Land Cover Mapping and Monitoring Program

North Coast Project Area Report, Cycle II (1998 - 2003)

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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 derive land cover change (losses and gains) within five-year periods (approximate timeframes). This report summarizes vegetation change between 1998 and 2003 (second cycle) for the North Coast project area, one of five project areas under the LCMMP. 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.

The North Coast project area covers all or most of Alameda, Del Norte, Humboldt, Lake, Marin, Mendocino, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Sonoma and Trinitycounties, and covers portions of twelve other counties. It also completely encompasses the Mendocino and Six Rivers National Forests, partially covers the Shasta-Trinity National Forest and covers a small portion of the Siskiyou National Forest. 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 North Coast Project Area in the time period 1998 to 2003 resulted in a change in canopy cover over 3% or 447,629 acres. Decreases across vegetation types occured on approximately 197,500 acres or 1.4% of the project area, and increases on about 109,500 acres or 0.8%. Fire and harvest/plantation activity was the primary cause for both increase and decrease in vegetation and is summarized below. Development, pests, agricultural conversion and unidentified causes accounted for the remainder of the change detected. Approximately 94% of the change area was labeled with a cause type, only 6% of the overall change was due to unidentified causes.

Causes of Decreased Vegetation Cover

- 64% of the total change was due to a decrease in vegetation cover
- Net loss of 85,000 acres of conifer cover
- Net loss of 20,500 acres of hardwood cover
- 41% of the vegetation decrease was fire related, 76% from four fires, greater than 500 acres
- Compared with change from cycle 1 there was much less fire, (79,075 acres) than cycle 2 (132,778 acres) with most of the fire activity in the first cycle due to the 1996 Forks fire
- 46% of the vegetation decrease was harvest/plantation related
- 47% of the harvesting and management activities on private land were clearcuts

Causes of Increased Vegetation Cover

- 36% of the total change was due to an increase in vegetation cover
- 33% of the vegetation increase was post-fire regrowth/planting
- 61% of the vegetation increase was harvest/plantation related

Change and Land Ownership

- Timber harvesting on private land accounted for most of the change in the North Coast, while fire on federal land accounted for most of the change further inland from the coast.
- Fire affected approximately 184,000 acres on US Forest Service land, accounting for 74% of change in canopy cover on USFS land.
- Fire affected approximately 40,000 acres on private land, accounting for 53% of the change in canopy cover on private land.
- Harvesting occurred on approximately 167,000 acres of private land, and 12,000 acres of US Forest Service land.

INTRODUCTION

The California Land Cover Mapping and Monitoring Program (LCMMP) is a collaboration between the USDA Forest Service (FS) and the California Department of Forestry and Fire Protection (CDF) to create seamless vegetation and monitoring data across most ownerships and vegetation types within the state. This program uses Landsat Thematic Mapper (TM) satellite imagery to derive land cover change (vegetation decreases and increases) within five-year periods. It also determines the cause of change through fieldwork, aerial photo interpretation and GIS analysis. Monitoring data created by the LCMMP quantify changes in California's landscape and provide necessary information for regional assessment across jurisdictional boundaries. These data provide consistent, high quality information to manage, assess and protect California's diverse vegetation resources at a low per acre cost (approximately $0.01 per acre).

Reporting is complete for all areas. Completed reports can be downloaded from http://www.fs.fed.us/r5/spf/publications/landcover/index.shtml. The FS and CDF have mapping, resource management and resource protection responsibilities across much of the non-irrigated and non-urban land in the north coast region. The FS manages most 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 provide a single consistent source of current landscape level and site-specific change to the FS and CDF as well as other interested 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.

Monitoring land cover change occurs in one of five distinct project areas per year (Figure 1). Statewide analysis is now complete for all project areas covering two time periods ranging from 1994 through 2003. This time frame is broken into two 5-year cycles. Land cover monitoring maps can be downloaded from http://www.fs.fed.us/r5/spf/fhp/fhm/landcover/geodatabase.shtml. The north coast project area covers all or most of Alameda, Del Norte, Humboldt, Lake, Marin, Mendocino, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Sonoma and Trinity counties, while partially covering twelve other counties. It also completely encompasses the Mendocino and Six Rivers National Forests, partially covers the Shasta-Trinity National Forest and covers a small portion of the Siskiyou National Forest, and other federal, state, county and privately owned lands (Figures 2 and 3). This report assesses land cover changes on 16.5 million acres within conifer, hardwood, shrub/chaparral and grass/forb vegetation types from 1998-2003. Although the total project area spans 16.5 million acres of land, 2.4 million acres are non-vegetated (e.g., urban, agriculture, barren and water) and are not included in this analysis.

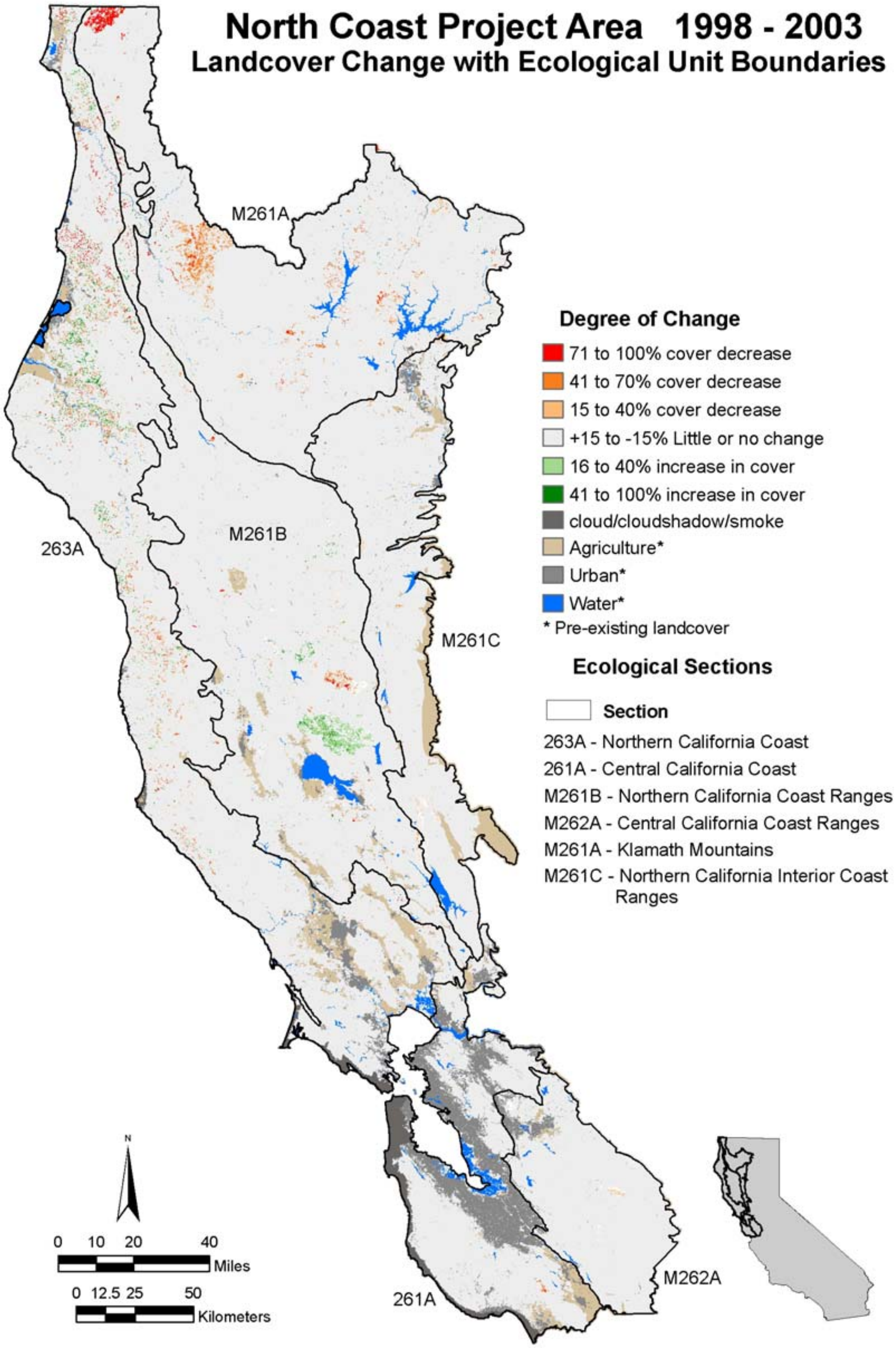

Figure 1. Ecological regions and landcover change of the North Coast Project Area.

STUDY AREA

Ecoregions of the North Coast project area

The north coast region of California is divided into 6 ecological subregions (or sections) based on the associations of biotic and environmental factors including climate, geomorphology and vegetation communities (Miles and Goudy., 1997). The sections listed below are wholly or partially covered by the north coast project area boundary (figure 1).

1. Section 263A - Northern California Coast
2. Section 261A - Central California Coast
3. Section M261A - Klamath Mountains
4. Section M261B - Northern California Coast Ranges
5. Section M261C - Northern California Interior Coast Ranges
6. Section M262A – Central California Coast Ranges

Coastal

The two coastal sections, 263A and 261A have a maritime climate with summer fog and an annual precipitation ranging from a low of 305 to 508 mm (12 to 20 inches) in the Santa Clara Valley up to 1524 to 3048 mm (60 to 120 inches) along the Del Norte county coast to the north (McNab and Avers, 1994). Elevation ranges from sea level to 912m (3000 ft). Average temperatures range from 10-17° C (50-63° F). The higher rainfall and summer fog in the coastal sections support the coast redwood (*Sequoia sempervirens*), which is restricted to a narrow coastal strip.

Inland

The adjacent inland mountainous sections (M261A and M261B) receive annual precipitation ranging from 760 to 3050 mm (30 to 120 inches). Elevation ranges from 304 to 2432m (1000 to 8000 ft). Average temperatures range from 7-15° C (45-59° F) The natural disturbance regime for these regions was historically dominated by frequent, low intensity fires, especially at low to mid elevations.

The Northern California Interior Coast Ranges (M261C) and the Central California Coast Ranges (M262A) receive annual precipitation ranging from 250 to 1,020 mm (10-40 inches). Elevation ranges from 61 to 1064m (200-3500 ft.). Average temperatures range from 13-18° C (55-64° F). Fire is the primary natural disturbance.

Vegetation

The distribution of vegetation life forms is distinct for each of the six ecological sections. Conifers and hardwoods are the predominate life forms in the Northern California Coast, Klamath Mountains, and Northern California Coast Ranges (263A, 261A and M261B). Urban land cover dominates the Central California Coast section (261A), which includes the San Francisco bay area. Hardwoods and grasslands dominate the drier inland valleys (Northern California Interior Coast Ranges (M261C) and Central California Coast Ranges (M262A) (Figure 2).

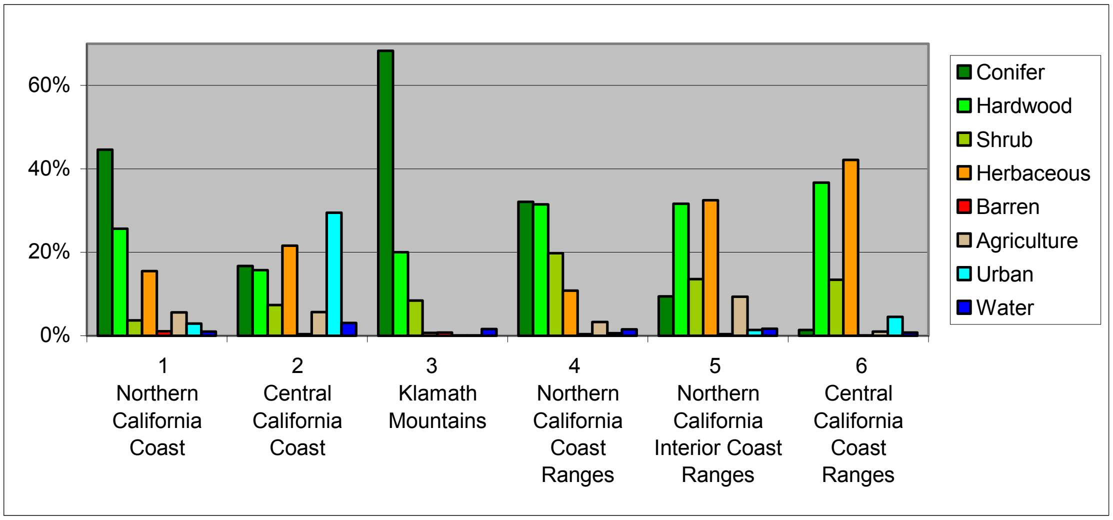

Figure 2 Vegetation life form percentages within the north coast ecological sections.

Ownership

The study area encompasses the Mendocino and Six Rivers National Forests, partially covers the Shasta-Trinity National Forest and covers a small portion of the Siskiyou National Forest, and other federal, state, county and privately owned lands (Figure 3).

The Northern California Interior Coast Ranges (M261C) and Central California Coast Ranges (M262A) are primarily in private ownership. Although most of the land in the Klamath mountains section is in the Shasta-Trinity and Six Rivers national forests, most of the logging is on private in-holdings and Tribal land. About half the land ownership in the Northern California Coast Ranges section is federal but again, most of the timber harvesting is on private and Tribal reservation lands.

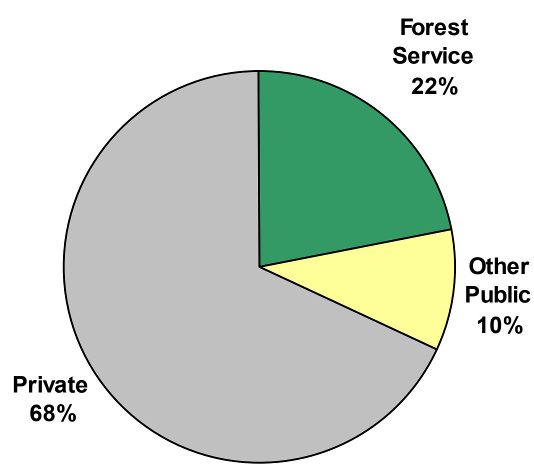

Figure 3. Ownership for the North Coast Project Area.

METHODS

Preprocessing

Terrain corrected image pairs are acquired and coregistered using a nearest neighbor resampling method to maintain the spectral integrity of the data. A maximum RMSE of 0.5 is required to minimize or eliminate false change. 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).

Data processing

Image data are from the Landsat TM and ETM+ sensors (see Landsat Project for more details: http://landsat.usgs.gov). Change processing (Figure 4) begins by applying the Kauth-Thomas (KT) transformation to both dates of coregistered imagery (Kauth and Thomas, 1976). The KT transformation uses model coefficients, specific to the Landsat sensor, to produce three orthogonal axes: brightness, greenness, and wetness (BGW) (Crist and Cicone, 1984). The time 2 BGW images are regressed against the time 1 BGW images and the Euclidean distance of residuals is calculated to reduce phenological differences between the two times (personal communication, Richard Walker). An unsupervised and maximum likelihood classification is performed for each stratified lifeform resulting in a relative change image.

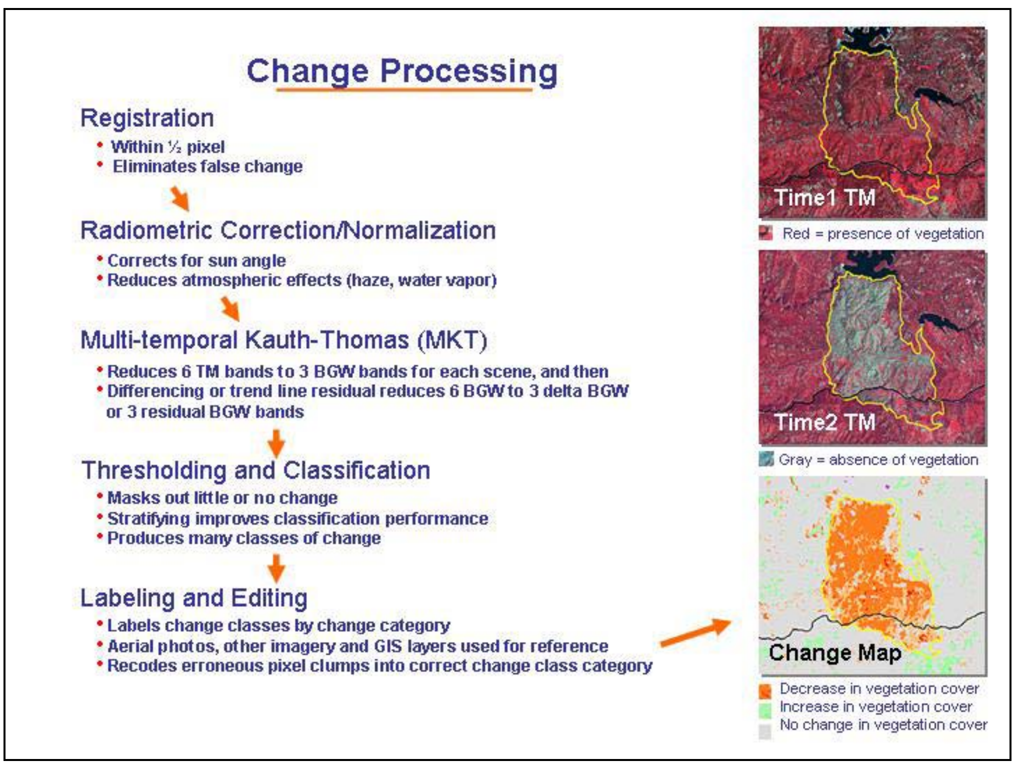

Figure 4. Change processing methodology.

Ancillary Data

Vegetation data is compiled from multiple sources including eVeg (R5 USDA-FS Remote sensing Lab, Ecosystem Planning), California multi-source vegetation (CDF-FRAP) and GAP

Analysis data (USGS-NBII Program). The California Wildlife Habitat Realtionships (CWHR) classification system is used for the final vegetation layer. Vegetation layers not in this classification system, such as CalVeg (USDA-Forest Service, Regional Ecology Group, 1981), are crosswalked using standardize corporate crosswalks.

A multi-source change cause layer is created from timber harvest plans (CDF), stand records system (USDA-FS), FACTS, regional fire layers and other ancillary GIS layers that contain information for attributing the cause of canopy cover decrease.

Change Labeling

Change labeling converts the change image to a change map that identifies relative decreases and increases in vegetation cover. These groupings are assigned to one of nine change classes (Table 1). Photo interpretation, vegetation data, topographic maps, GIS data and bi-spectral plots aid in assigning change class labels.

Table 1. 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)

Accuracy assessment

A formal accuracy assessment was not conducted for cycle 2 of the North Coast project area due to budget and time constraints. Since methods used for mapping change are consistent between both cycles, the accuracy assessment from the first cycle can be used as *a proxy* of the accuracy that can be expected for the second cycle (Appendix C). For a full accuracy assessment from cycle 1 go to: http://www.fs.fed.us/r5/spf/fhp/fhm/landcover

The final change map includes the change information which displays the land cover change classes, and a change-cause layer which contains attribute information detailing the natural or anthropogenic disturbance event responsible for the change in canopy cover (fire, type of harvest, etc.).

RESULTS AND DISCUSSION

HIGHLIGHTS FOR NCCDP2 - 1998 - 2003

Major Findings

From 1998 to 2003, change in canopy cover affected 3% of the total North Coast Project Area, with the amount of change evenly split between increases and decreases in canopy cover. The primary causes for decrease in canopy cover were fire and timber harvesting (Figure 5). Post-fire and timber harvest regeneration were the main contributors to regrowth or canopy cover increases. Development, pests, agricultural conversion and unidentified causes accounted for the remainder of the change detected through our analyses (Table 2). Approximately 6% of the overall change was due to unidentified causes. These areas of change are unaccounted for because no ancillary GIS data was available at the time of cause attribution.

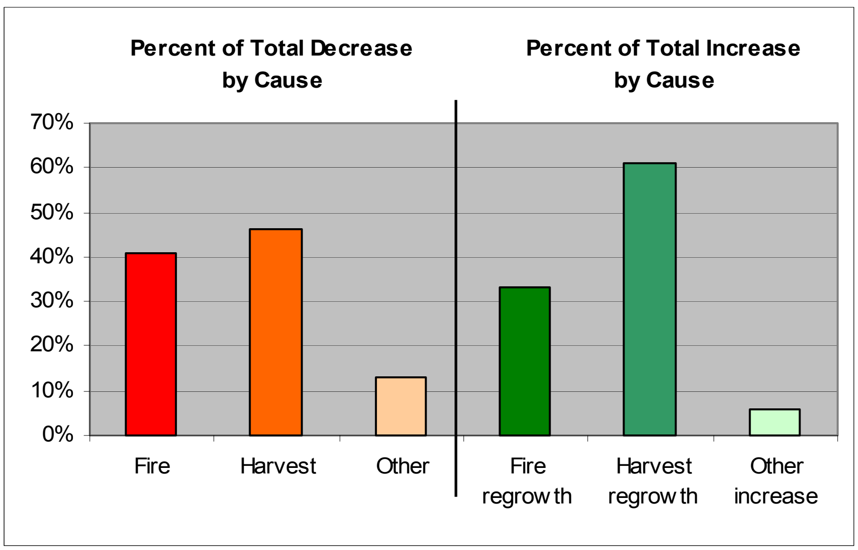

Figure 5. North Coast Project Area 1998 - 2003. Vegetation increase and decrease by cause.

Although there were many fires within the project area between 1998 and 2003, most of the change due to fire was the result of a few large (>500 acres) fires. The Megram fire of 1999 (124,440 acres) accounted for more than half the acreage within fire boundaries. The four largest fires together accounted for 76% of the decrease in vegetation due to fire (100,596 acres of decrease in vegetation). Most of the regrowth in the project area is the result of post-fire regeneration detectable in cycle 1. The Forks fire of 1996 accounts for more than half of the regrowth in cycle 2. Most of the change occurred in the Northern Coast/Range and the Klamath Mountains, with very little change detected in the Central and Interior Coast/Range (Figure 6). Timber harvesting on private land accounted for most of the change in the North Coast, while fire on federal land accounted for most of the change further inland from the coast.

Table 2. Acres of cause of change in the North Coast Project Area, 1998-2003.

	Cause of Change								
Change Class	Fire	Harvest	Devlelopment	Pest	Regrowth	Other	Unknown	Total Acres	% of Total
-71 to -100% CC	25,980	35,817	811	26	224	1,435	1,294	65,588	0.4%
-41 to- 70% CC	30,643	34,952	637	30	288	1,725	5,552	73,827	0.5%
-15 to -40% CC	36,512	42,398	962	64	453	1,912	8,658	90,958	0.6%
-15 to +15% CC*	0	0	0	0	0	0	15,518,102	15,518,102	96.1%
+16 to +40% CC	4	823	425	0	80,141	333	3,045	84,772	0.5%
+41 to +100% CC	11	453	159	0	39,797	125	1,495	42,040	0.3%
Shrub/grass CC < -15 %	39,203	5,780	5,215	3	121	2,978	3,294	56,593	0.4%
Shrub/grass CC > +15%	10	575	84	0	30,238	238	2,705	33,850	0.2%
Cloud/smoke	0	0	0	0	0	0	174,961	174,961	1.1%
Total Acres	132,364	120,798	8,294	123	151,262	8,745	15,719,106	16,140,692	100%

* Little or no change. This includes agriculture, urban, and water which are not analyzed

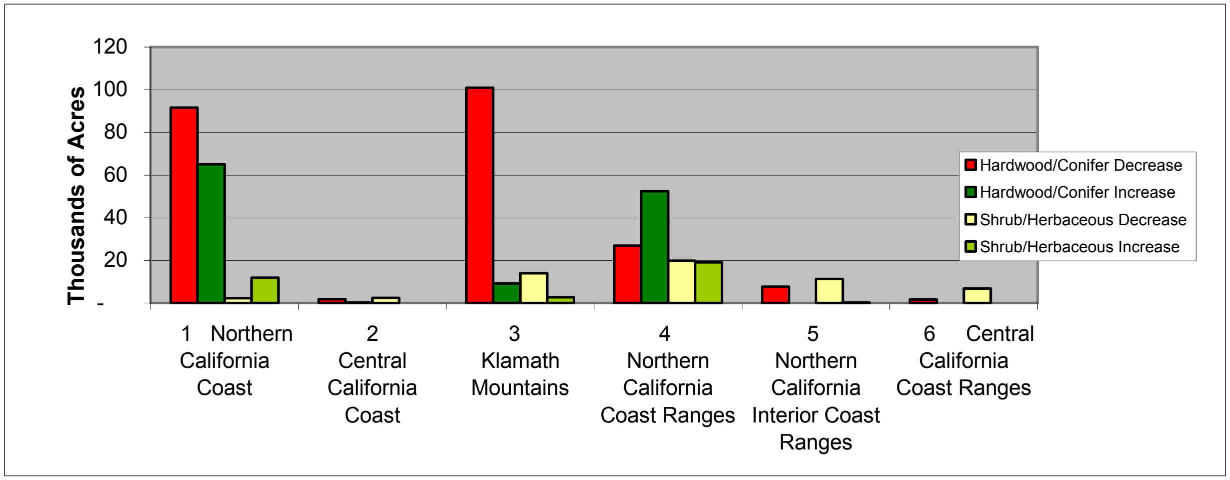

Figure 6. Distribution of change within each ecological section.

Change by Life Form

In the North Coast project area, conifer is the dominant life form type followed by hardwoods, shrubs and grass/herb. These types account for 90% of the landcover in the North Coast, with the remaining 10% falling into urban, agricultural, barren and water classes (Figure 7). Decreases in vegetation cover by area were greater than increases in vegetation for all life form classes, except for barren.

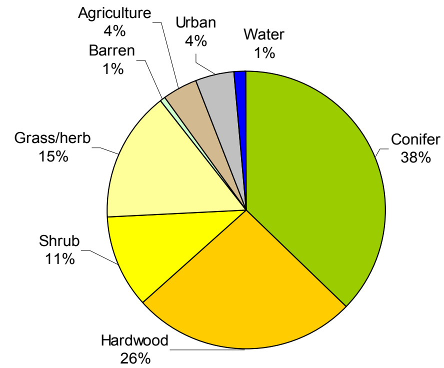

Figure 7. Landcover for the North Coast Project area, by percent of total area.

- Conifer decrease ~85,000 acres
- Hardwood decrease ~20,500 acres
- Shrub cover declined by approximately 24,000 acres
- Grass/herb cover declined by roughly 1,300 acres.
- Land classed as barren increased by approximately 3,000 acres (Figures 8 and 9).

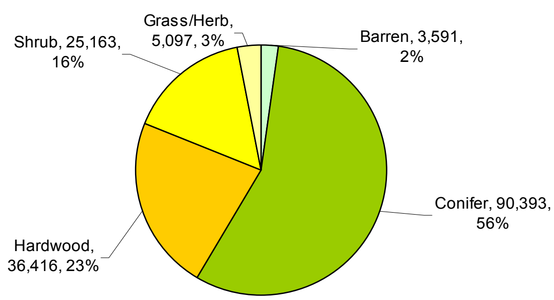

Figure 8. Increase in vegetation cover by life form, in acres and percent of total area, 1998-2003.

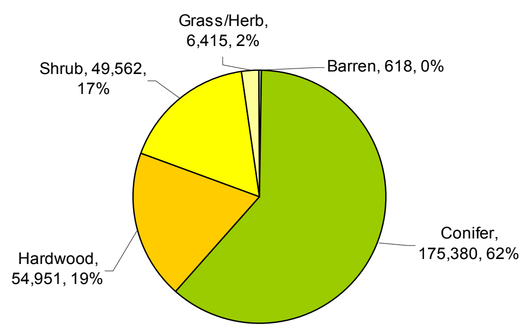

Figure 9. Decrease in vegetation cover by life form, in acres and percent of total area, 1998-2003.

Timber harvest and plantation activity on private and Forest Service land

Change due to timber harvesting and plantation activity was verified using the stand record system (SRS) on national forest land and timber harvest plan data (THP) on private land. Obvious recent clearcuts were labeled during the cause editing process. Clearcuts identified in the imagery and not part of the cause database represented ~13% of the total area harvested and were identified using the SRS or THP databases.

- Most harvesting and management activities (such as shelterwood cuts) occurred on private land and 47% of that was from clearcuts
- Most clearcut harvesting activities on private land resulted in a large decrease in vegetation cover
- The majority of other harvests, such as shelterwood removal and pre-commercial thins, showed a small decrease in vegetation, 45% and 40%, respectively

- Harvests with unidentified cause on both private and forest service land exhibited a change class pattern similar to identified management harvests and pre-commercial thins.

Forest Stand Density Relationships to Change in Vegetation Canopy Cover

Forest canopy density analysis was completed using vegetation data generated from the same imagery used for change detection. There are over 9 million forested acres in this project area with 72% of the forest having at least 60% tree canopy cover. The largest canopy cover class, 70-79%, comprises 25% of the total forested acres. Figure 10 shows the distribution of tree density, including conifer, hardwood and mixed lifeform, over the 9 density classes.

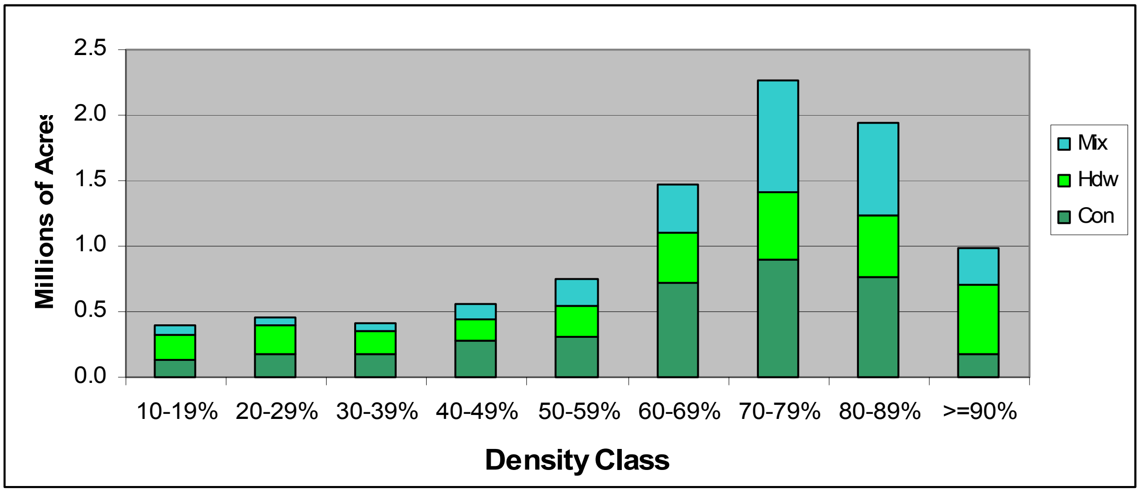

Figure 10. Distribution of Stand Density in project area by lifeform.

The mean tree stand density for both change and little or no change is 67%, with distribution of density by change class shown in Figure 11.

- In high density stands, harvesting was the primary cause of change (47% of total acreage) followed by fire (28%)

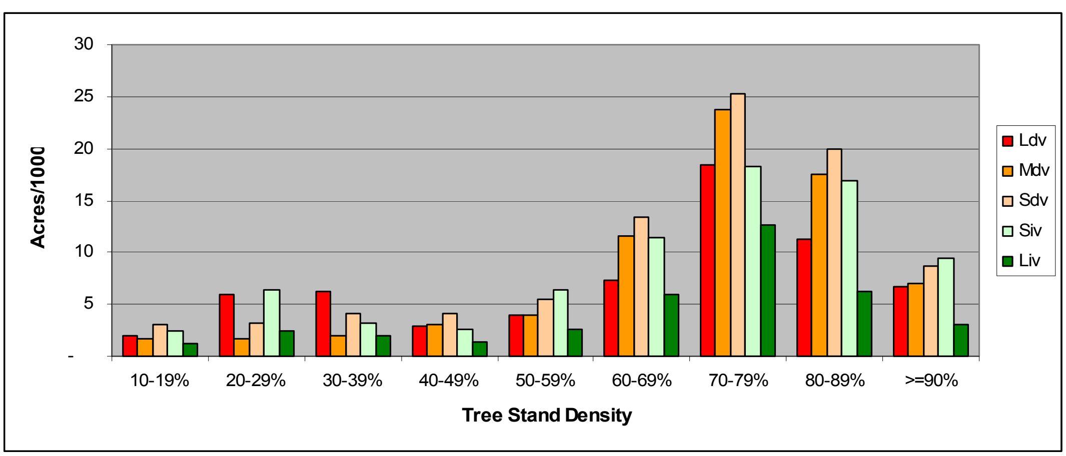

Figure 11. Distribution of change class by stand density for all causes; fire, harvest, and other.

Comparing the distribution of tree canopy cover decrease within fire perimeters (Figure 12) by tree density class between cycle 1(1993-1998) and cycle 2(1998 – 2003) show:

- Larger fires occurring over higher canopy densities.
- Fires primarily responsible for these trends include:
  - 2002 Biscuit fire (501,000 acres),
  - 1999 Megram fire (124,400 acres),
  - 1996 Forks fire (83,000 acres),
  - 1995 Vision fire (11,800 acres).

Most of the decrease in vegetation due to fire falls within the small and moderate change classes, especially in the denser stands (Figure 13).

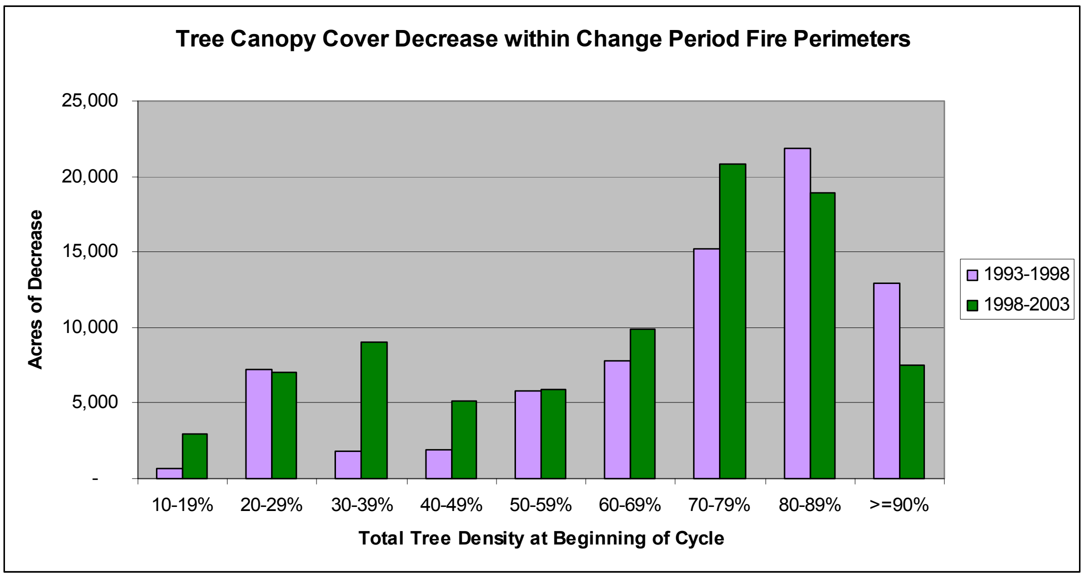

Figure 12. Tree canopy cover decrease within change period fire perimeters. Cycle 1 1993-1998, Cycle 2 1998-2003

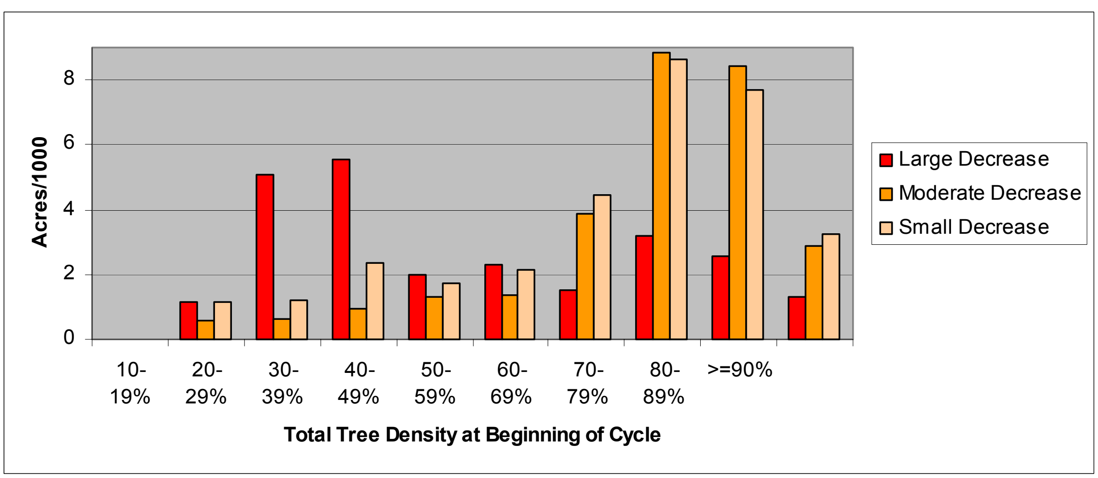

Figure 13. 1998-2003 canopy cover decrease by fire perimeters.

Changes detected in canopy cover over the five years from 1998-2003 in the North Coast project area followed similar patterns as those detected in the first change detection cycle for the North Coast project area in terms of both agents of change and where change occurred. Based on the data collected over the 10 year period from the two change detection cycles, timber harvesting on private land and fire will likely continue to be the dominant sources of disturbance across the landscape in the North Coast study area.

The two largest fires that occurred in the North Coast study area, the Megram fire of 1999 and the Biscuit fire of 2001 burned over extensive areas and accounted for the majority of the reduction of canopy cover due to fire in the study area. Some areas within the Megram fire perimeter had been previously treated to reduce surface and ladder fuels, which reduced fire severity in those areas (Agee and Skinner, 2005). The effects of these treatments may also be reflected in the change data that show for the area within the Megram fire perimeter, most of the reduction in canopy cover fell within the moderate and small decrease change classes. One potential application of the change data may be in assessing the effectiveness of treatments in reducing fire severity.

The information summarized in this report can provide an invaluable source of information for monitoring how the landscape is changing, and how these changes may impact management goals on both private and public land. Monitoring change may also be critical for assessing impacts to wildlife habitat and overall stand structure and predicting potential future conditions based on current land-use practices and policies. While beyond the scope of this report, the monitoring data can also be used for analyzing landscape-scale changes in spatial patterns of vegetation cover (Staus et al. 2002) over time.

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APPENDIX A-DATA SOURCES

Image Data

TM imagery provides the base data for deriving changes in vegetation cover. The North Coast project area requires seven TM images from each date (14 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 consists of thousands of pixels, each having a spatial resolution of 900 m2 (30 m on each side) or approximately 1/5 of an acre.

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. WHR stands for Wildlife Habitat Relationships System, and is a habitat 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, or crosswalk, CALVEG types from WHR types or other vegetation labels from non-LCMMP vegetation layers. However, WHR types can be ascertained, or crosswalked, from CALVEG labels, which is the current method for obtaining WHR types in areas mapped by LCMMP.

For the analysis of the North Coast project area, CALVEG types were analyzed only on Forest Service land, because Forest Service managers and personnel prefer the detailed CALVEG label. For reporting that was not limited to Forest Service land, analysis was performed and summarized using the WHR type. See Appendix E and F for WHR and CALVEG code descriptions.

LCMMP vegetation data are not available for the entire project area, so the best available vegetation data are collected and combined into one seamless layer (Table 1a). Vegetation layers in vector format are converted to raster 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. LCMMP vegetation data are used for most of the project area. Areas in and around the Bay Area are not currently mapped by the LCMMP. The CDF Hardwood Rangelands map is then used where LCMMP vegetation data does not exist. The GAP vegetation data is used where LCMMP and CDF data does not exist.

In areas where both a primary and secondary CALVEG label existed, the WHR type also drives what CALVEG type was used in the analysis. Using the example from the previous paragraph, if the primary CALVEG label was Sitka spruce and the secondary CALVEG label was red alder, then, depending on the size and density of each CALVEG type, some of the areas would be assigned a WHR type of montane hardwood and some of the areas would be assigned a WHR type of montane hardwood-conifer. In those areas assigned a WHR type of montane hardwood, red alder would be the CALVEG type that was reported on and analyzed. Conversely, in those areas assigned a WHR type of montane hardwood-conifer, Sitka spruce would be the CALVEG type that was reported on and analyzed.

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

Name	Classification	Source	Resolution	Extent	Percent of Project Area
CA Mapping & Monitoring Program Vegetation Data	CALVEG / WHR	1997 TM imagery	2.5 acre minimum mapping unit	All of project area excluding in and around the Bay Area	100
Hardwood Rangelands	WHR	CDF, updated 1990	25 meters	Hardwood Rangelands Below 5000 ft.	19
Gap Analysis 1990	WHR	TM Imagery, field data	100 Hectares (250 acres)	Statewide	1

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 North 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 includes the preparation of Thematic Mapper (TM) imagery for processing. The early date TM image (time 1) is registered to the later date TM image (time 2). Registration matches the position of ground features (from time 1 and time 2) and is accomplished by creating control points that identify identical features throughout both images (e.g., road intersections). These control points 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 help reduce false change. The images are then radiometrically corrected to account for differences in atmospheric conditions (e.g., haze and water vapor). This process involves the selection of dark and light groups of pixels in each image date followed by the application of a regression-based correction to the pixel brightness values of the early date image to effectively remove differences in atmospheric conditions (Schott et al., 1988).

Change Processing

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 0.45μm to 0.52μm, which corresponds to the color blue. The thermal-IR band was not used because its pixel size is 120 meters on each side (all other bands are 30 meters on each side). The spectral information of the 12 bands (six for each date) of the co-registered and radiometrically corrected TM imagery is reduced to three bands in two steps. First, a Kauth-Thomas transformation is applied to each date. For each TM image, the Kauth-Thomas transformation uses the spectral information from six bands with 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. Then 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; time 2 – time 1) to produce a new three band image depicting changes in those components on a pixel-by-pixel basis (the delta brightness/greenness/wetness (dBGW) image).

Threshold Mask

A thematic layer was created for each scene processing area which identifies the following classes: urban, water, and agriculture (derived directly from the master vegetation image) and thresholded pixels representing much of the little or no change, large decrease in vegetation, large increase in vegetation and non-vegetation change which were easy to identify. In the thresholding process, ranges of delta brightness, delta greenness and delta wetness for these classes were determined interactively on an 8-bit dBGW image by manipulating the lookup table breakpoints and then applied in a model to create the threshold mask (Maurizi and Longmire, 2002). This mask reduces the number of pixels that need to be classified and labeled.

Classification

Classification is a multi-step process that converts the dBGW change image into a change map depicting decreases and increases in cover or changes in grass. The change image was divided into multiple parts (stratified), with each part (or map subset) corresponding to a different lifeform type (e.g., conifer, hardwood, shrub/chaparral). This was accomplished by overlaying the vegetation layer and threshold mask and selecting those areas in the change image that had the same lifeform and were not already identified with a change class. The result was multiple change images, with each one corresponding to a different lifeform and spatial extent. An unsupervised classification of the 16 bit dBGW image was performed on each individual lifeform change image to create 15 to 30 distinct classes (depending on lifeform and areal extent), with each class containing pixels that had similar levels of brightness, greenness and wetness.

Change Labeling

The pixels were temporarily labeled according to their level of change based on a qualitative gradient from large decreases in vegetation to large increases in vegetation. Image appearance, aerial photos, bispectral plots (e.g., greenness vs. wetness), and vegetation and topographic maps were used to aid in assigning the final quantitative change classes (Table 1b). Each individual lifeform change image was 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 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
Grass/Shrub Decrease > 15%	16 to 100% decrease in grass
Grass/Shrub Increase > 15%	16 to 100% increase grass
Cloud, Cloud Shadow or Smoke	Clouds, cloud shadows or smoke (prevents change assessment)

Once the change image was mosaicked, pixels of similar change classes that were adjacent to each other are temporarily grouped together. All increases in canopy cover and shrub/grass are grouped together, all decreases in canopy cover and shrub/grass are grouped together and non-vegetation change pixels are grouped together. These groups were then filtered to see if they meet the minimum mapping unit (mmu) of 2.5 acres, or 11 pixels. All groups that did not meet the mmu were removed from the change map and assigned the change class matching the majority of the surrounding pixels (usually little or no change). The temporary groupings were then removed, giving the pixels their original value (change class).

The classification system was designed to discriminate between different levels of change in cover (i.e., 16 to 40% CC decrease vs. 71 to 100% CC decrease). The +15 to -15% CC (little or no change) indicates either that change did not occur, that the change area falls below the mmu or that the change was too subtle to be detected. The 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 has changed or remained stable in these areas.

Cause Verification

Once the final change map was complete, an attempt was made to verify cause on all change areas. GIS overlay analysis, fieldwork and photo interpretation are used to determine the causes of change areas. The statewide fire history database was overlaid onto the change map to attribute changes caused by wildfires. A series of cause identification workshops were conducted and include FS resource managers, CDF personnel and other stakeholders in the project area. FS, CDF and other land managers interpreted change maps by applying local knowledge and fieldwork to identify sources of change on public lands. Similarly, UC Integrated Hardwood Rangeland Management Program (IHRMP) personnel consulted 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 of these efforts, complete coverage of cause verification was 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, 10 to 30 acre polygons for use as reference data were randomly selected from all of the change classes (see Table 1c for change class descriptions). The number of reference sites per change class was based upon the acreage amount of change (e.g., the little or no change class has the largest acreage thus the most sites), with a goal of 50 reference sites per change class.

Reference sites 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. A number of the reference sites had to be discarded from the accuracy assessment because the data used to determine vegetation cover change for each of them was either absent or of poor quality. The final result was 382 reference sites. These 382 sites with known vegetation change were then compared to the classified change map to create an error matrix.

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	Shrub/Grass Decrease > 15%
8	Shrub/Grass Increase > 15%
9	Change Within Existing Developed Area
15	Cloud or Cloud Shadow

Table 2c displays the error matrix for the North Coast project area. (See Table 1c for change code descriptions). The overall accuracy of the change map is 89.8%. 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 measures how well the reference class of a particular change type is classified, while the user's accuracy indicates the probability that an area classified as a particular change type actually represents that category on the ground.

Table 2c. Change Map Accuracy Assessment Error Matrix for the North Coast Project Area

		Reference Class									
Map Classification	**Change Code**	1	2	3	4	5	6	7	8	9	**Total**
	1	14									**14**
	2	3	10	1							**14**
	3	1	2	21	2						**26**
	4			2	218	4		5		6	**235**
	5				1	18	1				**20**
	6				1	3	12				**116**
	7				1			10			**11**
	8				4				23		**27**
	9				2					17	**19**
	Total	**18**	**12**	**24**	**229**	**25**	**13**	**15**	**23**	**23**	**382**

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

Producer's Accuracy

1	14/18	78%
2	10/12	83%
3	21/24	88%
4	218/229	95%
5	18/25	72%
6	12/13	92%
7	10/15	67%
8	23/23	100%
9	17/23	74%

User's Accuracy

1	14/14	100%
2	10/14	71%
3	21/25	81%
4	218/235	93%
5	18/20	90%
6	12/16	75%
7	10/11	91%
8	23/27	85%
9	17/19	89%

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	Blue Oak/ FOOTHILL PINE	COASTAL OAK WOODLAND
CA black oak **pacific madrone** **tanoak** **alder** **interior live oak** **canyon live oak**	**blue oak**	**blue oak** **foothill pine**	**coast live oak**
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	coast live oak interior live oak canyon live oak	California bay madrone tanbark oak canyon live oak

DOUGLAS FIR	REDWOOD	KLAMATH MIXED CONIFER	MONTANE HARDWOOD-CONIFER
Douglas fir **port orford cedar** **Jeffrey pine** **sugar pine** **western hemlock**	**redwood** **Douglas fir** **red alder** **grand fir** **tanoak**	**white fir** **Douglas fir** **Ponerosa pine** **sugar pine** **incense cedar**	
tanoak CA huckleberry poison oak	western redcedar western hemlock Bishop pine Monterey pine sugar pine Jeffrey pine	lodgepole pine Jeffrey pine knobcone pine port orford cedar canyon live oak Ca. black oak	Ponderosa pine incense cedar Douglas fir tanoak madrone canyon live oak coast live oak

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

APPENDIX E – WHR VEGETATION HIERARCHY

Lifeform	WHR Code	WHR Type
Hardwood	ASP	Aspen
	BOP	Blue Oak- Foothill Pine
	COW	Coastal Oak Woodland
	EUC	Eucalyptus
	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
	EPN	Eastside Pine
	JPN	Jeffrey Pine
	KMC	Klamath Mixed Conifer
	LPN	Lodgepole Pine
	MHC	Montane Hardwood-Conifer
	PPN	Ponderosa Pine
	RDW	Redwood
	SCN	Subalpine Conifer
	SMC	Sierran Mixed Conifer
	UCN	Undetermined Conifer
	WFR	White Fir
Shrub/ Chaparral	BBR	Bitterbrush
	CRC	Chamise-Redshank Chaparral
	CSC	Coastal Scrub
	DSC	Desert Scrub
	LSG	Low Sagebrush
	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