N O T I C E

NASA Technical Memorandum 81255

Statewide Landsat Inventory of California Forests

William Likens and David Peterson

(E81-10134) STATEWIDE LANDSAT INVENTORY OF CALIFORNIA FORESTS (NASA) 28 p HC A03/MF A01 CSCL 02F
N81-22430
Unclas
G3/43 00134

February 1981

NASA
National Aeronautics and
Space Administration

NASA Technical Memorandum 81255

Statewide Landsat Inventory of California Forests

William Likens
David Peterson, Ames Research Center, Moffett Field, California

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

STATEWIDE LANDSAT INVENTORY OF CALIFORNIA FORESTS

Abstract

As mandated by the California Forestry Resources Assessment and Policy Act of 1977 (Assembly Bill 452), the California Department of Forestry (CDF) was required to undertake an initial forest land assessment for completion by July 1, 1979. A more detailed assessment and program plan is to be completed by 1987. As part of the initial assessment, imagery from NASA's Landsat resource mapping satellite was utilized. A cooperative mapping effort was agreed upon between the CDF, NASA's Ames Research Center (ARC), and the Jet Propulsion Laboratory (JPL), Pasadena, California, in August of 1978. The statewide mapping for the initial assessment was completed by July 1, 1979 and represented considerable time and cost savings over traditional statewide mapping methods. Six forest cover categories were mapped, along with 10 general land cover classes. To map the state's 100 million acres, 1.6 acre mapping units were utilized. Map products were created. Standing forest acreage for the state was computed to be 26.8 million acres.

Introduction

The California Forest Resources Assessment and Policy Act was created by the enactment of California Law AB452 in 1977 (State of California 1977). This Act required the California Department of Forestry to develop an initial statewide forest assessment by July 1, 1979, and a complete assessment by 1987. The assessment included an evaluation of existing forest data issues involved in the management of various forest resources, current policy, and the need for developing data collection and analysis systems. The initial report, "California's Forest Resources," was published in June, 1980 (California Department of Forestry 1980). Serious data limitations were found in resource issue after resource issue. One deficiency is the lack of a usable comprehensive data base.

In California there are numerous detailed forest maps of limited areal coverage, including ones by the U.S. Forest Service, and various timber company lands usually without public access. At least three maps have statewide coverage: the Forest Resources map (Weislander and Jensen 1945), Küchler's Natural Vegetation of California map (in Barbour 1977), and the CALVEG map developed by the U.S. Forest Service (USFS 1978). Only the CALVEG map was used extensively in the initial assessment. The Natural Vegetation map is published at a scale of 1:1 million and displays "potential" natural vegetation. The CALVEG map was produced through visual photo-interpretation of Landsat false color composite photographic prints. This was completed without precise geometric control of the mapping surface using an 800 acre minimum mapping unit.

Although CALVEG is useful for developing policy information, its polygonal nature, large mapping units, imprecise geometry, and at times questionable interpretation, make it questionable as a data base for future assessment of an operational analysis system.

Use of Landsat satellite digital data in the construction of a suitable map base was then considered. Several advantages are found. The data is digital, thereby allowing computer processing, and providing discrete information for much smaller mapping units (down to 1.6 acres). It is possible to obtain complete state coverage in a single nine day period which can be updated frequently. In addition, previous studies have shown Landsat can provide useful resource information in a timely fashion.

These factors resulted in CDF's decision to undertake statewide forest mapping using Landsat. This effort provided CDF an initial test of the suitability of this technology in fulfilling their resource data needs. A cooperative agreement to accomplish this task was formalized in June of 1978, between the California Department of Forestry, NASA's Ames Research Center, and the Jet Propulsion Laboratory (California Forest Resources Mapping Program Project Plan, 1978, available from NASA Ames Research Center, Technology Applications Branch, Moffett Field, California 94035). This project was to be completed by July 1, 1979. Final products were to be Landsat based digital and photographic land cover data for California. In addition, digital terrain data were to be derived from Defense Mapping Agency/National Cartographic Information Center digital elevation data.

Introduction to Landsat

The first Landsat satellite, ERTS-1, was launched on July 23, 1972. Since then there have been two replacements, Landsat 2 (launched January 23, 1975) and Landsat 3 (March 3, 1978). Today both Landsats 2 and 3 are operational.

The special-purpose Landsat satellites have been designed to measure Earth resource features. Landsat imagery has been used in such fields as geology, urban planning, hydrology, mining, agriculture, and forestry (NCSL 1978).

Landsat is actually a satellite system and is normally referred to in the singular, even though more than one satellite may be operating at a time.

Landsat operates at an altitude of 570 n. mi. Its orbit is designed so that repetitive ground coverage is obtained every nine days when more than one satellite is operating, as their orbits are complementary. The satellite is in a "sun synchronous" orbit. At any location, images obtained on different days will be at the same local time of day (the middle to late morning in the northern temperate latitudes) (USGS 1979).

The heart of Landsat is the Multi-Spectral Scanner (MSS). It obtains images roughly 100 n. mi. on a side. Each image is made of a grid of discrete picture resolution elements called "pixels." Each pixel represents a ground rectangle of roughly 1.1 acres. For each pixel, four spectral values are measured in four broad bands: one in the green (0.5 to 0.6 microns), one in the red (0.6 to 0.7 microns), and two in the near infrared (0.7 to 0.8 and 0.8 to 1.0 microns). These values describe the integrated solar reflectance intensities for all objects within the pixel (USGS 1979).

The 100 n. mi. × 100 n. mi. images are known as "frames" or "scenes," not as photographs, as they are actually obtained in a digital electronic format that is computer compatible. As such, they are recorded in original form on magnetic tape and can be visually displayed on photographic film or color video monitors. This is done by displaying the green image band as blue, the red band as green, and one of the infrared bands as red. The "false color" image has the same visual appearance as a color infrared photograph.

There are two ways to analyze Landsat imagery. It can be photo-interpreted in much the same way as one interprets a color infrared photograph, or it can undergo computer analysis (NCSL 1978). In the first approach the image is analyzed using spectral and spatial pattern recognition. This is the approach used for the CALVEG map. The second approach relies upon automated spectral analysis. Advantages and disadvantages exist with both methods. The computer approach is presently handicapped by a lack of spatial pattern recognition capability. On the other hand, manual photo-interpretation is subjective, and interpreted results are often inconsistent between analysts. Computer processing yields quantified results. Computers are also very fast and do not tire of processing voluminous quantities of data. This allows automated analysis of each of the 7-1/2 million pixels contained in a Landsat image.

Each method benefits from the use of collateral information, such as aerial photography and ground knowledge of the image area. In fact, Landsat data works best in harmony with other data structures, especially in digital form.

Landsat imagery can yield cost savings when the area to be analyzed is large, and the level of information required is broad and moderate. Large area ground surveys and aerial photographic mapping techniques are relatively expensive both for data acquisition and analysis. Landsat image analysis of large areas can be relatively inexpensive as fewer data sets are required for area-wide coverage and spectral analysis is reasonably efficient (NCSL 1978).

Landsat data are available from both the U.S. Geological Survey's Earth Resources Observation System Data Center, Sioux Falls, South Dakota, and the Canadian Centre for Remote Sensing, Ottawa, Ontario.

Project Method

The Landsat analysis for this project was composed of several components. First, the image data had to be selected. Then a digital mosaic of all the Landsat images covering the state was produced (Fig. 1). The data were then broken into image blocks for spectral analysis (Fig. 2). The final steps involved production of final output products and project documentation.

One of the initial steps was selection of appropriate Landsat imagery for analysis. A digital mosaic of August 1976 scenes of Southern California had already been prepared at the Jet Propulsion Laboratory for the Bureau of Land Management (BLM). This month's imagery was good statewide, except for a small cloud-covered area along the northern coast. Extending the August 1976 southern California mosaic northward was chosen as an economical method for producing suitable project data. The year 1976 was a drought year, and although tree mortality was not visible in August, overgrazing and very low reservoir levels were quite evident. An April, 1977, scene was used in place of the cloud-covered north coastal area. In total, 31 Landsat scenes were used to produce the final mosaic, including some scenes from the BLM work.

Because of the scene geometry, spacecraft-induced anomalies, and the overlapping nature of adjoining Landsat scenes, a continuous Landsat digital mosaic must be produced. This is done by accounting for geometric and radiometric differences between scenes and removing redundant data in overlapping areas. Projecting onto a map base of fixed geometry gives a continuous statewide image that can be processed as a single image rather than 31 parts. Various edge matching techniques are used to digitally blend images. In addition, through resampling image elements, pixel size was changed from the original 57 m × 79 m to 80 m × 80 m. This larger, 1.6-acre, pixel size reduces the pixels needed to cover the state by 38%, thereby reducing computer processing time.

The data still to be mosaicked is large (62 million pixels). The complete mosaic could not be produced in a single block, so it was completed in 5 pieces, each yielding a complete geographic sub-block (Fig. 3). The NASA Jet Propulsion Laboratory produced the mosaic (Development of the California Mosaic, 1978, Jet Propulsion Laboratory, Pasadena, California 91103, unpublished document).

Each block was sent to Ames upon completion, starting from the already processed southern end of the state and moving north. The data were subsectioned into 1° long by 1° lat quadrangles to simplify downstream processing and applications work. This convenient size is equal to one-half of a standard U.S. Geological Survey 1:250,000 scale topographic series map. A Lambert conformal conic projection was used for the data.

In addition to Landsat image data, digital elevation, slope, and aspect data were provided for each quadrangle. JPL developed this information from Defense Mapping Agency (DMA) digital terrain tapes. The terrain data were also registered to the map base. These data were useful during analysis as a means of differentiating vegetation types, as vegetation variations often relate directly to terrain variations (Strahler, Estes, and Maynard 1980).

JPL also provided a translation equation relating latitude and longitude to pixel locations. This made it possible to readily relate map features to their corresponding pixels in the image and terrain data.

Ames Research Center analyzed the image of each quadrangle. The "unsupervised classification" method was selected as the means of analysis. In this method, a clustering algorithm is used to develop spectral clusters. These clusters are defined by a spectral mean and variance in each of the 4 Landsat bands. The analyst controls the formation of clusters by defining the number desired and the minimum degree of separation between each. The spectral values of all pixels are then examined in a four-dimensional space defined by the Landsat MSS bands. The algorithm will partition the spectral space so that the mean value of each cluster centers on some congregation of values in the four-dimensional spectral space. Each pixel can then be defined as belonging to a spectral group. Ideally features picked out by each spectral cluster can be easily related to some desirable land cover type. Difficulties result, however, when a spectral class includes 2 types, for example, picking out both residential and vineyard areas. This particular spectral class may pick out these features well, but data use is limited when thematic classes receive names such as residential/vineyard. This results in some specialized stratification to differentiate the 2 components, or simply labeling the spectral class either residential or vineyard, depending on which is the major component.

This description is generalized. The actual method undertaken employed several variations (Fig. 4). First, the total area of each 1° × 1° quadrangle was not clustered as a unit. In order to eliminate confusion between spectrally similar, but thematically opposed, land cover types, clustering was applied by ecological areas (Fig. 5) (Newland, Peterson, and Norman 1980). These areas were delineated by CDF staff based on Küchler's Map of Potential Natural Vegetation (in Barbour 1977). Thirty-one ecological zones (ecozones) were developed in this manner. As can be seen in Fig. 4, they extend across the Landsat 1° × 1° quadrangle boundaries. Each ecozone covers an area of similar and broad plan communities. Clustering analysis was carried out on each ecozone.

As mentioned, several quadrangles are contained in each ecozone. The computer capability available did not support simultaneous clustering of portions of multiple quadrangles. Some form of data assembly and compaction was required. A process known as "weighting" was carried out (Newland, Peterson, and Norman 1980). As may already be evident, the development of spectral cluster mean and variance statistics can be obtained without reference to the spatial relationships between pixels. Only spectral values need be recorded. In weighting, each spectral value encountered is recorded, and a counter keeps track of the rate of occurrence. In the process, inter-pixel spatial relationships are lost, but a great deal of data reduction results. This weighting process was used to interrogate the pixels within each quadrangle containing a given ecozone, extract the spectral values of the pixels in the ecozones, and record them in a computer file. When this was done, the 1° × 1° image quadrangles could be removed from the computer system, thus simplifying storage requirements. The weighted file developed would undergo clustering, normally for 35 to 45 spectral classes, this range having been determined optimum for the mapping task at hand.

Each Landsat 1° × 1° quadrangle had the spectral class statistics reapplied to it once the clustering process was carried out on each ecozone. Each pixel within an ecozone was matched against the spectral statistics for that ecozone and assigned to a spectral class using a maximum likelihood decision algorithm. The resultant "classified" image obtained by the interrogation of each pixel in this manner has 1 piece of information per pixel — the spectral class to which it was most similar.

This raised the question of exactly what features were to be mapped. Prior to full-scale processing, several quadrangles were put through the weighting, clustering, and classification processes described above. These were analyzed against the context of an anticipated classification scheme to derive a legend of types and a definition in categorical form that could be achieved. Mapping of the rest of the state was then made to conform to the legend (Table 1).

Spectral class identification for each ecozone was undertaken once the block of image quadrangles covering that ecozone was classified. Each spectral class was examined by CDF and NASA to determine which of the land cover classes it best represented. This was done by examining each class on a color display, locating where it was occurring on U-2 color infrared photography (scales varied between 1:30,000 and 1:130,000), and photo-interpreting the land cover at those sites. Examination of the land cover picked out by a spectral class at several sites was usually sufficient to allow the analysts to extrapolate their identification across the whole ecozone. The CDF foresters were instrumental in accomplishing spectral class identification due to their field experience in the areas mapped.

Fitting an appropriate land cover name from the mapping legend to a spectral class was not always straightforward. Occasionally, spectral confusion resulted when 2 cover types were represented by a spectral class. When possible, these confusions were resolved by stratifying an ecozone with the digital elevation data and assigning the appropriate label within each elevation band. This type of stratification was used to a limited degree, recognizing that a great deal more specificity could be obtained with more time and effort; in general, classes were labeled on a "best fit" or majority basis.

After all labeling of the classes in a classified quadrangle was complete, the spectral classes were grouped into the 16 basic land cover types. County boundaries were digitally encoded and overlaid on the data. Acreage tabulations of the land cover types by county, and a color-coded photographic map of the state's resources, were then created.

Results

As a result of the project, acreage tabulations for all land cover types mapped were produced (Table 2). Photographic color prints were made at 1:1,000,000 and 1:250,000 scales for each quad, the latter scale being useful as it is the same scale as the USGS topographic map series. All information is also stored on computer tapes.

The total cost for the project has been estimated to be less than $300,000 (figure includes industry equivalent salaries), or less than 0.3¢ per acre.

The project was established in June 1978, and completed in June 1979. The image analysis at Ames Research Center by NASA and CDF staff was accomplished in the 8 months between November 1978 and May 1979.

The output is presently undergoing further analysis in areas of special interest by CDF and other state and local agencies. The map output will be used with other data from the CDF to help complete the program plan required by 1987.

References

Barbour, Michael A., Major, Jack (eds.). 1977. Terrestrial Vegetation of California, John Wiley & Sons, New York.

California Department of Forestry. 1980. California's Forest Resources Preliminary Assessment. Sacramento, California.

California, State of. 1977. California Forestry Resources Assessment and Policy Act. Sacramento, California.

Landsat Data Users Handbook. 1979. U.S. Geological Survey, Arlington, Virginia.

National Conference of State Legislatures Remote Sensing Project. 1978. A Legislator's Guide to Landsat, National Conference of State Legislatures, Denver, Colorado.

Newland, W. L., Peterson, D. L., and Norman, S. D. 1980. Bulk Processing Techniques for Very Large Areas: Landsat Classification of California, proceedings of the 1980 Machine Processing of Remotely Sensed Data Symposium, West Lafayette, Indiana.

Strahler, A. H., Estes, J. H., Maynard, P. F., Mertz, F. D., and Stow, D. A. 1980. Incorporating Collateral Data in Landsat Classification and Modeling Procedures, proceedings of the 14th International Symposium on Remote Sensing of Environment, San Jose, Costa Rica.

Parker, I., and Matyas, W. J. 1978. CALVEG: Vegetation Classification and Mapping of California, U.S. Forest Service, 630 Sansome Street, San Francisco, California.

Weislander, A. E., Jensen, H. A. 1945. Map of Vegetation Types of California, U.S. Forest Service, Forest and Range Experiment Station, Berkeley, California.

Table 1. Classification scheme.

1.	Alkali flats	
2.	Bare rock	
3.	Barren	<5% vegetation.
4.	Water	
5.	Other	Ice, snow, or clouds.
6.	Grassland	>5% vegetative cover; <10% tree canopy.
7.	Open shrub	5-24% vegetative cover is shrub species; <10% tree canopy.
8.	Brush	25% or greater of vegetation is shrub species; <10% tree canopy.
9.	Conifer	≥25% conifer canopy closure; hardwoods <20% of the tree species present.
10.	Conifer/hardwood	>25% canopy closure; conifers comprise 50-80% of the stand; hardwoods 20-40% of the stand.
11.	Hardwood	>25% hardwood canopy closure; conifers <20% of the tree species present.
12.	Hardwood/conifer	>25% canopy closure; hardwoods 50-80% of the stand; conifers 20-49% of the stand.
13.	Conifer/woodland	10-25% conifer canopy closure; hardwoods <50% of tree species present.
14.	Hardwood/woodland	10-25% hardwood canopy closure; conifers <50% of tree species present.
15.	Agriculture	
16.	Urban	

Table 2. Total acres by class by county.

County	Bare rock	Water	Agri-culture	Urban	Alkali flats	Barren	Grassland	Open shrub	Brush
Alameda		73,596	12,102	101,131		21,439	154,106		120,576
Alpine	10,433	12,582	5,640		182	12,090	48,232	16,986	69,183
Amador	2,115	3,085	1,646			7,849	57,547		50,163
Butte	1,127	16,518	222,012			10,219	265,278	528	196,168
Calaveras	296	5,216	948			4,225	79,813		95,987
Colusa	179	689	209,384			25,805	295,995		33,794
Contra Costa		53,145	62,608	54,279		19,548	195,578		91,379
Del Norte		61,962	11			10,099	110,409	963	30,792
El Dorado	10,918	48,640	1,324			12,230	68,891		111,044
Fresno	198,128	43,311	751,826			421,796	902,766	2,234	317,010
Glenn	231	1,624	174,217			25,366	386,675		49,707
Humboldt		83,732	5			29,026	400,833	1,490	146,324
Imperial	179,971	188,835	175,774		375,468			1,740,480	136,078
Inyo	1,402,081	8,884	38,445		178,996	107,305	17,803	4,240,547	165,807
Kern	59,845	7,848	629,319		113,314	515,660	1,439,359	1,355,597	285,218
Kings		3,452	312,584			136,401	410,714		18,246
Lake	567	36,436	6,504			8,359	117,974		171,439
Lassen	1,221	34,413	3,226			401,269	199,121	1,241,319	501,126
Los Angeles	4,413	149,931	20,145	562,418	15,396	15,847	404,258	588,383	791,278
Madera	38,160	6,699	250,924			106,556	195,493	2	78,224
Marin		48,108	10,976	19,657		16,264	133,635	12,272	13,812

Table 2. Continued.

County	Bare rock	Water	Agri-culture	Urban	Alkali flats	Barren	Grassland	Open shrub	Brush
Mariposa	18,770	8,095	1,875			16,384	159,669		168,689
Mendocino	143	2,626	9,142			20,908	305,953		249,971
Merced		10,708	514,608			107,357	528,883		74,157
Modoc		104,359	13,614			237,783	344,375	1,121,661	292,484
Mono	45,913	43,558	87,517		68,434	81,149	30,245	889,557	118,935
Monterey		2,874	165,560			77,879	658,604		884,110
Napa		22,806	5,138	6,941		9,433	122,585		84,383
Nevada	3,484	5,658	536			10,908	35,019	7	181,390
Orange		2,013	12,477	97,722		4,919	123,413	12,145	103,703
Placer	3,342	53,339	33,723	1,932		32,128	121,259		147,735
Plumas	254	33,026	845			55,080	32,816	87,769	548,867
Riverside	375,521	68,488	104,345	47,612	211,009	33,323	342,306	2,480,344	716,554
Sacramento		10,692	180,455	84,230		7,631	340,690		3,947
San Benito		68	21,450			12,480	313,135		489,946
San Bernardino	825,967	15,324	34,760	138,045	959,982	997,733	392,846	8,619,205	515,518
San Diego	29,817	76,851	19,220	87,984	68,926	25,532	453,565	560,621	902,272
San Francisco		31,814		23,049		2,633	2,687		
San Joaquin		5,795	507,811			61,134	298,634		30,386
San Luis Obispo		67,259	99,094			138,182	1,083,842		616,317
San Mateo		46,923	1,286	54,468		13,036	63,157	6,899	11,222
Santa Barbara		35,390	40,723	31,068		31,241	701,489		616,423

Table 2. Continued.

County	Bare rock	Water	Agri- culture	Urban	Alkali flats	Barren	Grassland	Open shrub	Brush
Santa Clara		9,230	15,488	135,561		8,682	140,592	4,515	313,782
Santa Cruz		66,672	6,179	23,014		14,090	29,923	2,725	17,415
Shasta	1,547	23,146	7,684			54,373	264,869	21,885	404,019
Sierra	225	2,700	101			21,159	51,110	16,227	92,722
Siskiyou		76,189	24,546			159,663	871,897	308,417	290,597
Solano		42,587	158,848	11,683		12,823	318,941		11,974
Sonoma		13,609	34,808	18,409		50,265	319,697	7,652	78,738
Stanislaus		4,056	399,895			42,314	372,895		140,995
Sutter		798	233,658			6,932	151,746		3,836
Tehama	207	2,915	70,151			30,246	647,832	923	344,271
Trinity	11	21,084	10			19,509	238,865	2,115	238,443
Tulare	209,182	11,851	415,417		434	269,646	402,273	27,486	188,960
Tuolumne	89,528	23,964	598			41,572	61,172		210,666
Ventura		12,312	10,564	180,078		18,069	421,268	2,430	467,681
Yolo		1,843	183,668	3,723		28,984	338,489		26,095
Yuba	2,025	3,977	75,365			10,334	107,792	124	90,560
Total acres (in millions)	3.5	1.9	6.4	1.7	2.0	4.7	17.1	23.4	13.1

Table 2. Continued.

County	Hwd. wld.	Con. wld.	Hwd.	Hwd. con.	Con. hwd.	Con.	Other	Unclas-sified	Total
Alameda	24,472		12,645	2,622			504	171	523,364
Alpine	24	156,387	17,535	12,328	18,982	85,425		3,113	469,122
Amador	74,797	16,699	92,326	8,788	33,028	33,306		573	381,922
Butte	67,752	3,119	71,464	46,722	79,862	111,847		1,450	1,094,066
Calaveras	129,411	12,984	169,841	16,810	69,230	74,380		792	659,933
Colusa	143,498	3,759	3,645	5,018	5,639	5,666	99	6,663	739,833
Contra Costa	23,937		15,997	1,184			31	2,204	519,890
Del Norte	22,561		42,260	76,807	115,970	208,578	517	1,962	682,891
El Dorado	84,988	92,910	213,089	52,354	210,679	229,092		5,055	1,141,214
Fresno	147,574	259,912	208,559	59,379	23,152	567,060		12,911	3,915,618
Glenn	109,795	14,370	8,152	10,952	22,076	39,920	520	1,155	844,760
Humboldt	125,395	41,751	219,951	235,167	404,193	509,615	20,703	5,699	2,223,884
Imperial						42,552		4,036	2,843,194
Inyo	2,385	122,876	123		8,053	120,109		111,467	6,524,881
Kern	144,731	6,632	161,230	346,874	28,754	87,087		11,019	5,192,487
Kings	7,101		2	123				2,897	891,520
Lake	233,474	34,646	59,234	77,650	38,503	62,687	1,135	1,894	850,502
Lassen	25,790	177,392	6,262	11,025	32,473	354,282		5,354	2,994,273
Los Angeles	23,991	11,385	546	2,608	2,084	22,023	22,958	3,930	2,641,594
Madera	117,528	77,992	129,828	8,904	19,628	255,192		1,968	1,287,098
Marin	46,255		31,498			11,274	61,132	46,327	451,210

Table 2. Continued.

County	Hwd. wld.	Con. wld.	Hwd.	Hwd. con.	Con. hwd.	Con.	Other	Unclas- sified	Total
Mariposa	92,123	38,365	130,312	8,251	23,119	262,491		1,662	929,805
Mendocino	247,479	297,169	158,026	356,742	233,997	316,224	65,874	40,641	2,304,895
Merced	15,968		2,010	397	33	340		3,490	1,257,951
Modoc	3,116	10,955	151	923	2,275	566,732		2,242	2,700,670
Mono	11,665	360,630	6,369	1,168	23,786	202,345		18,743	1,990,014
Monterey	41,583	19,836	115,026	80,520		52,069	6,608	33,413	2,138,082
Napa	156,716	11,615	39,358	39,405		7,042			505,422
Nevada	53,549	68,418	34,006	17,709	120,668	88,611		860	620,823
Orange	35,520		13,396				117,452	4,894	527,654
Placer	16,864	69,437	72,122	73,122	173,149	152,245		2,218	952,651
Plumas	7,539	65,280	120,429	81,867	117,095	510,093		4,137	1,665,097
Riverside	84,332	6	55,451			80,645	32,753	7,365	4,640,054
Sacramento	9,210		2,978						639,833
San Benito	24,576		14,050	7,246		44,684	5,606	31,409	964,650
San Bernardino	25,775	12,561	10,942	1,580		236,941	2,411	16,634	12,806,224
San Diego	212,725		141,046			27,552	186,251	11,720	2,804,082
San Francisco			838						61,021
San Joaquin	1,077		289	63				3,830	909,019
San Luis Obispo	119,022		40,436	17,085		2,053	925	8,715	2,192,930
San Mateo	48,775		28,015	12,130	21,789	15,314	35,200		358,214
Santa Barbara	170,499		60,473	1,501			14,109	43,349	1,746,265

Table 2. Concluded.

County	Hwd. wld.	Con. wld.	Hwd.	Hwd. con.	Con. hwd.	Con.	Other	Unclas-sified	Total
Santa Clara	113,902		46,552	13,127	16,428	13,675	65	1,901	833,500
Santa Cruz	30,950		15,370	8,701	15,623	9,829	23,059	17,941	281,491
Shasta	349,640	177,164	218,254	300,109	290,468	338,728	169	3,844	2,455,899
Sierra	6,482	81,878	54,574	28,884	82,925	175,129		539	614,655
Siskiyou	199,489	183,064	118,749	305,558	360,587	1,121,353	7,812	6,568	4,034,489
Solano	9,671	1,252	5,765	2,530				77	579,151
Sonoma	116,144	38,693	58,617	124,925	101,166	39,391	43,411	28,952	1,074,477
Stanislaus	1,615		111	1,726				807	964,414
Sutter								433	397,403
Tehama	375,722	32,714	44,745	84,686	66,435	159,207	394	3,926	1,864,374
Trinity	186,685	107,711	98,865	184,431	296,527	633,795	13,102	3,206	2,044,359
Tulare	298,301	298,301	257,421	31,334	64,088	607,258		7,809	3,089,761
Tuolumne	111,196	198,561	99,181	6,658	73,750	534,455		5,384	1,456,685
Ventura	65,210	2,836	4,675			417	4,739	1,057	1,191,336
Yolo	58,867	90	1,166	1,911				75	644,911
Yuba	22,389	202	15,212	14,600	38,049	19,726		388	400,743
Total acres (in millions)	4.9	3.4	3.5	2.8	3.2	9.0	0.7	0.5	101.5

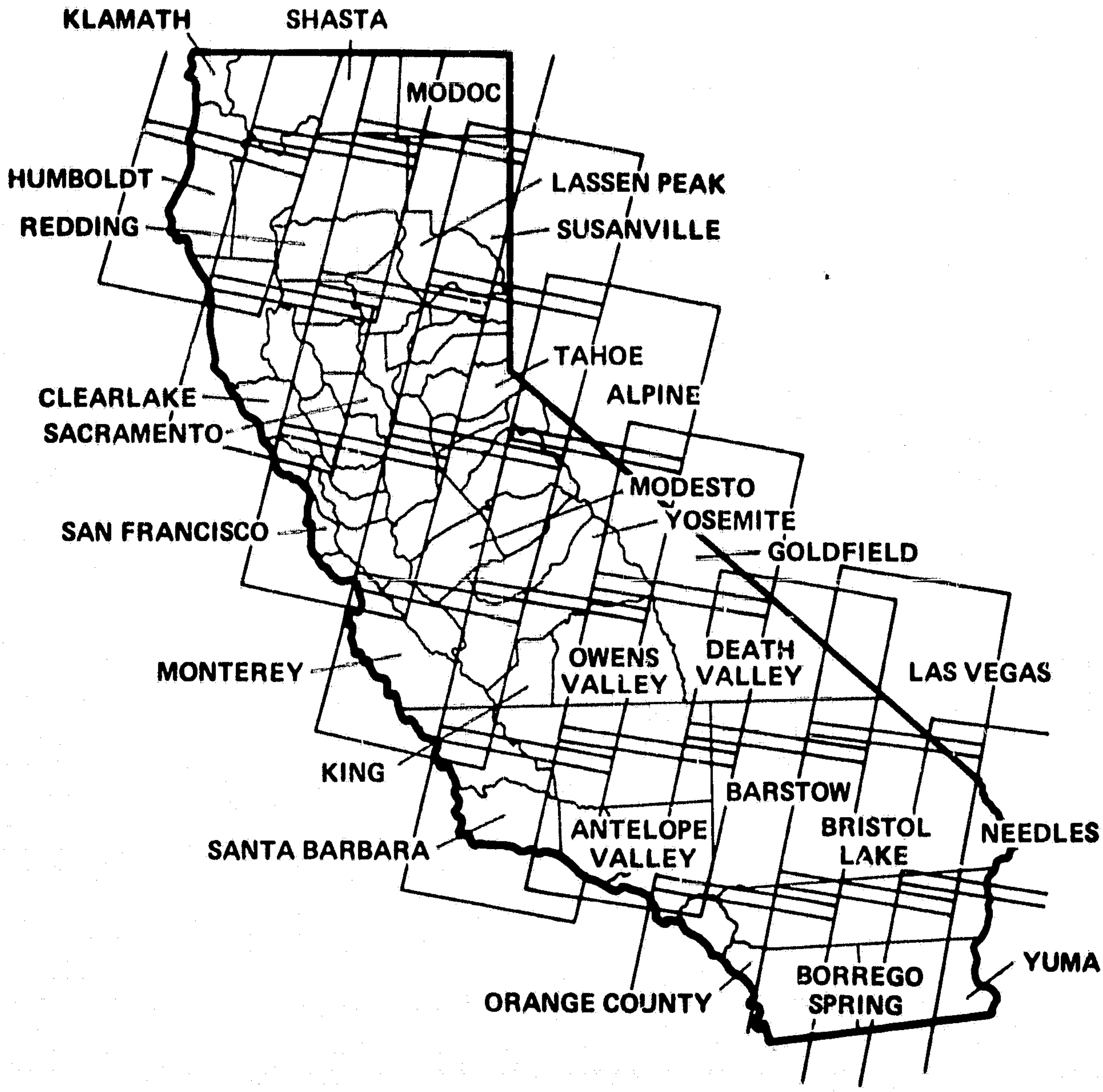

Figure 1.- Landsat scenes covering California.

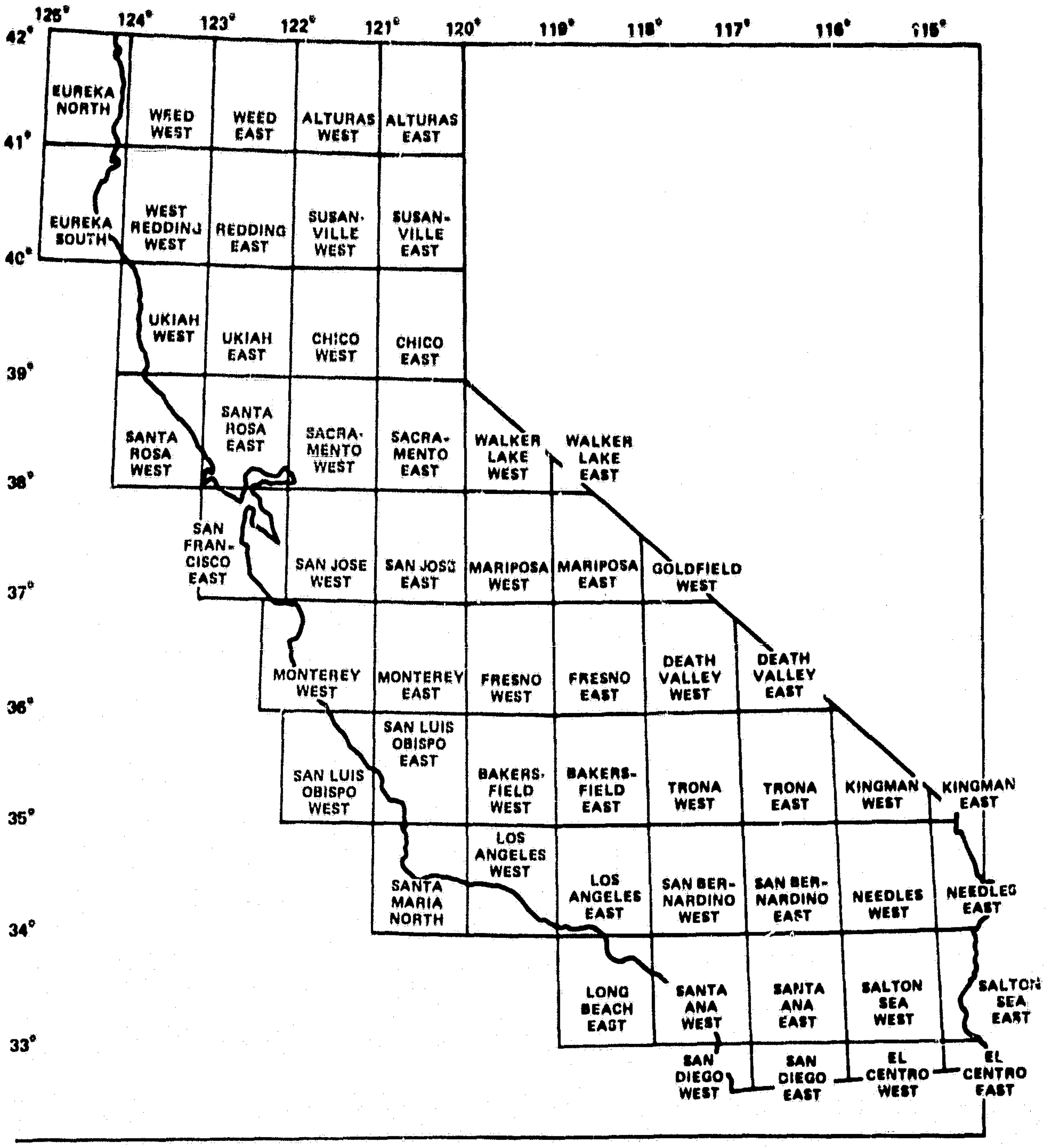

Figure 2.- 1° quadrangles of California.

Figure 3.- Image sub-blocks of California.

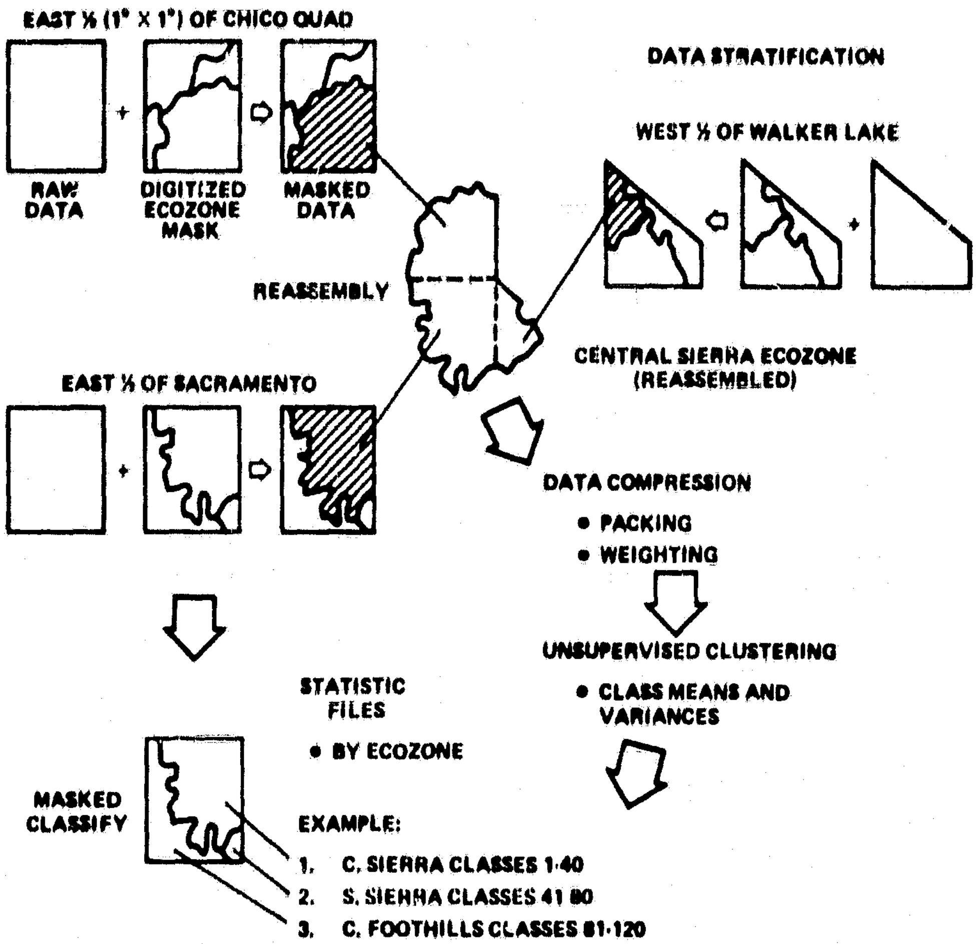

Figure 4.- Classification process.

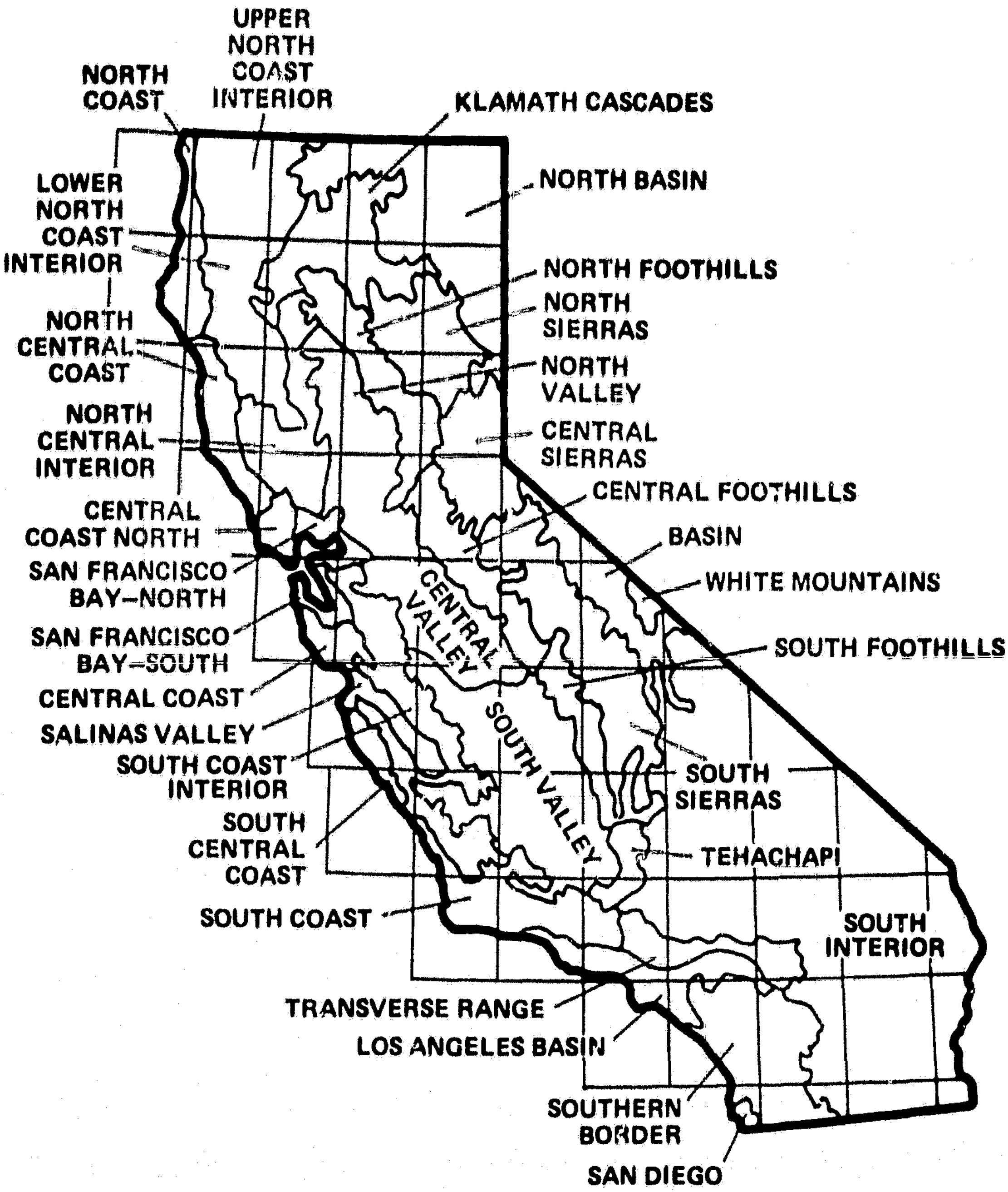

Figure 5.- Ecozones of California.