

**MONITORING WILDLAND VEGETATION IN CALIFORNIA
ON A 5-YEAR COORDINATED SCHEDULE
USING REMOTE SENSING, GIS AND GROUND BASED SAMPLING**

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Abstract

The USDA Forest Service (FS), Pacific Southwest Region (Region5) and the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CDF) coordinate vegetation mapping and land cover monitoring within California. Remotely sensed data, geographic information systems (GIS), and ground based plots are used to accomplish program goals. Data generated from this program describe the extent and condition of various land cover types, and the magnitude and cause of land cover changes. This information serves as the basis for assessing the vegetation resources and associated uses such as: forest health, timber volume and growth, wildlife habitats, old growth forests, watershed conditions, and fire hazard and risk. The cooperative program uses a coordinated schedule on a 5-year cycle which includes the acquisition of airborne and satellite imagery, baseline vegetation mapping, land cover monitoring and field inventory measurements.

Introduction

The Coordinated 5-Year Schedule

Over time the landscape is modified by natural and human events. Resource agencies are tasked with mapping, monitoring and assessing these alterations. Creating baseline vegetation data from which to monitor changes over time can help resource managers to evaluate the effects on wildlife habitats or fire conditions and, influence management and policy decisions. Methods for mapping and monitoring range from field sampling to use of remotely sensed data. Satellite imagery has proven more cost effective for large area analysis.

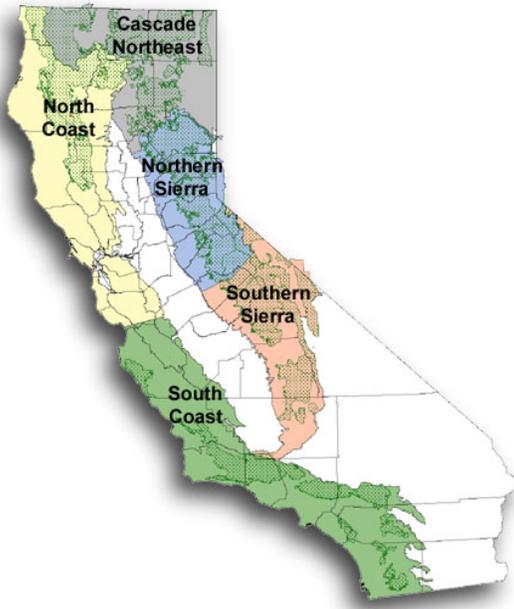
The USDA Forest Service (FS), Pacific Southwest Region (Region 5) and the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CDF) coordinate vegetation mapping and land cover monitoring within California on a 5-year schedule. The

objective of establishing a coordinated schedule is to ensure efficiency and common data standards for mapping and monitoring on a large scale, and to minimize duplication of work. This coordinated schedule brings together multiple cooperators and programs in California needing updated vegetation, land cover change, and field based inventory data.

The State is divided into five project areas covering approximately 62 million acres of wildland on state, private and public lands within California, (Figure 1.) Each project area is re-visited on a 5-year cycle. Project areas are delineated by a combination of TM scene boundaries, ecological subsections, bioregions and FS province boundaries. For each project area, baseline vegetation land cover is established using resource photography and satellite imagery. At the beginning of the 5-year cycle for any one project area, resource photography and satellite imagery is acquired and, using the baseline vegetation data, change detection methodology is conducted to assess changes and causes in land cover. Once changes in land cover have been assessed, vegetation and surface fuel map updates occur. Following this re-map process forest inventory plots that have change are re-measured.

This schedule enables multiple partners to realize cost savings where current photography and imagery are substituted for ground based inventories through aerial photo interpretation. The intent of this schedule is to move to a coordinated approach in acquiring resource photography, satellite imagery and vegetation resource information. Existing vegetation mapping, surface fuels mapping, ground based inventory, and change detection monitoring programs require the acquisition of aerial photos and imagery to be coordinated to ensure the efficiency of these efforts. Physiographic Provinces, Administrative Provinces, National Forest acreages, and current status of vegetation mapping, change detection and Forest Inventory and Analysis (FIA) ground plots were all considered in development of the coordinated schedule for California.

Figure 1.
Project Areas



Monitoring Goal

The Goal for vegetation resource information is to have baseline vegetation maps no older than 5 years; update map areas where changes to vegetation and surface fuels has occurred from various causes. And for these same change areas, re-measured inventory plots. In order for to achieve a coordinated cycle, baseline

vegetation maps and FIA grid inventory plots need to be completed to a common standard and common source dates within a province as much as possible, balancing workloads and budget constraints.

Large scale monitoring depends on consistent baseline information to assess changes to wildlife habitats, late successional old growth, as well as forest conditions and trends. Specifically, this information is developed to meet the needs of Resource Planning Act Assessment, Forest Resource Management Plans, Northwest Forest Monitoring Plan (EMT, 1997), large scale bioregional assessments, and more localized watershed and county planning efforts.

Establishing Baseline Vegetation Maps

The FS vegetation mapping team is responsible for producing a comprehensive vegetation database that meets regional and national vegetation mapping standards. A mapping methodology has been developed to capture forest vegetation characteristics using automated, systematic procedures that efficiently and cost-effectively map large areas with minimal bias (Woodcock, C.E., J.B. Collins, S. Gopal, V. Jakabhazy, X. Li, S. Macomber, S. Ryherd, V.J. Harward, J. Levitan, Y. Wu, and R. Warbington, 1994). Vegetation layers are created in a hierarchical approach that focuses on building a foundation land cover / life form layer through image classification, segmentation (Woodcock, C., V.J. Harward, 1992) and canopy modeling (Strahler, A.H., X. Li., 1981). Vegetation alliances, the floristically based level of the hierarchy, are mapped in conformance with the CALVEG system, which was originally developed by the Region's Ecology Program (U.S. Forest Service - Regional Ecology Group, 1981). These data are being developed and maintained at the Region 5, Remote Sensing Lab (U.S. Forest Service - Region 5, 1999). Other data layers include forest stand characteristics such as tree size and density and relative percentages of conifers and hardwoods in mixed stands.

Natural Region Delineation

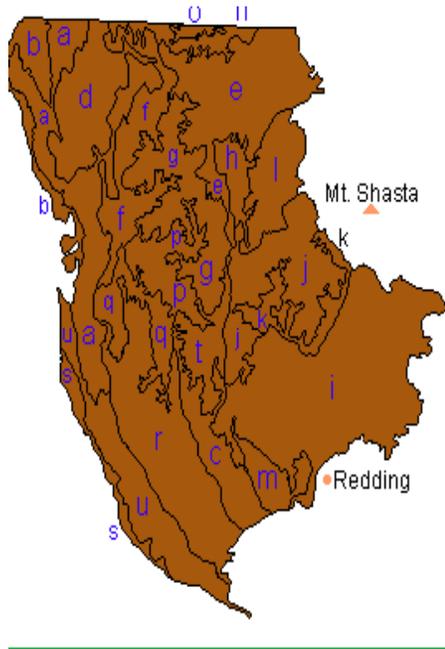
Natural regions are defined as areas within which the elevation, slope, and aspect ranges of the major vegetation types remain constant. Traditionally, these regions have been designed primarily on the basis of ground reconnaissance, interviews with resource professionals familiar with a particular area, and relevant background material such as geology and terrain maps and published documentation. With the implementation of the National Hierarchical Framework of Ecological Units, Sections and Subsection of California divisions are now used to determine appropriate natural regions initially, with further refinements as necessary (Miles, S.R., C. Goudey, 1997).

Classification

Field and existing data collection drives the classification system to enable the development of models that predict the occurrence of existing vegetation alliances. This process provides updated alliances for the CALVEG classification system as areas across the state are systematically mapped within regional or Ecological Unit boundaries (see figure 2). Extensive field time is allocated to collect new information throughout the project's mapping boundaries, including, at the minimum, slope angle, elevation, slope aspect, and dominant species for each alliance in its varied expression throughout the mapping area. Alliances are then described for the general mapping area.

Figure 2.

Ecological (Natural) Regions



Terrain Model Development

In addition to floristic information, terrain variables such as elevation, slope angle, slope aspect, soil and geologic or land form type, precipitation averages, fire history, etc. are addressed in the vegetation predictive models in ARC Macro Language scripts. Models are processed separately for each of four life form types - conifer, hardwood, mixed conifer/hardwood stands, and shrub. Herbaceous types are usually assessed from remotely sensed imagery corrected and edited by interpreting information from aerial photos (Macomber, S., C. Woodcock, R. Warbington, K. Casey, 1991). In cases where vegetation cannot be modeled, such as in serpentine or other edaphically defined vegetation types, ancillary data is used and supercedes the model's output. Model results are analyzed for conformance with new field data and field observations. A final "run" of the model merges output from the four life form models with land cover classifications derived from edited remotely sensed data to assure the labeling of all map areas.

Field Verification and Final Editing

Maps are provided for field reviewers and brought into the mapping area for comments and corrections that produce the final CALVEG data layers. The models are corrected and rerun, or the needed edits are made on the computer screen in ARC/INFO to produce a final CALVEG map product. The final completed map includes the incorporation of a plantations layer, the results of tree crown and density models and tree size estimates. Crosswalks to the California Wildlife Habitat Relationships (WHR) (Airola, D. A., 1988) and regional descriptions of the vegetation alliances are supplied with the final map products.

Accuracy Assessment

Accuracy assessments are conducted on vegetation map products using FIA plots as an independent sample, as compared to the map label. The accuracy results are available to map users to improve utility of the maps by providing information about the nature, magnitude, frequency and source of errors. The two primary methods used in the Lab are the Error Matrix and the Fuzzy Set (Gopal, S. and C.E. Woodcock, 1994). Forest inventory information can be used in the preparation of accuracy assessments, as long as all unique vegetation types and conditions are sampled in a non-biased fashion. An error matrix involves comparing mapped labels with on-the-ground conditions at the site to determine if the mapped label is right or wrong. If the mapped unit is labeled as "conifer" and to plot samples only "shrubs", it counts as an error. A matrix table is constructed using mapped labels on one axis, and observed conditions on the other

axis. The higher the proportion of “matches” there are, the more accurate the map is. The error matrix is sometimes referred to as a “Confusion Table” because it can highlight the types that are often confused.

Fuzzy Set theory goes a step beyond looking at right vs. wrong and confusion. It requires the analysis of vegetation from plot information, without knowledge of the map label, to develop an unbiased evaluation of the site and rating all possible labels on a relative scale from “absolutely right” to “absolutely wrong”. For example, if an all conifer stand was sampled from the plot consisting of mostly red fir trees, a label of “hardwoods” would be rated as absolutely wrong, but a map label of “mixed conifer-fir” would be rated as wrong, but close. A mixed shrub/hardwood plot on the ground might get an OK rating for either the “shrub” or “hardwood” label, but would receive “absolutely wrong” for a “conifer” label. Accuracy assessments are rated on map products for life form categories, vegetation type alliances, tree size classes, and tree canopy closure classes (Milliken, J., D. Beardsley, S. Gill, R. Warbington, 1998).

Establishing Baseline Ground Plots

The inventory of existing vegetation on National Forest land is done to provide information for strategic-level planning at the National, Regional and Forest levels. The National Forest Management Act (NFMA) directs the collection and use of vegetation inventory information in the development of National Forest planning and assessments. The Resource Planning Act (RPA) requires the Forest Service to collect data on all forestlands and report to Congress on the status of the forestland resource on a periodic basis (U.S. Forest Service, Forest Inventory, Economics and Recreation Research, 1992). The Region 5 vegetation inventory program fits within a National program Forest Inventory and Analysis (FIA), a Grid based sample design to allocate plots across all forestlands regardless of ownership. The Region has augmented the National program by installing plots on all vegetation types, not just forests, and by targeting rare types than require additional samples. The design is intended to provide a baseline vegetation inventory from which long-term monitoring of change (growth, mortality, species composition, etc.) can be assessed. These data are linked statistically to vegetation maps and used for a wide variety of purposes, including timber resource status, wildlife habitat assessment, wildfire hazard rating and monitoring of biological diversity and climate change.

Ground Plot Layout and Design.

Vegetation ground plots have been established on a prescribed 3.4-mile systematic grid, one plot for every 7,400 acres, common to all forested lands in California, Oregon and Washington states. Ground samples consist of five subplots contained within a 2.5-mile primary sample. The Pacific Northwest Research Station, as the basis for forest inventory, developed both the plot layout and design with the intent of re-measuring them on a periodic basis. A National Hexagon sample system, one plot per 6,000 acres, and ground samples consisting of four subplots, has been recently adopted. Fortunately, most of the existing plot locations will be used in the new National Hexagon system to maintain consistency between current and future ground based measurements, and in capturing trends in growth, mortality and overall forest health conditions.

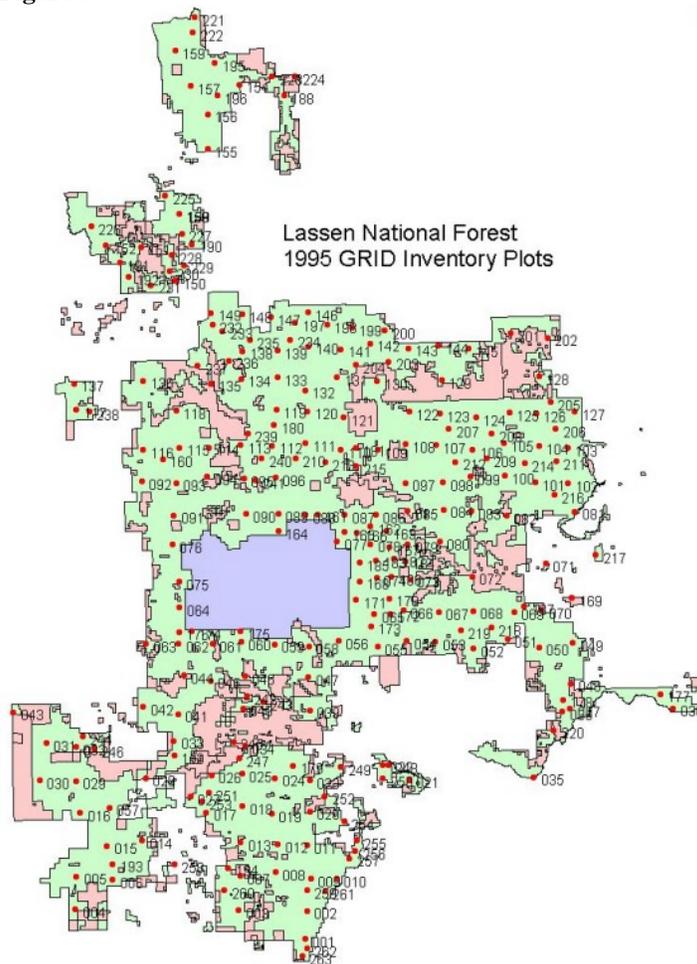
Sampled Data Elements.

Vegetation is measured using a variety of fixed area and variable plots to collect data on trees (both live and dead) shrubs, herbaceous plants and grasses. Data is also collected on large woody debris, small woody debris, and surface cover material, duff and fuel-bed depth. Site information collected includes slope, elevation, and aspect, stand structure, stand history, and site index.

Linking Ground Plots to Vegetation Maps

Ground inventory plots are used to estimate vegetation populations by linking the plot using post stratification of the plots with an existing vegetation map. The resulting vegetation inventory strata GIS coverage is then used to as mapped strata area to represent the population area expansion for estimating forest average conditions. The existing vegetation map is used to post stratify the 3.4-mile grid plots, (see figure 3) and to select intensification plots for rare regional types as well as conifer plantation age classes. Inventory plots are grouped into like populations through assigning condition classes or Strata labels to both the inventory plots and to a Strata map for each National Forest.

Figure 3.



Strata are created using crosswalk logic from CALVEG type, size and cover classes to more general regional types, size groups and density groups. Care is taken to maintain consistency between Forest strata logic, to facilitate any analysis across National Forests. Some lumping of unique vegetation labels takes place to simplify the inventory into a smaller set of sampling populations. Stands of similar species, productivity, size and cover is lumped into strata for volume, growth, mortality, and structural estimates. The strata GIS coverage identifies the vegetation map and inventories that are used to develop the layer. Those strata with no inventory plots are also identified. This occurs for some rare vegetation types, conifer plantations less than 10 years old and/or non-stocked forestland (U.S. Forest Service - Region 5, 1999).

Monitoring - Change Detection

Examining changes in vegetation at sub-regional or local scales can help resource managers to evaluate the impacts of disturbances on natural resources of local interest. This information is useful to monitor and assess the effectiveness of existing policies, programs, management activities and regulations, and to develop alternatives as needed (e.g., county voluntary guidelines for oak woodland management). It also provides an important opportunity for agencies to look across jurisdictions and programs. Baseline vegetation data is necessary for assessing changes overtime and tying those changes to vegetation types. In the beginning of the 5-year coordinated schedule, change detection is performed using the baseline vegetation data as input to the process.

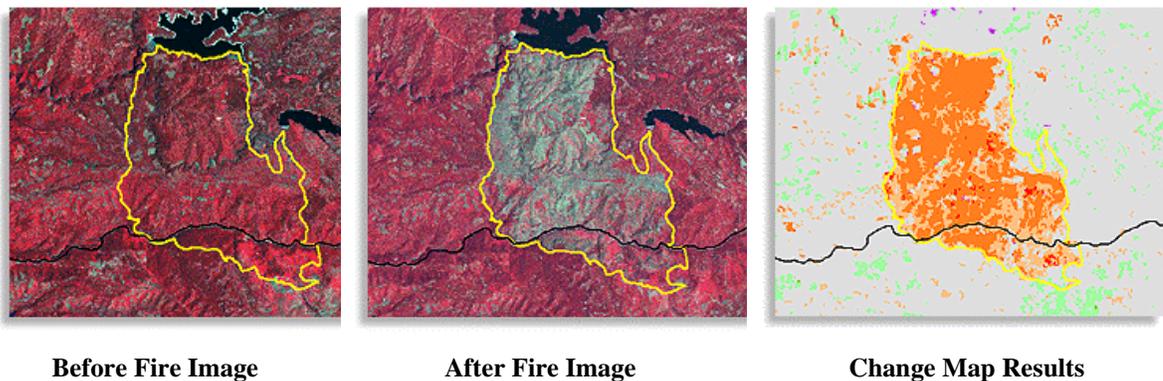
Unsupervised classification of the transformed imagery creates a preliminary landscape level change map portraying change classes with multiple levels of vegetation increase, decrease, and no change. Using a

stratified random sampling scheme, this preliminary change map facilitates selection of field sites for collecting vegetation canopy cover measurements. Ground truth for the classifier is obtained by estimating canopy cover change over the 5-year timeframe using color-IR digital photos, digital orthophoto quads, and aerial photography. Canopy cover estimates from the second date of photography is calibrated using transect measurements of canopy cover from a sample of field sites. Attributes such as species and vegetative cover are also noted. A machine learning classifier approach is then employed. The classifier uses an inductive learning algorithm to generate production rules from training data, including the transformed change data and other ancillary data layers. An expert classifier, to produce classes of crown closure change, then uses the resultant knowledge base. Approximately half of the field sites are reserved for accuracy assessment.

Data Base Development.

Multitemporal Landsat Thematic Mapper (TM) satellite imagery is used in the change detection process. For a given project area changes are detected with an approximate five-year time interval. Landscape changes are initially detected using a multi-temporal Kauth-Thomas transform. A difference in spectral reflectance between TM image dates determines whether change occurred or not. For example, in the images below, the red areas indicate live vegetation, gray areas indicate an absence of vegetation and black areas indicate water. Between 1991 and 1996 a large fire (the Cleveland fire), which is shown by the yellow polygon, burned much of the vegetation and changed the spectral reflectance between images from red (the 1991 TM image) to gray (the 1996 TM image). The change detection process interprets these differences and produces a map identifying a continuum of change classes. The classes range from little or no vegetation change to large increases or decreases in vegetation cover.

Figures 4, 5 and 6.



When using satellite imagery to detect change, imagery must be co-registered and radiometrically corrected. Image registration ensures that multi-date images from the same path and row are registered to each other within one pixel by on-screen identification of common features, such as road intersections. If pixels do not correctly correspond, then changes due to misregistration will occur on the final change map. Geometric correction is performed for all image pairs each project area.

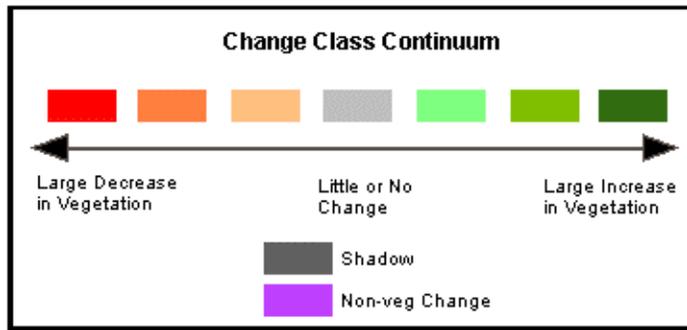
Imagery that has been registered, normalized, and subset into processing areas, is ready for input into the change detection process. A concurrent process involves preparing and mosaicking ancillary data layers, including vegetation, fire history, plantation and other harvest information. Ancillary data are used as a masking tool and as a means for stratification to label the change classes and to implement the sampling design for field data collection.

Change processing involves image segmentation and Multi-temporal Kauth-Thomas (MKT) transformation. Image segmentation creates regions (polygons based on spectral similarity) from TM bands 3 and 4, and a texture band generated from band 4 (Ryherd and Woodcock, 1990). Texture is a spatial component that enhances subtle edges in the scene over large areas. Generally, regions ranged from 15 to 50 acres. The MKT transform is a linear transformation that reduces several TM bands into brightness, greenness, and wetness components. 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 MKT transform is applied to the two dates of imagery. The difference is a change image representing changes in brightness, greenness and wetness values between the two dates.

In order to identify change classes based on the change image the data is stratified by lifeform (e.g., conifer, hardwood, shrub, grass, non-forested/other) using the mosaicked vegetation data layer. An unsupervised classification is applied to each change image by lifeform and results in 50 change classes per lifeform. Image appearance, photo interpretation, vegetation and topographic maps, GIS coverages, and bispectral plots (e.g., greenness vs. wetness) aid in identifying levels of change. Each change class is labeled according to its level of change based on a gradient of change classes from large decreases in vegetation to large increases in vegetation.

Figure 7.



Using a stratified random sampling scheme, this preliminary change map facilitates selection of field sites for collecting vegetation canopy cover measurements. Ground truth for the machine-learning classifier is obtained by estimating canopy cover change over the 5-year timeframe using color-IR digital photos, digital orthophoto quads, and aerial photography. Canopy cover estimates from the second date of photography is calibrated using transect measurements of canopy cover from a sample of field sites. Attributes such as species and vegetative cover are also noted.

Xueqiao Huang and John Jensen developed the machine-learning classifier used in this project as a module integrated within the ERDAS IMAGINE image processing environment (Huang and Jensen, 1997). The classifier uses the inductive learning algorithm C4.5 (Quinlan, 1993) to efficiently generate production rules from training data using a decision tree strategy. The resultant knowledge base is used by the expert classifier within the module to produce classes of crown closure change. As with a neural network, there are several advantages of this approach. With machine learning, fewer field samples are generally required for training data since ancillary data layers may be used to help improve discrimination between classes. As a machine-learning model is non-parametric, it does not require normally distributed data or independence of attributes. A machine learning classifier can also recognize nonlinear patterns in the input data that are too complex for conventional statistical analyses or too subtle to catch the eye of an analyst. Once suitable production rules have been developed for a given project area, they can be quickly applied the next time that area is revisited without having to retrain the classifier. Areas of similar land cover may require only a slight modification of the rules. This could represent considerable timesavings during the classification stage of future project areas, in addition to providing us with an empirical understanding of the relationships between our variables.

Training layers for the machine-learning classifier are assembled using data from field sites and other ancillary data. Layers currently being tested with the classifier include the transformed change data, cover-type, tree density, harvest/fire history, local climate, slope, aspect, and time interval between acquisition dates.

The final step in the change detection process is to identify cause of change. This process begins by overlaying fire, harvest and plantation layers onto the change detection map in a GIS. This process readily attributes areas of change due to wildfire, prescribed fire, silvicultural practices and vegetation regrowth. Once these areas are identified, 7.5-minute quadrangle-size change maps are created for the conifer and hardwood vegetation types. National Forest resource managers interpret the conifer change maps by applying local knowledge regarding sources of change in the conifer forests. Similarly personnel from the

University of California Integrated hardwood Rangeland Management Program (IHRMP) consult private landowners to identify sources of change in hardwood rangelands.

Collecting field data on National Forest land and hardwood rangelands further aids in interpreting natural and human-induced change. Fieldwork conducted by IHRMP personnel in hardwood rangelands has identified causes of changes in canopy cover due to fire, thinning, harvest, urban development, mortality, regeneration and tree planting. Areas of mortality, timber harvesting not included in our current ancillary data, and recent fires were identified on National Forest lands. A database is created with causal information.

The final product includes a refined change map featuring discrete canopy cover change classes, and a GIS database that identifies the locations of known vegetation change for coniferous forestland, hardwood rangeland, shrub land cover and urban areas. It is also used to identify areas of update in both existing vegetation and surface fuel map coverages.

Interpreting Changes in Vegetation.

Change detection results answer different questions at a variety of scales. At a regional scale, users investigate ecosystem characteristics or function by examining the cause of change over time, the ratio of vegetation increase to decrease, and whether changes are temporary or permanent (e.g., fire versus development). Examining changes in vegetation at a more sub-regional or local scale can help resource managers to evaluate the impacts of disturbances on natural resources of local interest. This information is useful to monitor and assess the effectiveness of existing policies, programs, management activities and regulations, and to develop alternatives as needed (e.g., county voluntary guidelines for oak woodland management). It also provides an important opportunity for agencies to look across jurisdictions and programs.

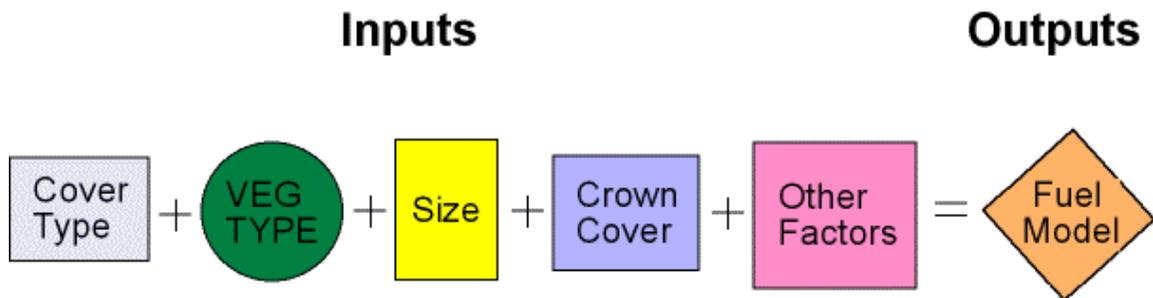
Surface Fuel Mapping

The California Interagency Fuel Mapping Group (CAIFMG), a consortium of State and Federal agencies, is developing regional "surface fuel" maps that span jurisdictional boundaries. Surface fuels are vegetative materials near the ground through which fire will spread. These materials range from downed woody material (leaf litter, dead branches and logs) to brush and grass. The amount, size and moisture content of surface fuels determine how fast a fire spreads, how hot it burns and how high its flames reach.

CAIFMG developed surface fuel maps by translating vegetation information from a variety of sources into fuel characteristics, combining them with topographic and historical fire data and patching them together to form a seamless GIS fuels coverage (see figure 8.). This process, known as "cross walking," was originally developed by the Sierra Nevada Ecosystem Project (SNEP), and translates information on plant species, crown cover and tree size into 13 fuel behavior models based on the Fire Behavior Prediction System (FBPS) (Sapsis, D., Bahro B., Spero, J., Garbiel, J., Jones, R., Greenwood, G., 1996). The "crosswalk" process also includes other factors, such as slope; aspect and elevation data to further refine fuel models. Finally fire history information defines areas where surface fuel characteristics change in order to account for past fires and subsequent regrowth of vegetation.

Figure 8.

Input for Fuel Model Mapping

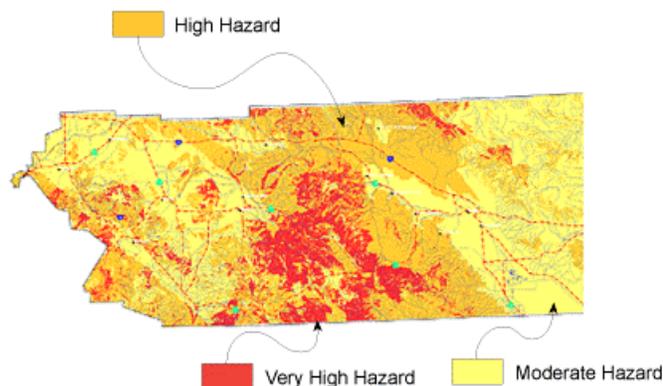


The scale and date of vegetation data from local, state and federal agencies often vary and therefore the scale and date of the resulting fuel data vary. The scale of the source data controls the minimum mapping unit (MMU), the smallest area that can be uniquely identified on the map. The MMU for fuels data developed by CAIFMG ranges from 900 square meters up to 100 hectares. The final data are maintained as raster GIS coverages in an Albers equal area projection with a cell size of 30 meters on a side.

Other Uses of Fuel Maps

State and Federal fire protection agencies combine regional fuel maps with other geographic information to identify hazardous areas and to prioritize projects. CDF combines surface fuels with slope data to rank areas as moderate, high and very high fire hazard. This initial surface fuel hazard is then associated with generalized ladder and crown fuel estimates to derive a final fuel hazard assessment and ranking. As part of the California Fire Plan, CDF combines these fuel hazard rankings with weather, assets at risk and historic level of service to identify and prioritize pre-fire projects (Kerstiens, R.J., Wilson, R., Wheeler, D., Wilson, P., 1996). Similarly, the USFS, BLM and NPS use surface fuel maps to implement the Federal Wildland Fire Policy and to identify and plan pre-fire projects that reduce fire hazard and ultimately improve ecosystem health. Region 5, in a variety of planning and assessment projects, Land Management Planning documents, including environmental impact reports, also uses these data.

Figure 9.



This map indicates moderate, high and very high hazard based on inputs, such as fuel, slope, brush density (ladder), and tree density (crown cover).

Conclusion

By establishing a systematic update cycle for mapping and inventory, opportunities for partnerships outside of the National Forests become more available. Currently a MOU (Memorandum of Understanding) exists between Region 5 and CDF for joint mapping of vegetation resources. The Lassen and Modoc Plateau (Miller S., H. Eng, M. Byrne, J. Milliken, M. Rosenberg, 1994) and Northern and Central Sierra Nevada Provinces areas were mapped under this agreement and an ongoing effort is underway to map baseline vegetation for the South and Central Cost Province. A cooperative effort was completed for the Klamath Province with Fish and Wildlife Service (FWS), California Department of Fish and Game (DFG) and the Forest Service for establishment of a vegetation map baseline for monitoring of the Northwest Forest Plan (Schwind B, C. Curlis, S. Daniel, 1999). To date, over 45 million acres have been mapped to a common standard as baseline information. This is approximately 2/3rds of the total area within the 5 panel schedule. Because of the ongoing efforts to date, an MOU between all major State and Federal resource management agencies is being developed to establish a common baseline vegetation map throughout California. Other related cooperative projects have been established between the FS and CDF for mapping surface fuels and conducting remote sensing based change detection in California under the coordinated cycle. Change detection as well as surface fuel maps are now available much of California's wildland areas (Levien, L. M., C. Fisher, P. Roffers, and B. Maurizi, 1998).

Other efforts could be coordinated on this same cycle. For example, Region 5 and the Pacific Northwest Research Station (PNW) could enhance FIA ground plot data collection on state, private and federal lands in California through coordination. Forest Health Monitoring program efforts could also benefit by a coordinated mapping and inventory schedule for off plot analysis. Identification of all altered ground plots can be located with the change detection and map updates, and subsequent re-measurements coordinated. Under the annualized inventory program, 1/2 of all FIA ground plots are re-measured in 5 years, providing a valid number of non-changed plots for assessing background changes in mortality, growth or other detailed vegetation attributes that cannot be mapped on non-changed areas. The non-changed re-measured plots could also be used for calibrating growth projections on the plots not re-measured. All FIA ground plots are scheduled for re-measurement within 10 years, as the annual measurement cycle progresses over the same geographic area. Region 5 has recently begun to use this methodology for selecting additional plots for re-measurement. Discussions are in-progress with PNW and CDF on coordinating re-measurements on private and other federal lands to begin in FY2003 under the National Hexagon sampling system.

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