

CLASSIFYING WILDLIFE HABITAT WITH PAN-SHARPENED LANDSAT 7 IMAGERY

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ABSTRACT

We compared three multi-resolution merging techniques for classifying land cover and land condition in the central coast of California using Landsat7 imagery. We preferred the Principal Components transformation method to the Multiplicative or the Brovey method.

Resolution merged imagery was used to classify and map wildlife habitat into physiognomic types based on vegetation canopy morphology including: needle-leaf trees, broadleaf trees, mixed trees, broadleaf shrubs, microphyllous shrubs, soft shrubs, verdant grass, senescent grass, and wet meadow/marsh. Vegetated areas were also classified into four classes of canopy closure and tree covered areas were mapped into four classes of tree size. Areas without vegetation were mapped as: bare soil, gravel/rock, or water. Attempts to further refine the classification into vegetation series, or agricultural land use, for example, were not successful because we failed to achieve 85 percent accuracy when compared to digital ortho-photos of the same region.

While improved resolution (15 meters instead of 30 meters) did not increase our ability to discriminate finer thematic classes of vegetation, it did allow us to map smaller landscape features thereby avoiding some of the mixed pixel problem experienced with 30-meter imagery. Landscape features mapped accurately included: narrow stringers of vegetation, narrow waterways and small patches of different vegetation in mixed land cover types. Because of the small pixel size (15 meters) the general classes of urban and agriculture (and even open woodland) had even less of a unique signature than experienced with 30-meter resolution imagery. For example, we feel the concept of an urban spectral signature has very little meaning with 15-meter data. Rather it seems obvious, spectrally, to classify these pixels according to the land condition sensed within the pixel: trees, shrubs, grasses, bare soil, etc. The spatial detail is superior than previously obtained from Landsat but the thematic detail is not improved. Moreover, land cover types previously defined by heterogeneous mixtures may not be defined at finer resolution. The challenge for wildlife managers will be how to most effectively use this fine spatial resolution information to characterize habitat.

INTRODUCTION

Recently launched imaging satellites often provide a panchromatic wavelength band having finer spatial resolution than the multispectral images traditionally provided. For example, Landsat 7 features a 15-meter resolution panchromatic band and seven, 30-meter resolution multispectral bands. Automated image classification requires multispectral bands to offer sufficient information to characterize land cover. In order to exploit the finer resolution of the panchromatic band for mapping at the local scale as well as the regional scale, the pan data must be merged with the multispectral data. While several merging techniques have been developed and finer resolution images rendered, their use for image classification has not been thoroughly investigated.

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Our objective was to compare the four multi-resolution merging methods available to ERDAS Imagine users: Principal Component, Multiplicative, Intensity-Hue-Saturation and Brovey transforms. We were looking for a method that would increase spatial resolution without degrading spectral discrimination. Once an appropriate merging method was selected, our goal was to classify and map wildlife habitat into the California Wildlife Habitat Relationships (CWHR) system, as closely as possible considering the limitations of per-pixel classification algorithms processing Landsat 7 spectral data acquired by the satellite in the summer of 1999.

MULTI-RESOLUTION IMAGE MERGE

Our efforts were directed to the Central Coast region of California, USA as this applied research project was funded by the California Department of Fish and Game. We were also fortunate to benefit from the cooperation of about twelve biologists in the Department's Region 3 as highlighted in Figure 1. The field biologists were instrumental in identifying habitats in the field and recording GPS coordinates for those field sites.

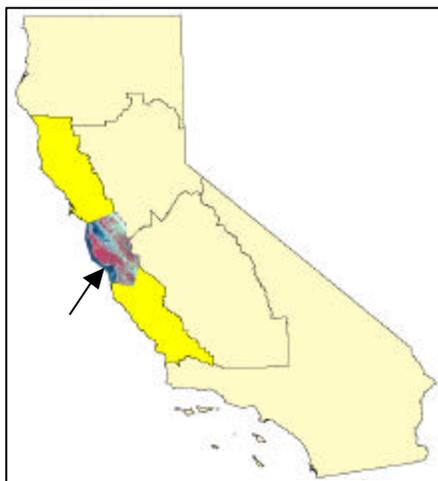


Figure 1. Region three (highlighted in yellow) of the California Department of Fish and Game comprised the study area. Portions of the eight Landsat 7 images acquired by the satellite in the summer of 1999 and used for this project are shown in false color. The black arrow indicates the Palo Alto region of South San Francisco Bay, the focus of this paper.

We first evaluated four methods for merging images of differing resolutions that were available in a commonly used commercial image-processing software package, ERDAS Imagine (ERDAS, 2000). We decided against the Intensity-Hue-Saturation transform as it produced only three output bands. Since we desired a method that would preserve the six optical spectral bands from Landsat 7, data reduction to three bands was determined to be too great an information loss for our purposes. The three methods that produced six output bands are illustrated for an area of Palo Alto that contains the Stanford Linear Accelerator, a large and unique cultural feature on the landscape, Figure 2).

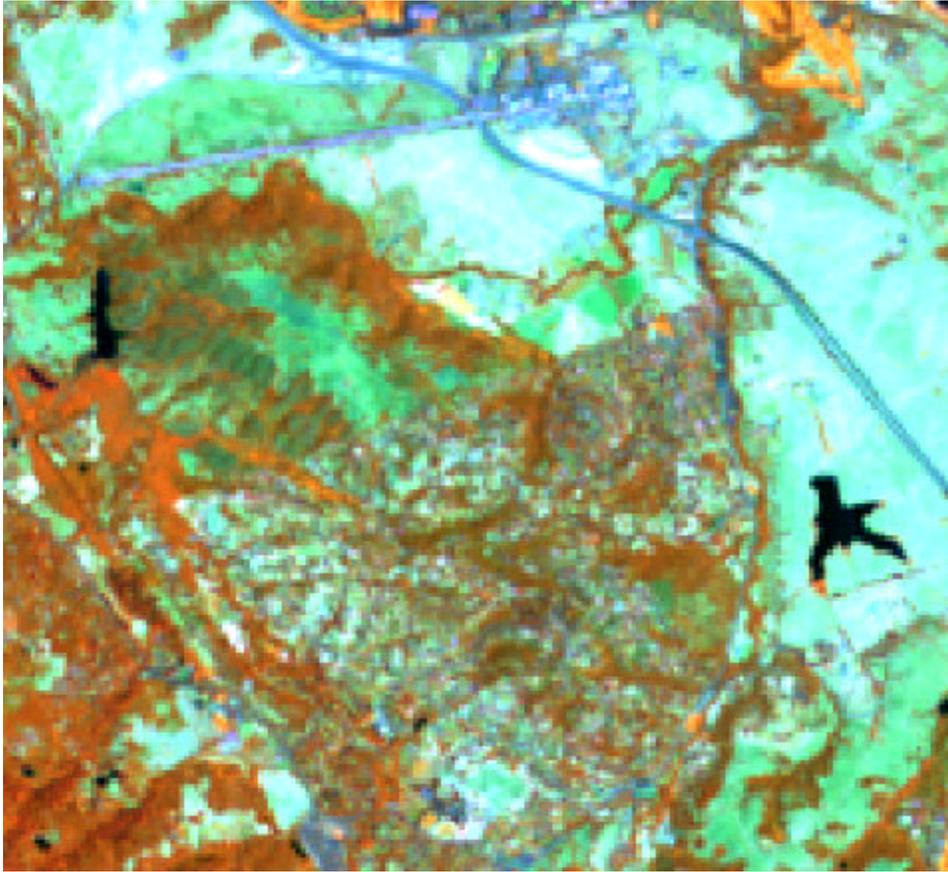


Figure 2. Landsat 7, multispectral, false color composite, 30-meter spatial resolution image. A Close-up of the Stanford Linear Accelerator (upper left), US Highway 280 (diagonally top right quadrant) and Felt reservoir (lower right) is shown. Sparse residential development is encroaching wildland habitats in the lower center of this view. Numerous riparian habitats are also visible along small streams.

A 30-meter resolution color composite is shown in Figure 2 to illustrate the detail available before the resolution merge. The 15-meter resolution Panchromatic band for this region is shown in Figure 3. The 15-meter image provides a clearer definition of the accelerator and other linear features such as the highway. Also apparent is a brighter and clearer rendition of sparsely vegetated surfaces in the urbanized area (lower center). Actual ground conditions can be better inferred from USGS digital ortho-photograph of the lower right portion of this region (Figure 4). A concern for habitat mapping is that riparian “stringers” of streamside habitat were actually less defined on the finer resolution image. Note the stream in the upper center. Even though the spatial resolution is finer in the panchromatic image, the spectral resolution is less able to clearly to differentiate the high very-near infrared reflectance of the living plant canopy from the high visible reflectance of the decadent plant canopies. By contrast the combined visible and near infrared sensitivity of the 15-meter resolution, panchromatic band enables a clearer definition of the highway (State Hwy 280, in the upper right) than is visible on the ortho photo of superior spatial resolution (approximately one meter in the original image).



Figure 3. Landsat 7 panchromatic image. Rendering visible and very near infrared reflectance at 15 meters ground resolution. The area shown is the same as in Figure 2. White box indicates coverage of Figure 4.



Figure 4. USGS digital Orthophotograph of the reservoir and surrounding area. Note residential development in the left center of the image. This image was acquired in the summer of 1992 rather than in 1999, the date of the Landsat image acquisition.

The results of the Principal Components merging technique are shown in Figure 5 along with the original 30-meter resolution image. The method first resamples the 30-meter multispectral image to 15 meters. It then computes all six principal components of the multispectral image (We deleted the thermal band due to its coarser resolution). Then the histogram of the panchromatic band (15-meter resolution) is rescaled to match the histogram of the first principal component of the 30-meter image and the first component is replaced with the rescaled panchromatic band. This is justified because the first principal component represents overall brightness in a way that is similar to the broad spectral band of the panchromatic image. After replacement, the six components are transformed back into the original data space, rendering an improvement in spatial resolution. While the bright red of the broadleaf vegetative canopies is rendered in a lighter pink color in the merged image, these habitats are still differentiable from neighboring habitats. Note the drastically improved definition of riparian features and small urban features in the pan sharpened image. Individual lots are almost discernable in the pan enhanced image. We selected the Principal Components merging method over the other two tested because it provided enhanced color contrast for various habitats and preserved divergence between spectral classes obtainable with the original data.

The results of the Multiplicative merging method are shown in Figure 6 along with the original image data. The method uses an algorithm that multiplies original image data by the panchromatic image data thus producing a very bright digital number for areas that were bright on the multispectral image and on the panchromatic image. While we did notice a brightening effect for some features, the main reason we preferred the Principal Components image was the increased contrast between green vegetation habitats when compared to the Multiplicative image. Note especially the green leaved habitats (red in the color composite) compared to the brown leaved habitats (blue-green on the color composite). The red areas were more discernable on the Principal Components image than on the Multiplicative image.

The Brovey transformed image is not displayed as it wasn't selected for classification and its visual appearance was very similar to the Multiplicative transform. The Brovey transform was developed to visually enhance the darker and lighter portions of the histogram and therefore was rejected because it increased contrast for the "tails" of the histogram, thus changing the spectral nature of habitat classes of interest. In addition the Brovey transformation was computationally tedious because it was designed to produce a three band color composite rather than a multispectral data set for image classification. The Brovey had to be actuated twice for the six bands of interest and then the two sets of three transformed bands were merged together.

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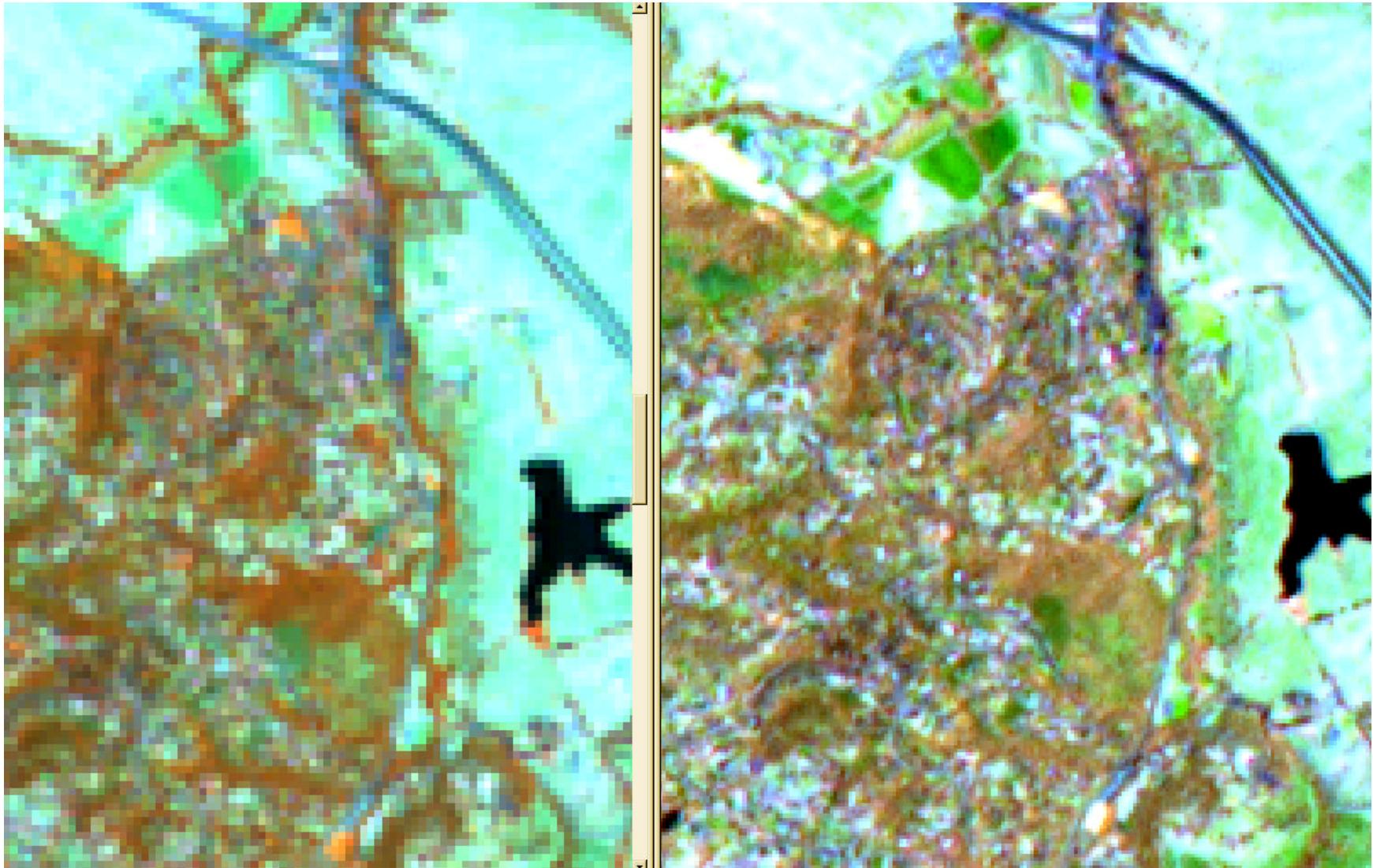


Figure 5. Landsat 7 image before the multi-resolution merge is shown on the left, after the Principal Components Transformation merge, on the right.

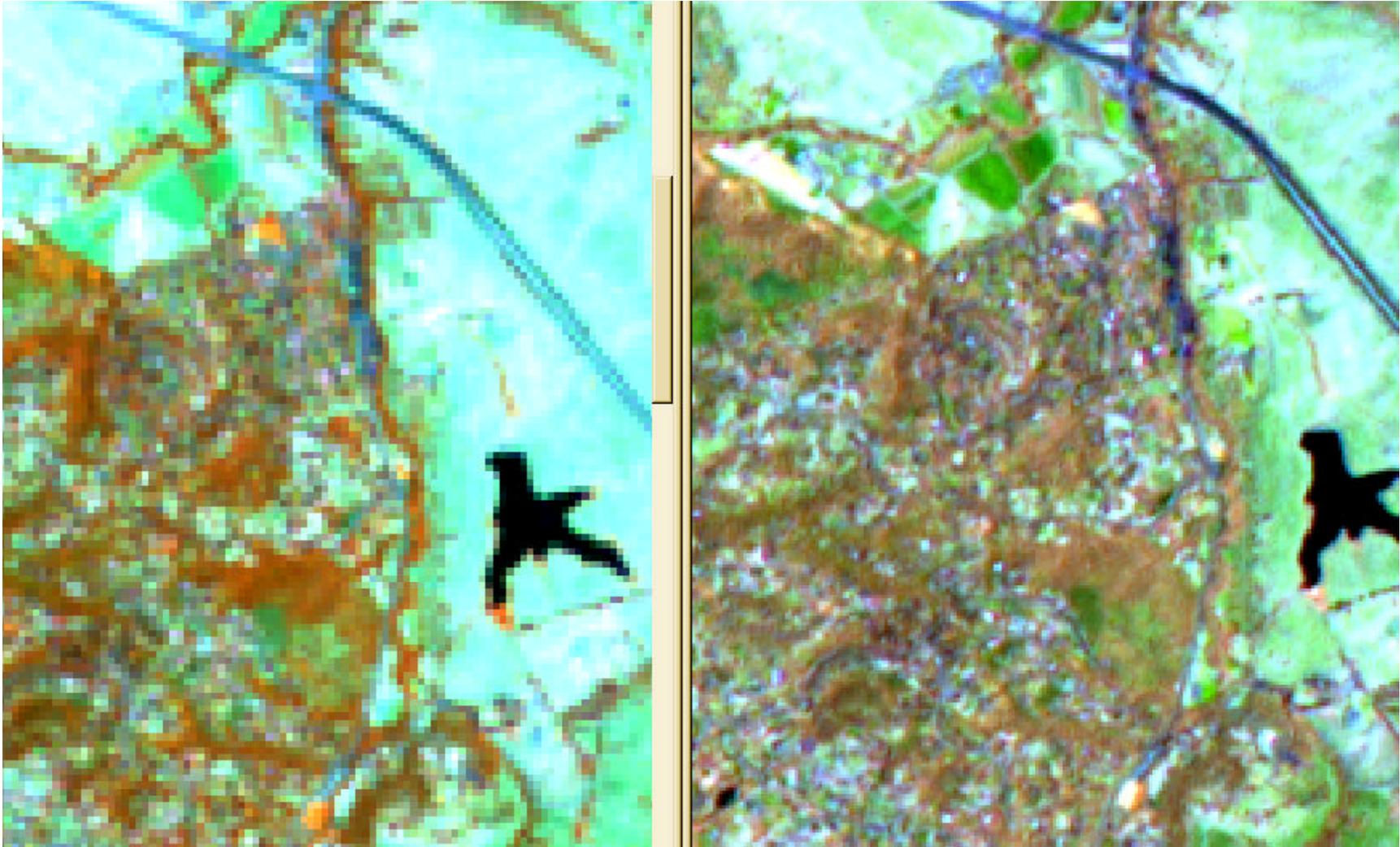


Figure 6. Landsat 7 image before the multi-resolution merge is shown on the left, after the Multiplicative Transformation merge, on the right.

IMAGE CLASSIFICATION

Pan sharpened (Principal Components technique) Landsat 7 images were classified using a combination of supervised and unsupervised methods (Fox, et al. 1992). We based our classification on spectral data alone (*Solamente Spectura*) in order to maximize the information available from Landsat imagery without the addition of extensive ecological modeling with a GIS. We have found these methods to be cost effective for regional mapping to the 15-meter pixel level (0.09 ha MMU). Correct and representative ground truth information is critical to this process. We had the cooperation of approximately 15 field biologists from the Department of Fish and Game. Field inspection teams followed a strict data collection protocol to provide GPS racks and waypoints to identify representative habitat types.

GPS tracks and waypoints were identified on USGS, digital ortho photo quads (DOQQs) or on 1:4,000 scale color aerial photographs taken over representative areas. This confirmed the field data and allowed us to *grow* a region based on spectral similarity of adjacent pixels (ERDAS region growing algorithm). These regions were used to define supervised spectral signatures for various habitat types. We also used the ISO-DATA clustering algorithm to define spectral signatures for those habitat types that were diversely spread across the landscape and were therefore resistant to region growing methods. We have developed analytical methods for editing spectral signature labels that allow us to inspect and compare the shape of the spectral plot as well as the distance between signatures in measurement space.

We modified the CWHR Habitat Type classification system (Mayer and Laudenslayer, 1988) to best utilize the discrimination abilities of Landsat spectral signatures. Most CWHR habitat classes were generalized to accommodate the limited species discrimination abilities of Landsat spectral data at 15-meters spatial resolution. Essentially, we provided a physiognomic habitat type emphasizing vegetation structure and leaf shape (broadleaf or needle- leaf). The CWHR system includes habitat stages defined by size classes and crown closure. These stages are critical for assessing the current condition and probable disturbance history of various habitat types. We have identified CWHR size classes 2 through 5 for tree types, omitting the very small trees, under 1 inch stem diameter. The spectral signatures of these small trees are normally masked by companion vegetation, which usually dominates the site. We have also identified all four CWHR crown closure classes for tree, shrub and herbaceous habitat types.

The habitat classification system that we developed from spectral data and used to map existing conditions in 1999, is shown in Table 1. The Landsat derived Habitat Type and its symbol is on the left side of the Table. CWHR classes that were included in the Landsat derived Habitat Type are listed in parentheses in the middle column. All discriminated stages of CWHR size and canopy closure are listed in the right column. A typical map symbol was: SHGD (Broadleaf Shrub, closure class D) or MCN5M (Mixed Conifer, size class 5, closure class M). Spectral signatures from the Landsat Thematic Mapper sometimes failed to discriminate a specific CWHR habitat type. Such an information loss occurred when the CWHR label contains a geographic reference that did not necessarily indicate a different spectral signature or even a different vegetation composition. For example, valley oak woodland and coastal oak woodland were aggregated to form a mixed oak woodland class. Generalization of the classification was also required when two or more vegetation types and/or stages, had very similar spectral signatures.

We did not label any spectral class with a symbol implying land-use, such as: agriculture, cropland, orchard, vineyard, residential, urban, roads, fallow, pasture, etc. We labeled these areas according to their vegetation cover (or lack there of) as defined by the classes we used. We did not label any spectral class with a reference to geographic location or geographic shape, such as: river, marsh, lake, bay, ocean, coastal valley, etc. We labeled these areas according to their land cover condition. This was done because spectral signatures recognize surface features of individual pixels as a spectral pattern without regard to where that feature is located, or to what landscape feature that pixel belongs. For example, water in a lake looks like water in a river, to a spectral signature classifier operating with satellite imagery. Color-coded maps were produced using this classification (Figure 7).

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Table 1. The Habitat Type Classification System used to map existing land cover/condition from 1994 Landsat Imagery. Equivalent California Wildlife Habitat Relationships (CWHR) Types are shown in parentheses (Mayer and Laudenslayer, 1988). Three letter CWHR Type codes are explained at the end of this table.

GENERAL TREE TYPES			Identified Stages			
<u>HABITAT TYPE</u>	<u>Symbol</u>	<u>Included CWHR Types</u>	<u>(CWHR tree size & closure¹)</u>			
(1) Mixed Conifer (Needle-leaf, <20% broad-leaf)	MCN	(SCN, RFR, SMC, WFR, KMC, RDW, DFR, JPN, PPN, EPN, CPC, LPN)	2S 2P 2M 2D 4S 4P 4M 4D	3S 3P 3M 3D 5S 5P 5M 5D	The above classes repeat for all tree types.	
			CWHR tree size classes are:			
			<u>Size Class</u>	<u>DBH Range (inches)</u>		
			2	1 - 6		
			3	6 - 11		
			4	11 - 24		
			5	>24		
(2) Mixed Conifer-Hardwood (Mixed needle-leaf & broad-leaf, >50 % Needle-leaf)	MCH	(MHC, KMC, DFR, JPN, PPN, EPN, RDW, CPC)	CWHR canopy closure classes are:			
			<u>Closure Class</u>	<u>Canopy Closure (%)</u>		
			S	10 - 24		
			P	25 - 39		
			M	40 - 59		
			D	60 - 100		
(3) Mixed Hardwood-Conifer (Mixed broad-leaf & needle- leaf, >50 % broad-leaf)	MHC	(MHC, MHW, BOP)				
(4) Mixed Hardwood (Broad-leaf, <20% needle-leaf)	MHW	(MHW, MHC, MRI, VRI, EUC, ASP)				
(5) Mixed Oak Woodland (Oak dominated broad-leaf)	MOW	(VOW, COW, BOW)				
GENERAL SHRUB TYPES			Identified Stages			
<u>HABITAT TYPE</u>	<u>Symbol</u>	<u>Included CWHR Types</u>	<u>(CWHR shrub closure²)</u>			
Broadleaf Shrub (dominated by broad leaves)	SHG	(ADS, MCP, MCH, CSC)	S (10-24)	P (25-39)	M (40-59)	D (60-100)
Microphyllous Shrub (dominated by woody sticks)	SHD	(ASC, MCH, CRC, BBR)	Percent crown closure			
Soft Shrub (lacking stiff woody stems)	SHS	(LSG, SGB)	S	P	M	D

NOTE 2: We did not discriminate CWHR, "size" (actually maturity) classes for shrubs.

Table 1. Continued.

GENERAL HERBACEOUS TYPES

<u>HABITAT TYPE</u>	<u>Symbol</u>	<u>Included CWHR Types</u>	<u>Identified Stages (CWHR herb. closure³)</u>			
Senescent Grass/Forb (dominated by dead leaves)	GSD	(PGS, AGS, CRP, PAS)	S (2- 9)	P (10-39)	M (40-59)	D (60-100)
Verdant Grass/Forb (dominated by live leaves)	GSG	(WTM, PGS, AGS, OVN, CRP, PAS)	Percentage of herbaceous cover			
			S	P	M	D
Wet Meadow/Marsh	GSW	(WTM, FEW, SEW)	S	P	M	D

NOTE 3: We did not discriminate CWHR height classes for herbaceous types.

GENERAL BARREN TYPES

<u>HABITAT TYPE</u>	<u>Symbol</u>	<u>Included CWHR Types</u>
Snow & Ice	BSI	(none defined)
Soil	BSL	(RIV, MAR, EST, LAC, URB)
Rock/Gravel/Pavement	BGR	(RIV, MAR, EST, LAC, URB)

NOTE 4: We did not discriminate CWHR substrates. BGR and BSL types occurring in or near rivers and lakes are spectrally identical to BGR and BSL types occurring on upland sites.

GENERAL AQUATIC TYPES

<u>HABITAT TYPE</u>	<u>Symbol</u>	<u>Included CWHR Types</u>
Water	WTR	(RIV, MAR, EST, LAC)

NOTE 5: We did not discriminate CWHR substrates for the CWHR water class (WTR).

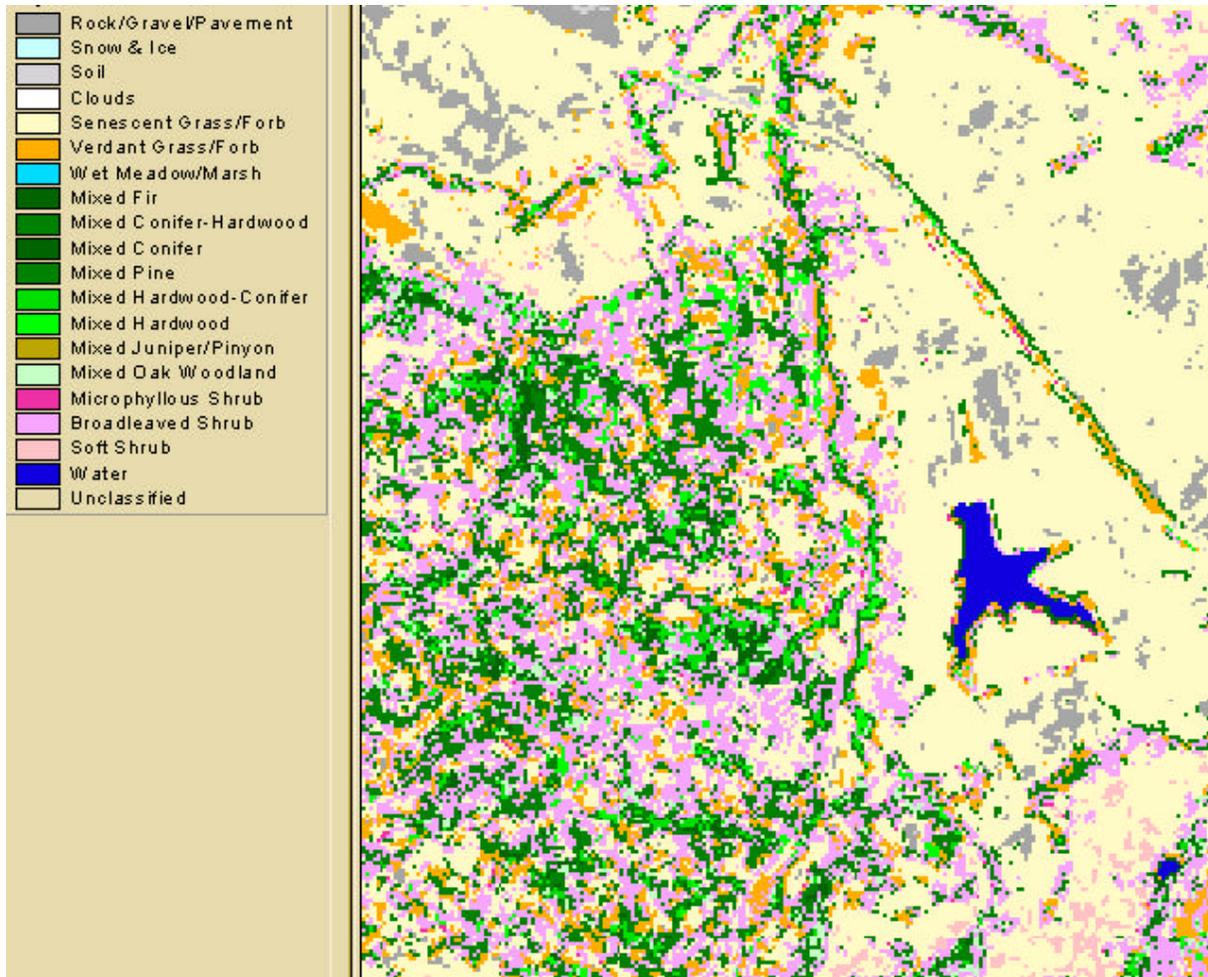


Figure 7. Multispectral classification of the area shown in Figure 6.

Classification of 15-meter pixels allowed the definition of riparian stringer habitat in more accurate proportion to the actual ground conditions because the stringers were made artificially wider by the 30-meter pixels. We were able to classify a narrowing strip of dense tree habitat rather than the wider strip of sparse tree habitat that the mixed, 30-meter pixels would have produced. We were also able to correctly classify very narrow features with the 15-meter data. For example, note the green colored tree class along highway 280 in Figure 7, upper right. These trees are not apparent in the 30-meter image or very obvious in the 15-meter image. However, they do show up conspicuously in the ortho-photo quad (Figure 4). The smaller, 15-meter pixels were able to capture a pure enough “tree” signature to enable them to be classified into a tree class in the final map.

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