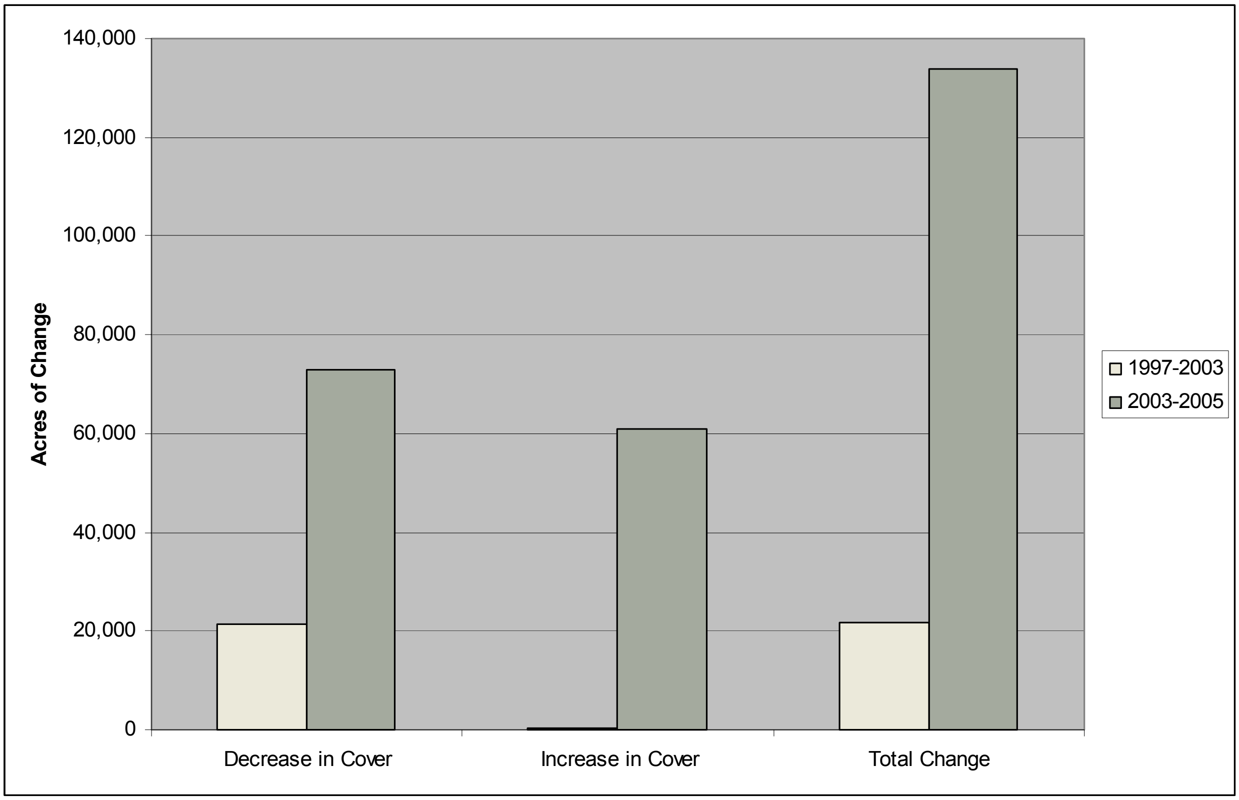


Figure 11. Change in vegetation cover across all vegetation types (conifer, hardwood, shrub, mixed conifer/hardwood and grass/forb), San Bernardino National Forest, 1997-2003 and 2003-2005.

2003-2005 San Bernardino National Forest Results

All Vegetation

The 2003-2005 change detection analysis for the South Coast project area was limited to the San Bernardino National Forest, where the 2003 bark beetle outbreak occurred. Most of the decreases in cover occurred within the shrub lifeform, followed by conifer, mixed conifer-hardwood, and hardwood. Increases in vegetation cover occurred primarily on shrub cover, followed by conifer, mixed and hardwood (table 32).

Table 32. Acres of Change by Cover Type, San Bernardino National Forest, 2003-2005.

Cover Type	Decrease	Increase	Total Change
Conifer	20,817	15,496	36,313
Hardwood	10,311	7,174	17,485
Mixed Conifer-Hardwood	16,460	10,091	26,551
Shrub	24,034	27,182	51,216
Herbaceous	1,275	996	2,271
Total	**72,897**	**60,940**	**133,836**

Conifers

Change in conifer cover affected primarily the Pinyon-Juniper cover type, followed by Sierra Mixed conifer, Jeffrey pine and Eastside pine. Much of the decrease in the Pinyon-Juniper and Sierra Mixed conifer types was due to a large fire that occurred in 2003, and affected over 91,000 acres in the Western part of the San Bernardino National Forest. Change in conifer cover by CALVEG type is shown in table 34.

Table 33. Acres of Conifer Change by WHR Type, 2003-2005

WHR Type	Decrease	Increase	Total
Closed Cone Pine-Cypress	58	138	196
Eastside Pine	2,402	1,361	3,763
Jeffrey Pine	2,817	3,451	6,268
Juniper	36	4	40
Lodgepole Pine	24	6	31
Montane Hardwood-Conifer	293	534	828
Pinyon-Juniper	7,511	5,643	13,154
Ponderosa Pine	46	15	61
Subalpine Conifer	1,772	419	2,191
Sierran Mixed Conifer	5,790	3,842	9,632
White Fir	67	82	149
Total	**20,817**	**15,496**	**36,312**

Table 34. Acres of Conifer Change by CALVEG Type, San Bernardino National Forest, 2003-2005

CALVEG**	Decrease	Increase	Total
DM	88	63	151
EP	2,402	1,361	3,763
JP	1,148	1,132	2,279
MF	5,790	3,842	9,632
MP	1,670	2,319	3,989
PC	205	471	677
PJ	7,511	5,570	13,081
Other*	2,003	737	2,740
Total	**20,817**	**15,496**	**36,312**

*CALVEG types composing less than 5% of the conifer lifeform are combined into this category.
**See Appendix F for CALVEG code descriptions.

Hardwoods

Change in hardwood cover in the San Bernardino occurred primarily in the montane hardwood vegetation type, which is widespread throughout the San Bernardino. Vegetation cover decrease in the montane hardwood type was significant for the 2003-2005 time period, due to large fires that burned during this time.

Table 35. Acres of Hardwood Change by WHR Type, San Bernardino National Forest, 2003-2005

WHR Type	Decrease	Increase	Total
Coastal Oak Woodland	87	590	676
Desert Riparian	10	37	48
Desert Wash	15	20	35
Eucalyptus	28	9	37
Joshua Tree	614	179	794
Montane Hardwood	8,868	5,510	14,378
Montane Riparian	624	775	1,399
Sagebrush	12	11	23
Valley Foothill Riparian	45	34	79
Total	**10,303**	**7,166**	**17,469**

Table 36. Acres of Hardwood Change by CALVEG Type, San Bernardino National Forest, 2003-2005

CALVEG**	Decrease	Increase	Total
QC	6,748	4,166	10,914
QK	1,711	1,123	2,834
UJ	614	179	793
Other*	1,230	1,698	2,927
Total	**10,303**	**7,166**	**17,469**

*CALVEG types composing less than 5% of the conifer lifeform are combined into this category.
**See Appendix F for CALVEG code descriptions.

Shrub/Chaparral

Shrub/Chaparral underwent the most change in the San Bernardino between 2003-2005, largely due to fire and vegetation regrowth. Change in shrub/chaparral cover occurred primarily within the mixed chaparral type, as well as desert scrub and montane chaparral. The majority of the decrease in the mixed chaparral cover occurred in the Western portion of the San Bernardino, where the Grand Prix fire burned in 2003. Increases in mixed chaparral cover were greater than overall decreases.

Table 37. Acres of Shrub/Chaparral Change by WHR/CALVEG Type, San Bernardino National Forest

WHR Type	Decrease	Increase	Total
Alpine Dwarf Shrub	0	2	2
Alkali Desert Scrub	6	2	8
Bitterbrush	412	224	636
Chamise - Redshank Chaparral	1,603	4,254	5,856
Coastal Scrub	260	282	543
Desert Riparian	15	7	22
Desert Scrub	4,738	4,084	8,823
Desert Succulent Scrub	6	14	20
Desert Wash	339	331	670
Juniper	602	843	1,446
Mixed Chaparral	12,370	15,206	27,577
Montane Chaparral	2,388	1,277	3,665
Montane Riparian	6	21	27
Sagebrush	1,303	654	1,957
Total	**24,034**	**27,182**	**51,216**

Table 38. Acres of Shrub/Chaparral Change by CALVEG Type, San Bernardino National Forest, 2003-2005

CALVEG**	Decrease	Increase	Total
CQ	4,754	9,384	14,138
CR	766	2,546	3,312
CS	4,406	2,693	7,099
CA	837	1,708	2,545
CZ	744	1,369	2,113
Other*	12,526	9,483	22,009
Total	**24,034**	**27,182**	**51,216**

*CALVEG types composing less than 5% of the conifer lifeform are combined into this category. **See Appendix F for CALVEG code descriptions.

Mixed Conifer-Hardwood

The mixed conifer-hardwood cover type underwent significant change in the montane-hardwood conifer cover type, with a decrease in vegetation cover affecting over 10,000 acres. The majority of this change occurred in the western part of the San Bernardino. Overall, decreases in vegetation cover across all cover types in the mixed category were greater than increases.

Table 39. Acres of Mixed Conifer-Hardwood Change by WHR/CALVEG Type, San Bernardino National Forest

WHR Type	Decrease	Increase	Total
Juniper	3	1	4
Closed Cone Pine-Cypress	4	1	4
Eastside Pine	168	251	419
Jeffrey Pine	1,689	924	2,613
Montane Hardwood-Conifer	10,211	6,211	16,423
Montane Hardwood	2,839	1,767	4,606
Pinyon-Juniper	838	589	1,426
Ponderosa Pine	79	46	125
Sierran Mixed Conifer	627	292	919
White Fir	2	7	9
Total	16,459	10,088	26,547

Table 40. Acres of Mixed Conifer-Hardwood Change by CALVEG Type, San Bernardino National Forest, 2003-2005

CALVEG**	Decrease	Increase	Total
MP	6,146	3,985	10,131
MF	2,251	1,222	3,473
DM	2,959	1,579	4,538
PC	1,906	1,332	3,238
JP	1,065	419	1,484
PJ	838	589	1,426
EP	861	665	1,526
Other*	434	297	735
Total	16,459	10,088	26,547

*CALVEG types composing less than 5% of the conifer lifeform are combined into this category.
**See Appendix F for CALVEG code descriptions.

Grass/Forb

Within the Grass/Forb cover type, annual grassland underwent the most change, with over 1,000 acres of decrease and approximately 750 acres of increase. An overall increase in wet meadow vegetation, which can provide important wildlife habitat, was also detected in the San Bernardino.

Table 41. Acres of Grass Forb Change by WHR/CALVEG Type, San Bernardino National Forest

WHR Type	Decrease	Increase	Total
Annual Grass	1,145	752	1,897
Fresh Emergent Wetland	0	1	1
Perennial Grass	10	20	30
Wet Meadow	80	195	276
Total	**1,275**	**996**	**2,271**

Table 42. Acres of Grass/Forb Change by CALVEG Type, San Bernardino National Forest, 2003-2005

CALVEG**	Decrease	Increase	Total
HG	1,145	752	1,897
HJ	80	195	276
Other*	51	48	99
Total	1,275	996	2,271

*CALVEG types composing less than 5% of the conifer lifeform are combined into this category.

**See Appendix F for CALVEG code descriptions.

Cause of Change

Where cause of vegetation change could be assessed, across all vegetation types, regrowth was the primary cause of vegetation change detected in the study area, with much of this being post-fire regeneration (Grand Prix and Old fires, which burned in 2003). Vegetation loss due to bark beetle-caused mortality was the primary cause of vegetation loss in the conifer cover type (figure 12). Within the hardwood, mixed conifer-hardwood and shrub cover types, fire was the primary cause of vegetation loss in the areas where cause could be determined.

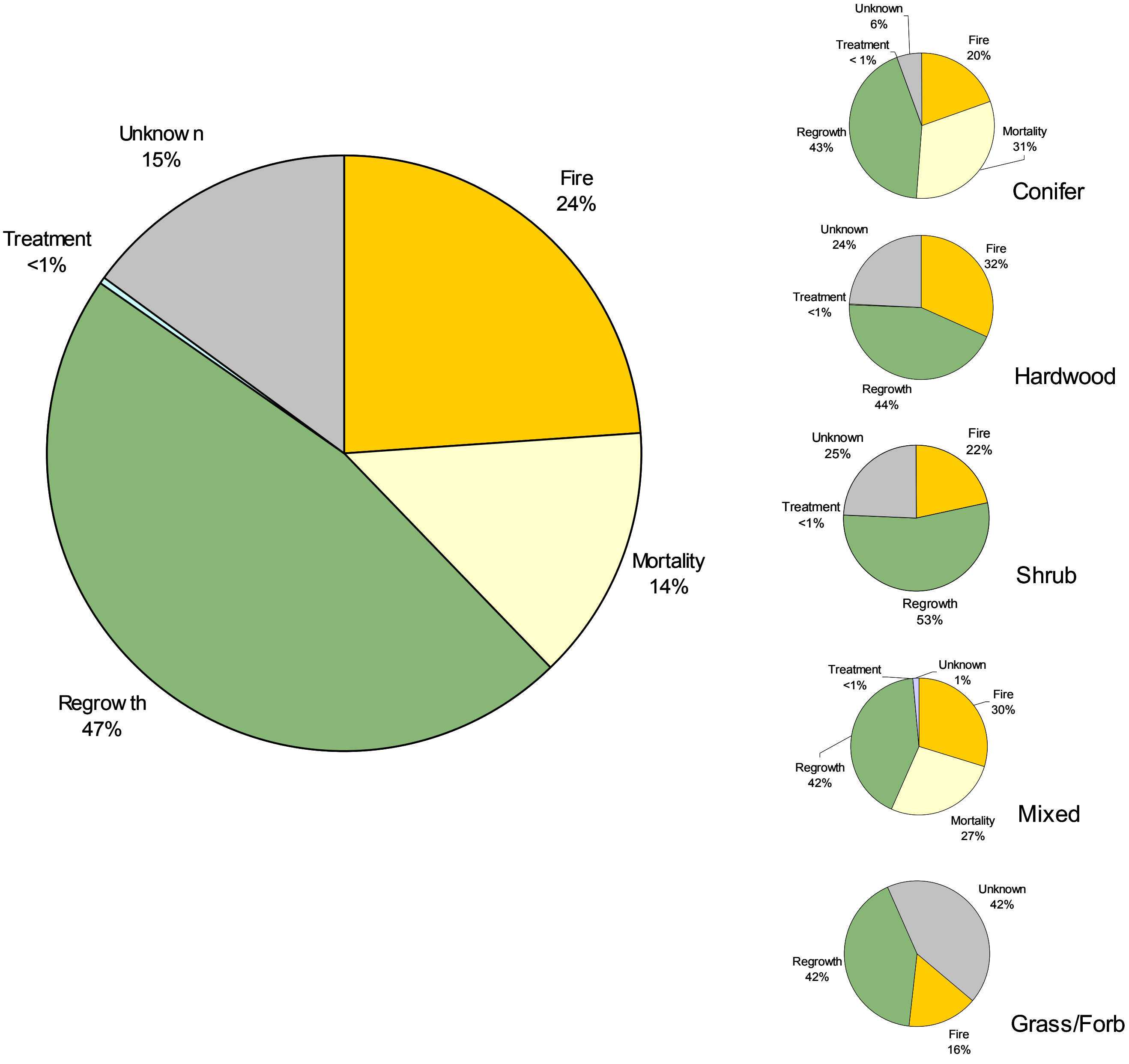


Figure 12. Cause of change in vegetation cover by all vegetation types and by conifer, hardwood, shrub, mixed conifer-hardwood and grass/forb, San Bernardino National Forest, 2003-2005.

TERMINOLOGY

CALVEG – A vegetation classification scheme based on the Classification and Assessment with Landsat of Visible Ecological Groupings system. This classification system, developed by the USDA Forest Service, describes existing vegetation communities. It is appropriate for mapping vegetation using Landsat TM imagery and recognizes eight regions within California.

Change Classes – Categorical classes of vegetation change used for this program. These levels are relative amounts of change in vegetation cover (a -16 to -40% CC has less vegetation change than a -41 to -70% CC). The Cloud/Shadow class includes areas covered by clouds, cloud shadows and terrain shadows.

Co-registration – The process of aligning pixels in one date of imagery to the corresponding pixels in another date of imagery that are in the same path and row.

Landsat TM Imagery – Thematic Mapper image data from the Landsat satellite. Each image covers approximately 13,225 square miles, has a pixel resolution of 900 square meters (30 m on a side) and contains seven bands of data. Six of the bands (bands 1-5 and band 7) contain information on the amount of reflected sunlight from ground features within specific wavelengths. The sixth band is a thermal band and is not used in the change detection process.

Lifeform – A plant community aggregation into the broad land cover classes of conifer, hardwood, shrub and grass.

Minimum Mapping Unit – The minimum size or dimensions for features to be mapped as lines or areas.

Mosaic – The process of piecing together several images into one larger image.

Nearest Neighbor Resampling – A resampling method where the output pixel value is the same as the input pixel value, but whose coordinates are closest to the resampled coordinates of the output pixel.

Pixel – The smallest unit of information in an image or raster map, also referred to as a cell in an image.

Radiometric Correction – The process of correcting variations in atmospheric conditions and sun angles in multiple dates of imagery.

Supervised Classification – A process aggregating pixels into classes based on training data (known areas representing the different classes) and multivariate statistics.

Thresholding – A process in which easily identified change classes (large increases and decreases in vegetation, little or no change) are masked out in order to reduce the number of pixels submitted to the classifier.

Unsupervised Classification – Classification algorithms that examine the unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values.

WHR – A vegetation classification scheme based on the California Wildlife Habitat Relationships System. This classification system describes wildlife habitats of vertebrate animals and tends to have broad vegetation classes.

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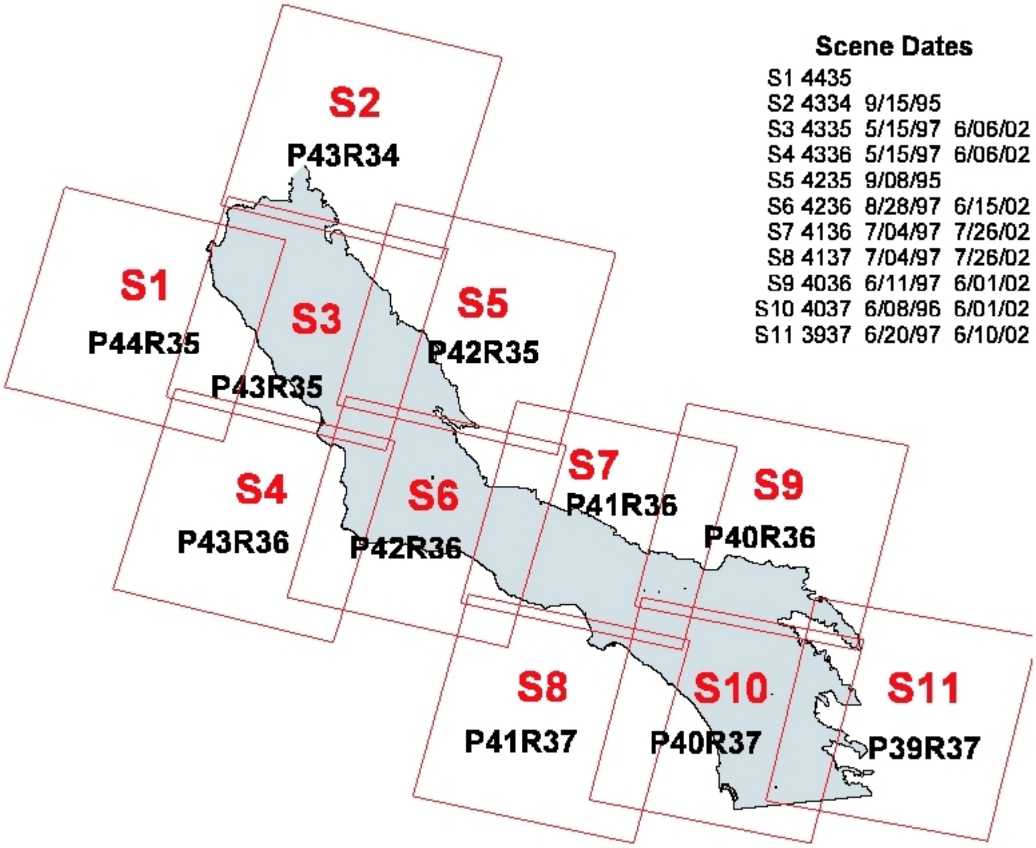
APPENDIX A – DATA SOURCES

Image Data

TM imagery provides the base data for deriving changes in vegetation cover. The South Coast project area requires 11 TM images from each date (22 total TM images). Images for each year are selected as close to the anniversary date as possible to minimize differences in vegetation moisture content and shadow effects. Images are also selected for minimal cloud coverage and overall image quality. TM imagery has a spatial resolution of 900 m^2 (30 m on each side) or approximately 1/5 of an acre. Figure 1a shows the path and row (World Reference System), image boundaries and date for the imagery used in South Coast project area.



Scene Dates

S1	4435		
S2	4334	9/15/95	
S3	4335	5/15/97	6/06/02
S4	4336	5/15/97	6/06/02
S5	4235	9/08/95	
S6	4236	8/28/97	6/15/02
S7	4136	7/04/97	7/26/02
S8	4137	7/04/97	7/26/02
S9	4036	6/11/97	6/01/02
S10	4037	6/08/96	6/01/02
S11	3937	6/20/97	6/10/02

Figure 1a. Path and row TM image boundaries and dates for the imagery used in the South Coast Project Area.

Vegetation Data

Vegetation data are used to determine which lifeforms, WHR types, and CALVEG types are experiencing various magnitudes of change. "Lifeforms" are general land cover categories, such as conifer and hardwood (Figure 2a). WHR stands for Wildlife Habitat Relationships System, and is a fairly detailed vegetation classification system (e.g., Blue Oak Woodland, Ponderosa Pine, and Coastal Scrub). Every WHR type is represented by a lifeform (See Appendix E for

WHR types and corresponding lifeforms). The more specific CALVEG types approximate alliance level and usually correspond to the primary overstory species. CALVEG is the principal label mapped and used by the LCMMP, so only LCMMP vegetation data carries the CALVEG label. Because the CALVEG label is more specific, it is not possible to extrapolate/crosswalk CALVEG types from WHR types or other vegetation labels from non- LCMMP vegetation layers. For this analysis of the South Coast Project Area, CALVEG types are mapped, and hence analyzed, only on Forest Service land. However, future iterations of change detection analysis will have CALVEG types for the entire project area, as vegetation mapping by the LCMMP will encompass the entire project area and not just Forest Service land. For example, the LCMMP vegetation layer currently covers a large portion of the South Coast Project Area, but the LCMMP vegetation data available at the time of the first image is limited to Forest Service land. See Appendix F of CALVEG code descriptions. Because LCMMP vegetation data is not available for the entire project area, the best available vegetation data are collected and combined into one seamless layer (Table 1a). Layers in polygon format are converted to pixel format. In areas that overlap, the most current and accurate vegetation data are used. Vegetation layers not containing a WHR classification (Mayer and Laudenslayer, 1988) are given a WHR classification based on the information in that layer. Within national forest boundaries, LCMMP vegetation data are used. The CDF Hardwood Rangelands map is then used where LCMMP vegetation data does not exist. SOCAL vegetation data are used where LCMMP and CDF data does not exist. For all remaining areas, the GAP vegetation data are used.

Table 1a. Vegetation Data for the South Coast Project Area

Name	Classification	Source	Scale	Extent	% of Project Area
CA Mapping & Monitoring Program Vegetation Data	CALVEG / WHR	1991 TM Imagery	2.5 acre mmu*	Angeles NF, Cleveland NF, Los Padres NF, San Bernardino NF	20
Hardwood Rangelands	WHR	CDF, updated 1990	Pixel size of 625 m2 (25 meters on each side; 0.15 acres)	Hardwood rangelands below 5000 ft. elevation	32
SOCAL Vegetation	Modified Holland/WHR	Aerial Photos	5 acres	All of Orange, Riverside and San Diego Counties. Portions of Los Angeles and San Bernardino County	32
GAP Analysis 1990	WHR used	Varies; TM imagery, Field data	100 hectares (~250 acres)	Statewide	16

*mmu - minimum mapping unit.

Other Data

Table 2a describes data layers that supplement our monitoring program. These layers are used to stratify change areas, verify causes and correlate change to mortality levels.

Table 2a. Supplemental Data for the South Coast Project Area

Name	Description	Data Type	Scale	Source	Extent
Ownership	Local, state federal, private	Polygon	1:100,000	CaSIL Data Center	Statewide
County	County boundaries	Polygon	1:24,000	CaSIL Data Center	Statewide
Fire Perimeters	Recent and past fires	Regions (polygon)	Varies; 1:24,000 to 1:100,000	Maintained by CDF and FS	Statewide
Harvest / Plantation	Silvicultural practices	Polygon	1:24,000	FS	Forest Service lands
THP Database	Harvest practices on private land	Polygon	1:24,000	CDF	Selected watersheds
NHFEU* Boundaries	Ecological subsection boundaries	Polygon	1:7,500,000	FS	Statewide
Digital Orthophoto Quads	1994	Image	1m^2 pixels	FS and CDF	Statewide
Aerial Survey Data	Sketch mapped mortality data	Polygon	Variable	FS	Forest Service lands, National Parks
Aerial Photos	9” x 9”	Print photograph	1:15,840 nominal	FS	Forest Service lands
	Color Infrared	Digital photograph	1:3,000 nominal	FS	Selected sites within project area

*National Hierarchical Framework of Ecological Units.

APPENDIX B – Methodology

Database Building

Database building requires the preparation of thematic mapper (TM) imagery for processing and the creation of a seamless vegetation layer. The early date TM image (time 1) is registered to the later date TM image (time 2). Registration functions to create overlapping images and is accomplished by placing control points that identify identical features throughout both images. These features are used in a nearest neighbor resampling technique to assign the early date pixel values to the later date pixel locations. These new pixel locations must be within ½ pixel of the later date pixels to eliminate any false changes. The images are then radiometrically corrected to account for differences in atmospheric conditions (e.g., haze and water vapor). This process entails the selection dark and light groups of pixels in each image date and applies a regression based correction to the early image date to effectively remove differences in atmospheric conditions (Schott et al., 1988).

A seamless vegetation layer is mosiacked together using the best available vegetation data (Table 1a in Appendix A). This produces the best possible vegetation layer spanning the entire project area. Layers that are in polygon format are converted to pixel format. In the mosaic process, precedence is given to the LCMMP vegetation layers, then the CDF hardwood layer, then the SOCAL vegetation layer and finally the GAP data, which fills in any remaining areas. Vegetation layers not containing WHR information are given WHR information by extrapolation from data in that vegetation layer, which creates a WHR vegetation map for the entire project area. See Appendix A for more details on the vegetation layer.

Change Processing

Co-registered and radiometrically corrected TM imagery are analyzed for change by applying a Kauth-Thomas transformation to both dates of imagery (Kauth and Thomas, 1976). A TM image contains spectral (or reflectance) information for 7 bands of data, each representing a different range of the electromagnetic spectrum. For instance, band 1 of the Landsat TM measures the reflectance of wavelengths from 0.45⌠m to 0.52 ⌠m, which corresponds to the color blue. The thermal-IR band is not used for this work because its pixel size is 120 meters on each side (all other bands are 30 meters on each side). For each TM image, the Kauth-Thomas transformation uses the spectral information from six bands and model coefficients to produce new images depicting values of brightness, greenness and wetness (Crist and Cicone, 1984). Brightness identifies variation in reflectance, greenness is related to the amount of green vegetation present in the scene and wetness correlates to canopy and soil moisture. The brightness, greenness and wetness values from the first image (time 1) are subtracted from the brightness, greenness and wetness values of the second image (time 2; time2 – time 1) to produce a new image depicting changes in those components on a pixel-by-pixel basis.

To reduce the variability of a change map produced on a pixel-by-pixel basis, image segmentation is employed, which produces regions, or polygons of spectrally similar pixels. This is accomplished by extracting bands 3 and 4 of the first image (time 1) and generating a texture band from band 4 of the first image. The multiband layers are input into the segmentation process (Ryherd and Woodcock, 1990) to create regions. For each region, the average (or mean value) of the change in brightness, greenness and wetness are calculated and given to that region.

Change Labeling

Change labeling is a multi-step process that converts the change image to a change map that depicts decreases and increases in canopy cover or changes in shrub/grass (Figure 5 of main report). The change image is divided into multiple parts, with each part (or map subset) corresponding to a different lifeform type (e.g., conifer, hardwood, shrub/chaparral). This is accomplished by overlaying the vegetation layer and selecting those areas in the change image that have the same lifeform. The result is multiple change images, with each one corresponding to a different lifeform and spatial extent. An unsupervised classification is performed on each individual lifeform change image, which results in 50 distinct classes, each displaying similar levels of brightness, greenness and wetness. These groupings are temporarily labeled according to their level of change based on a qualitative gradient from large decreases in vegetation to large increases in vegetation.

In order to quantify the temporary labels described above, a machine-learning classifier (MLC) is utilized to create a final change map with the proportion of canopy cover change for each region (Levien et al, 1999). This type of quantitative classification scheme is considered more useful to resource managers than a qualitative gradient of change classes, which has been used for previous project areas. The MLC assigns each region to one of 11 change classes (Table 1b) based on several inputs, including the qualitative vegetation gradient and ancillary data layers (roads, slope, aspect and others). Image appearance, photo interpretation, vegetation and topographic maps and bispectral plots (e.g., greenness vs. wetness) also aid in assigning the change classes. Each individual lifeform change image is then mosaicked (pieced back together) into one project area change map.

Table 1b. Change Classes and Corresponding Description

CHANGE CLASS	DESCRIPTION
71 to -100% CC	71 to 100% decrease in canopy cover
41 to -70% CC	41 to 70% decrease in canopy cover
16 to -40% CC	16 to 40% decrease in canopy cover
15 to -15% CC	(Little or No Change) Little or no change (in canopy cover or shrub/chaparral)
16 to +40% CC	16 to 40% increase in canopy cover
41 to +100% CC	41 to 100% increase in canopy cover
Shrub/Grass Decrease > 15%	16 to 100% decrease in shrub/grass
Shrub/Grass Increase > 15%	16 to 100% increase in shrub/grass
Non-vegetation Change	Change not related to a vegetation change
Change Within Existing Developed Area	Change within urban area
Cloud or Cloud Shadow	Cloud or cloud shadow (prevents change assessment)

This classification system is designed to discriminate between different levels of canopy cover changes (i.e., 16 to 40% CC decrease vs. 71 to 100% CC decrease). The +15 to -15% CC (little or no change) indicates that change did not occur, or that the change was too subtle to be detected. The non-vegetation change class accounts for variations in lake or reservoir water levels and snow pack in the higher elevations. Change within an existing urban area class is designated for changes observed in the urban landscape. Cloud or cloud shadow class accounts for clouds, cloud shadows and shadows in mountainous areas that obscure ground cover and make it impossible to determine whether the vegetation had changed or remained stable in these areas.

Cause Verification

Once the final change map is complete, an attempt is made to verify cause on all change areas. GIS overlay, fieldwork and photo interpretation are used to determine the causes of change areas. The statewide fire history database is overlaid onto the change map to attribute changes caused by wildfires (Figure 5 of main report). A series of cause identification workshops are conducted and include FS resource managers, CDF personnel and other stakeholders in the project area. FS, CDF and other land managers interpret change maps by applying local knowledge and fieldwork to identify sources of change on Forest Service lands. Similarly, UC Integrated Hardwood Rangeland Management Program (IHRMP) personnel consult private landowners to identify sources of change in hardwood rangelands. Areas without a causal agent identified through the above processes become the focus of further field efforts and aerial photo interpretation. Despite all these efforts, full coverage of cause verification is not always possible due to the large number of change areas, insufficient information and inaccessible lands.

APPENDIX C - DATA ACCURACY

To assess the accuracy of the change map, 260 randomly selected change areas were compared with known reference information of the same areas. All change classes were represented with accuracy assessment sites based on the acreage amount of change (e.g., the little to no change class has the largest acreage thus contains the most sites). Sites were developed randomly selecting 5 to 20 acre polygons from all of the change areas. These areas were interpreted for canopy cover and shrub/chaparral change using color aerial photography at a scale of 1:15,840, digital camera images at a scale of 1:3000, Digital Orthophoto Quadrangles with a 1-meter cell size and field collected data. Essentially, this assessment takes the 260 reference sites with known vegetation change and compares them to the classified change map.

Table 1c. Change Code and Corresponding Change Class

Change Code	CHANGE CLASS
1	-71 to -100% CC
2	-41 to -70% CC
3	-16 to -40% CC
4	+15 to -15% CC (Little or No Change)
5	+16 to +40% CC
6	+41 to +100% CC
7	Grass/Shrub Decrease > 15%
8	Grass/Shrub Increase > 15%
15	Cloud or Cloud Shadow

Table 2c displays the error matrix for the South Coast project area. (See Table 1c for change code descriptions). The overall accuracy of the change map is 89.6%. This means that of the 260 sample sites, 233 were correctly classified (the reference and classified classes are the same; Congalton and Green,1999). Errors of commission (reference class included in the wrong classified class) and omission (reference class excluded from the correct classified class) are also evident. For example, in Table 2c, one site is classified as little or no change when the reference class shows it was actually a 16 to 40% decrease in canopy cover. Therefore, one area was omitted from the correct –16 to –40% CC class and committed to the incorrect +15 to –15% CC (little or no change) class. The producer's accuracy of each change class ranged from 67% to 100% and the user's accuracy ranged from 71% to 100% (Table 3c). Producer's accuracy represents how well a particular class is classified. Or in other words, of all the referenced sites that have a particular change class, how many times (or what proportion) did those sites get classified as such? For instance, of the six reference sites with a –15 to –40% CC, five of those sites were classified correctly. The user’s accuracy looks at the matrix from a different approach. Instead of looking at known reference data and calculating how many are correct (producer’s accuracy), the user’s accuracy looks at the number correctly classified and compares that to the number of sites in that classification. As an example, seven sites are classified into the –15 to –40% CC class, but five of those sites are actually referenced to be in that class. User's accuracy indicates the probability that a given change class actually represents that same change on the ground.

Table 2c. Change Map Accuracy Assessment for the Southern Sierra Project Area

		Reference Class										
	Change Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**15**	**Total**
Reference Class	**1**	7										**7**
	2		12									**12**
	3			5	2							**7**
	4			1	148	1		3	7	2		**162**
	5					4						**4**
	6						1					**1**
	7				4			15		1		**20**
	8				1	1			15			**17**
	9				4					25		**29**
	15										1	**1**
	Total	**7**	**12**	**6**	**159**	**6**	**1**	**18**	**22**	**28**	**1**	**160**

Table 3c. Producer's and User's Accuracy of Each Class

Class	**Producer's Accuracy**	**Users Accuracy**
1	100%	100%
2	100%	100%
3	83%	71%
4	93%	91%
5	67%	100%
6	100%	100%
7	83%	75%
8	100%	88%
9	89%	86%
15	100%	100%

The accuracy assessment also shows that general vegetation cover decreases and increases were mapped well. Accuracy assessment sites classified as a decrease were never a referenced increase, although a few sites were referenced as little or no change. The same is true for the areas classified as an increase. Additionally, a referenced decrease site was never classified as an increase and a referenced increase site was never classified as a decrease.

APPENDIX D – WHR TYPE DESCRIPTIONS

Species Compositions for major Hardwood, Conifer and Shrub/Chaparral WHR Types; Species in bold are dominant and species in non-bold are associates.

MONTANE HARDWOOD	BLUE OAK WOODLAND	Coastal Oak Woodland	Blue Oak/ FOOTHILL PINE
CA black oak **pacific madrone** **tanoak** **alder** **interior live oak** **canyon live oak**	**blue oak**	**Coast live oak**	**blue oak** **foothill pine**
Oregon white oak coast live oak California laurel valley oak blue oak foothill pine ponderosa pine	interior live oak coast live oak buckeye juniper canyon live oak valley oak ponderosa pine	California bay madrone tanbark oak canyon live oak	coast live oak interior live oak canyon live oak

SIERRA MIXED CONIFER	MONTANE HARDWOOD CONIFER	PINYON-JUNIPER	PONDEROSA PINE	JEFFREY PINE
white fir **Douglas fir** **Ponerosa pine** **sugar pine** **incense cedar**		**singleleaf pine** **Perry pine** **western juniper** **Utah juniper** **CA juniper**	**ponderosa pine**	**Jeffrey pine**
western redcedar	Ponderosa pine incense cedar Douglas fir tanoak madrone canyon live oak coast live oak	shrub oak CA scrub oak canyon live oak Mojave yucca ponderosa pine Jeffrey pine	white fir incense cedar coulter pine Jeffrey pine sugar pine Douglas fir bigcone Douglas fir	ponderosa pine coulter pine sugar pine lodgepole pine white fir red fir limber pine incense cedar

MIXED CHAPARRAL	MONTANE CHAPARRAL	CHAMISEREDSHANK
oaks **ceanothus** **manzanita**	**ceanothus** **manzanita** **bitter cherry**	**chamise** **redshank**
chamise mountain mahogany buckeye sumac buckthorn California fremontia		toyon sumac buckthorn ceanothus manzanita scrub oak

Source: Mayer and Laudenslayer, 1988.

APPENDIX E – WHR VEGETATION HIERARCHY

Lifeform	WHR Code	WHR Type
Hardwood	BOP	Blue Oak- Foothill Pine
	BOW	Blue Oak Woodland
	COW	Coastal Oak Woodland
	DRI	Desert Riparian
	MHW	Montane Hardwood
	MRI	Montane Riparian
	VOW	Valley Oak Woodland
	VRI	Valley Foothill Riparian
Conifer	JUN	Juniper
	CPC	Closed Cone Pine-Cypress
	DFR	Douglas Fir
	JPN	Jeffrey Pine
	MHC	Montane Hardwood-Conifer
	PJN	Pinyon-Juniper
	PPN	Ponderosa Pine
	RDW	Redwood
	SCN	Subalpine Conifer
	SMC	Sierran Mixed Conifer
	WFR	White Fir
Shrub/ Chaparral	ADS	Alpine Dwarf Shrub
	ASC	Alkali Scrub
	CRC	Chamise-Redshank Chaparral
	CSC	Coastal Scrub
	DSC	Desert Scrub
	DSS	Desert Succulent Scrub
	DSW	Desert Wash
	MCH	Mixed Chaparral
	MCP	Montane Chaparral
	SGB	Sagebrush
	UND	Undetermined Shrub/Chaparral Type

Source: Mayer and Laudenslayer, 1988.

APPENDIX F – CALVEG CODES

Lifeform	CALVEG Code	CALVEG Description
Hardwood	QC	Canyon Live Oak
	QD	Blue Oak
	QG	Oregon White Oak
	QJ	Cottonwood/Alder
	QK	California Black Oak
	QM	Bigleaf Maple (Dogwood)
	QO	Willow
	QQ	Quaking Aspen
	QR	Red Alder
	QT	Tanoak
	QY	Willow-Alder
	QW	Interior Live Oak
	TA	Mountain Alder
	TC	Tree Chinquapin
Conifer	DF	Pacific Douglas-Fir
	DP	Douglas Fir-Pine
	DT	Douglas Fir-Tanoak
	DW	Douglas Fir-White Fir
	EP	Eastside Pine
	JP	Jeffrey Pine
	KP	Knobcone Pine
	LP	Lodgepole Pine
	MF	Mixed Conifer-Fir
	MP	Mixed Conifer-Pine
	PD	Gray Pine
	PO	Port Oreford Cedar
	PP	Ponderosa Pine
	PW	Ponderosa Pine-White Fir
	RD	Redwood-Douglas Fir
	RF	Red Fir
	SA	Subalpine Conifers
	WB	Whitebark Pine
	WF	White Fir
	WJ	Western Juniper
	WW	Western White Pine
Shrub/Chaparral	BB	Bitterbrush
	BL	Low Sagebrush
	BS	Basin Sagebrush
	CB	Salal-California Huckleberry Shrub
	CC	Ceanothus Chaparral
	CG	Greenleaf Manzanita
	CH	Huckleberry Oak
	CL	Wedgeleaf Ceanothus
	CM	Upper Montane Mixed Shrub
	CN	Pinemat Manzanita
	CQ	Lower Montane Mixed Chaparral
	CS	Scrub Oak
	CW	Whiteleaf Manzanita
	CX	Montane Mixed Chaparral

Source: USDA Forest Service Regional Ecology Group, 1981