Final Project
Geography 342 - Remote Sensing
Fall 2016

Konrad Pehl
W1576625@apps.losrios.edu

Preliminary Analysis of Forest Stands with Landsat and LIDAR Derived Vegetation Height Raster

Summary

Landsat 8 imagery and a LIDAR derived vegetation height raster were used to examine a forested area in Northwestern Sonoma County. The Landsat bands 2, 3, 4, 5 and 6 were combined in various band combinations of two to four bands to produce seven different combinations. A classification scheme of Grass, Recent (recently disturbed), Small Tree, Medium Tree, Big Tree, Water, Ocean, and No Vegetation was used. Training areas were selected for each class. A supervised classification on each band combination was conducted using the maximum likelihood classification method. The band compositions were then composited with a LIDAR derived vegetation height raster and the maximum likelihood classification was repeated. A maximum likelihood classification was also conducted on the vegetation height raster. Acreages for the classification categories in each combination were computed.

No ground truth study was conducted, and no other data was available for comparison, so no formal accuracy assessment was conducted. Strong conclusions were difficult to reach. No formal statistical analysis was conducted. Comparisons based on the resultant images and summary tables show the following:

With the exception of NDVI, the addition of the vegetation height data reduced the amount of area classified as Grass.

The addition of vegetation height data increased the amount of area classified as Recent (recently logged or disturbed).

With the exception of NDVI and Natural Color, the addition of vegetation height data decreased the amount of area classified as Small Trees.

Aggregating the vegetation height raster to 30 meters to match Landsat resolution probably obscured cover types that only occurred in small or narrow areas. In this case the non-forest classifications.

The classification of water was consistent with classification based only on spectral data, the addition of the vegetation height raster resulted in higher acreage classified as water.

All band combinations probably under classified the amount of area in big trees.

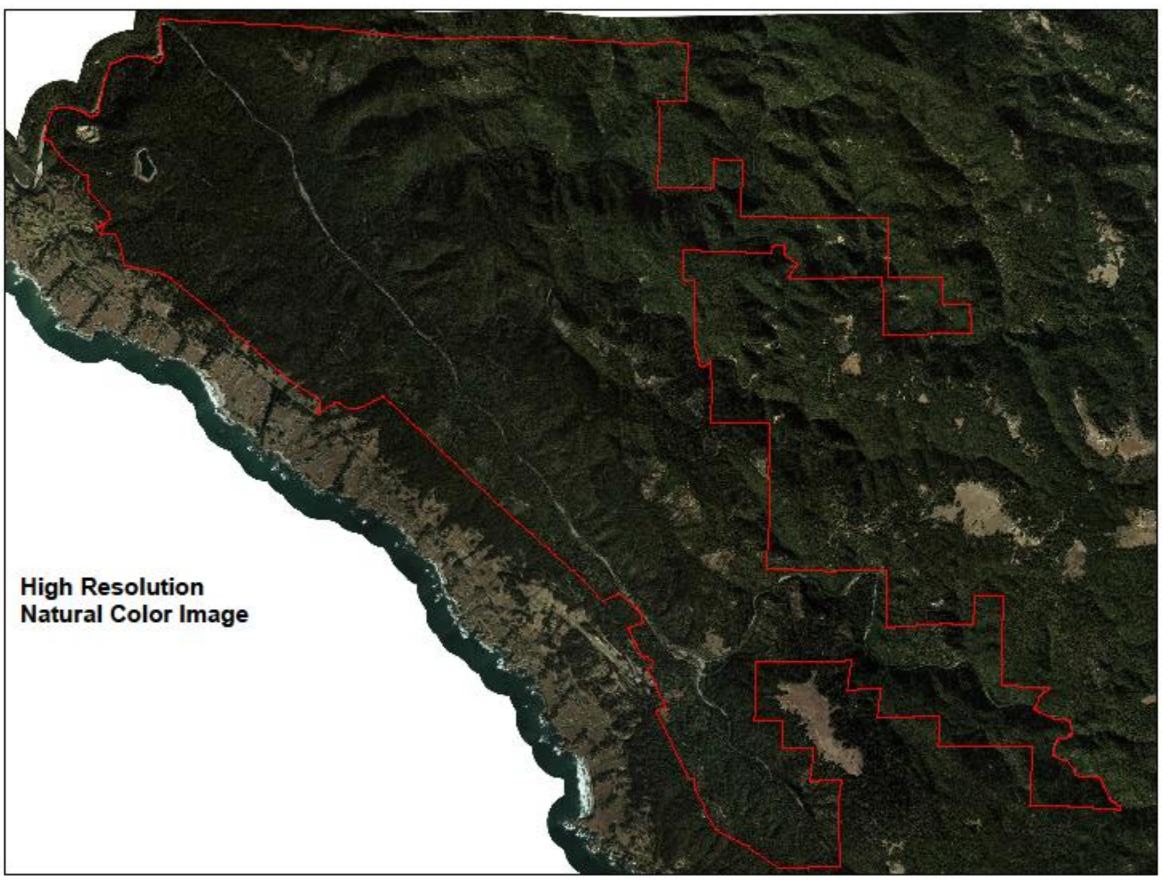
Although I have no ground truth data, after conducting this project I have concluded that the addition of height data to Landsat data can benefit the classification of land cover.

Purpose

Management decisions should be based on information. In forest management, resources are inventoried and summarized to use in decision making. Timber stand inventories are an essential part of a resource inventory system. When developing a timber stand inventory the forest is divided into inventory units, or "stands". A forest stand is a contiguous group of trees sufficiently uniform in composition, structure, age and size class distribution, spatial arrangement, site quality, condition, or location to distinguish it from adjacent groups. An essential step in conducting a forest inventory is delineating and mapping forest stands. Stand delineation has traditionally been done with aerial photographs. The process can be done with satellite imagery. I have used this project to learn about stand delineation and classification with satellite imagery.

Project Area

The project area is located in northwestern Sonoma County, near The Sea Ranch. The forest land is mostly in the lower Gualala River Watershed. It is a portion of the lands of the former Gualala Redwoods, Inc.



Imagery Sources

Imagery used came from Landsat 8 OLI sensor. The imagery was dated June 29, 2014. The image was selected because it was cloud free. The date was close to the summer solstice, reducing the length of shadows.

Spectral Band	Wavelength	Resolution	Solar Irrandiace
Band 1 - Coastal / Aerosol	0.433 – 0.453 μm	30 m	2031 W/(m²μm)
Band 2 - Blue	0.450 – 0.515 μm	30 m	1925 W/(m²μm)
Band 3 - Green	0.525 – 0.600 μm	30 m	1826 W/(m²μm)
Band 4 - Red	0.630 – 0.680 μm	30 m	1574 W/(m²μm)
Band 5 - Near Infrared	0.845 – 0.885 μm	30 m	955 W/(m²μm)
Band 6 - Short Wavelength Infrared	1.560 – 1.660 μm	30 m	242 W/(m²μm)
Band 7 - Short Wavelength Infrared	2.100 – 2.300 μm	30 m	82.5 W/(m²μm)
Band 8 - Panchromatic	0.500 – 0.680 μm	15 m	1739 W/(m²μm)
Band 9 - Cirrus	1.360 – 1.390 μm	30 m	361 W/(m²μm)

Seven band combinations were selected for comparison. These band combinations were selected from an ESRI blog article on Band Combinations for Landsat 8.
https://blogs.esri.com/esri/arcgis/2013/07/24/band-combinations-for-landsat-8/
These are common band combinations used for vegetation analysis.

Landsat 8 Band Combinations

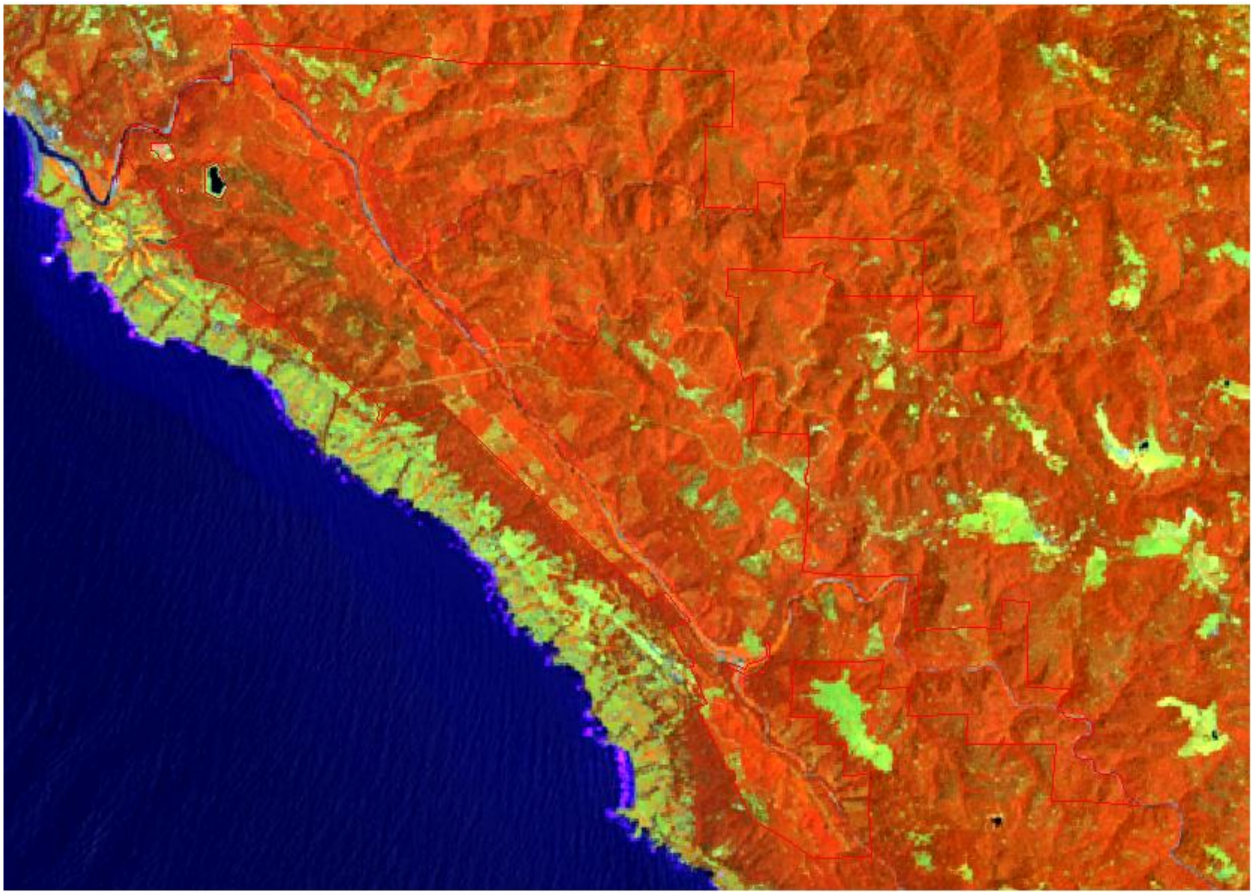
Combination	Bands (R, G, B, Alpha)
4 Band	2, 3, 4, 5
Color Infrared (vegetation)	5, 4, 3
Natural Color	4, 3, 2
Agriculture	6, 5, 2
Healthy Vegetation	5, 6, 2
Vegetation Analysis	6, 5, 4
NDVI	(5-4)/(5+4)

4 Band Combination (Bands 2,3,4,(5))

Agriculture Combination (Bands 6, 5, 2)

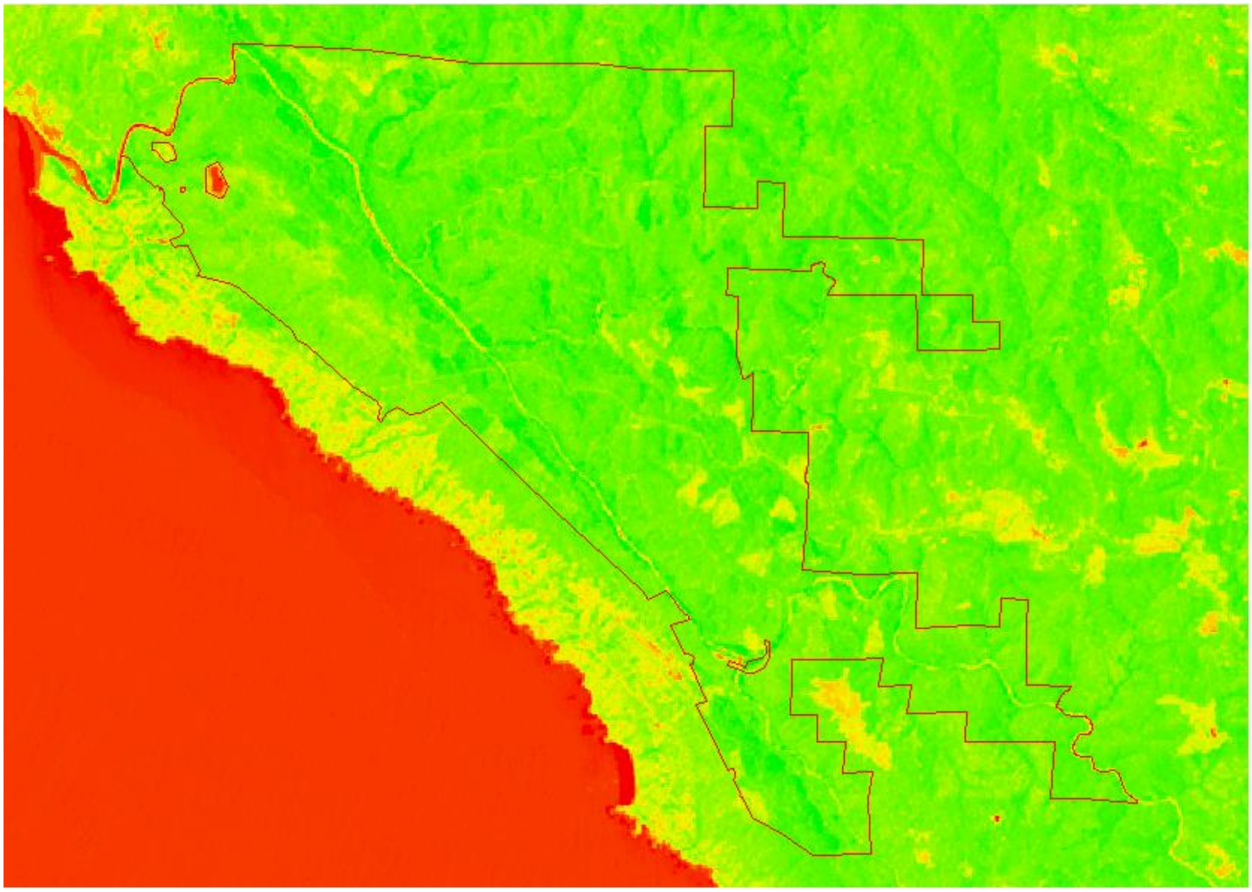
Color Infrared (Bands 5, 4, 3)

Healthy Vegetation (Bands 5, 6, 2)



Natural Color (Bands 4, 3, 2)

NDVI (Bands (5-4)/(5+4))



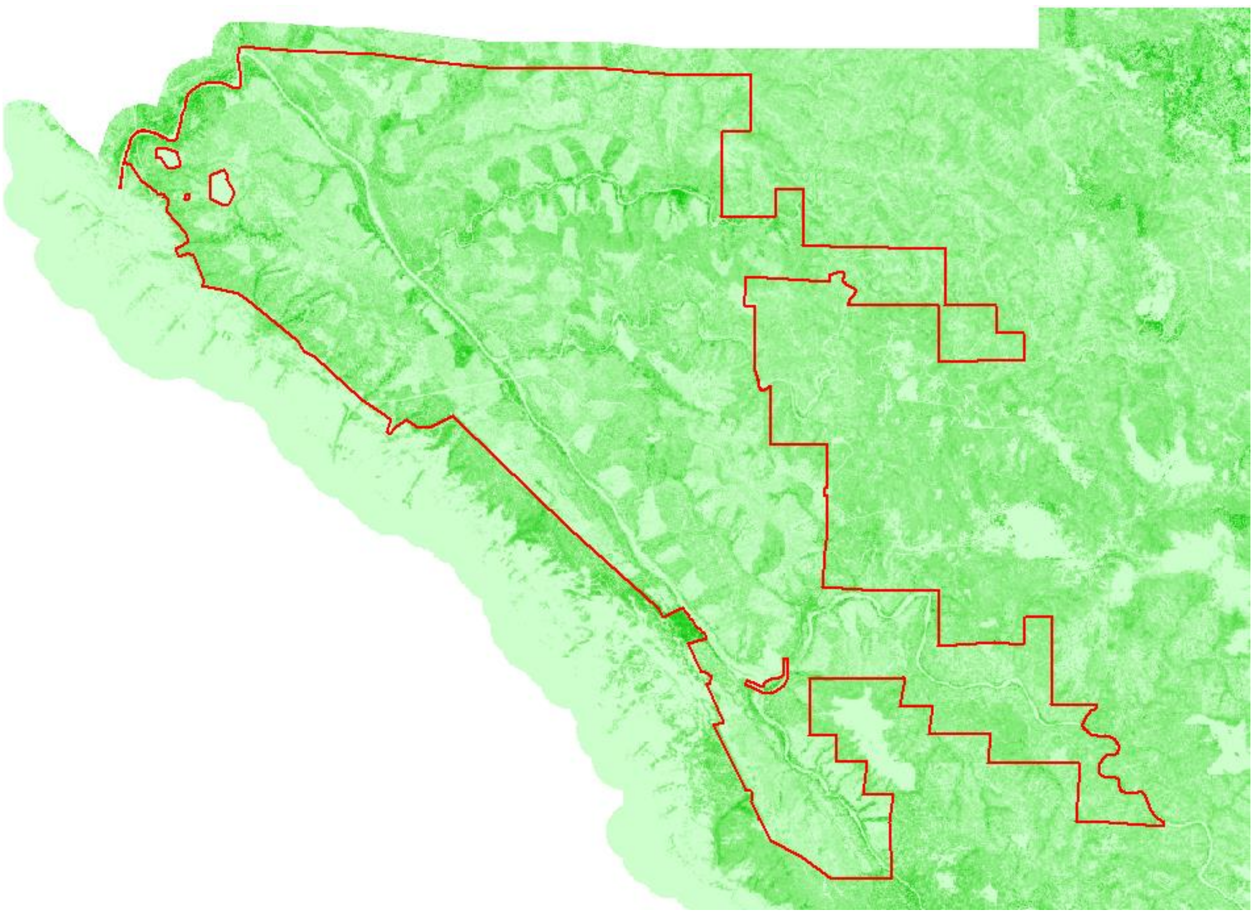
Vegetation Analysis (Bands 6, 5, 4)

A vegetation height raster was obtained from the Sonoma County Vegetation Mapping and LIDAR program. Sonoma Veg Map is a 5-year program to map Sonoma County's topography, physical and biotic features, and diverse plant communities and habitats. It is a joint program of the Sonoma County Agricultural Preservation and Open Space District and the Sonoma County Water Agency. Contributing partners include the California Department of Fish and Wildlife, the United States Geological Survey, the Sonoma County Information Systems Department, the Sonoma County Transportation and Public Works Department, The Nature Conservancy, the City of Petaluma, NASA, and the University of Maryland. The program has produced various products including countywide LiDAR data and orthophotography, which freely available. http://sonomavegmap.org/

The Sonoma Veg Map product of most interest to me was a 1-meter canopy height raster, which I refer to as the Vegetation Height Raster. This raster was created by subtracting the last returns from the first returns, resulting in height of vegetation.

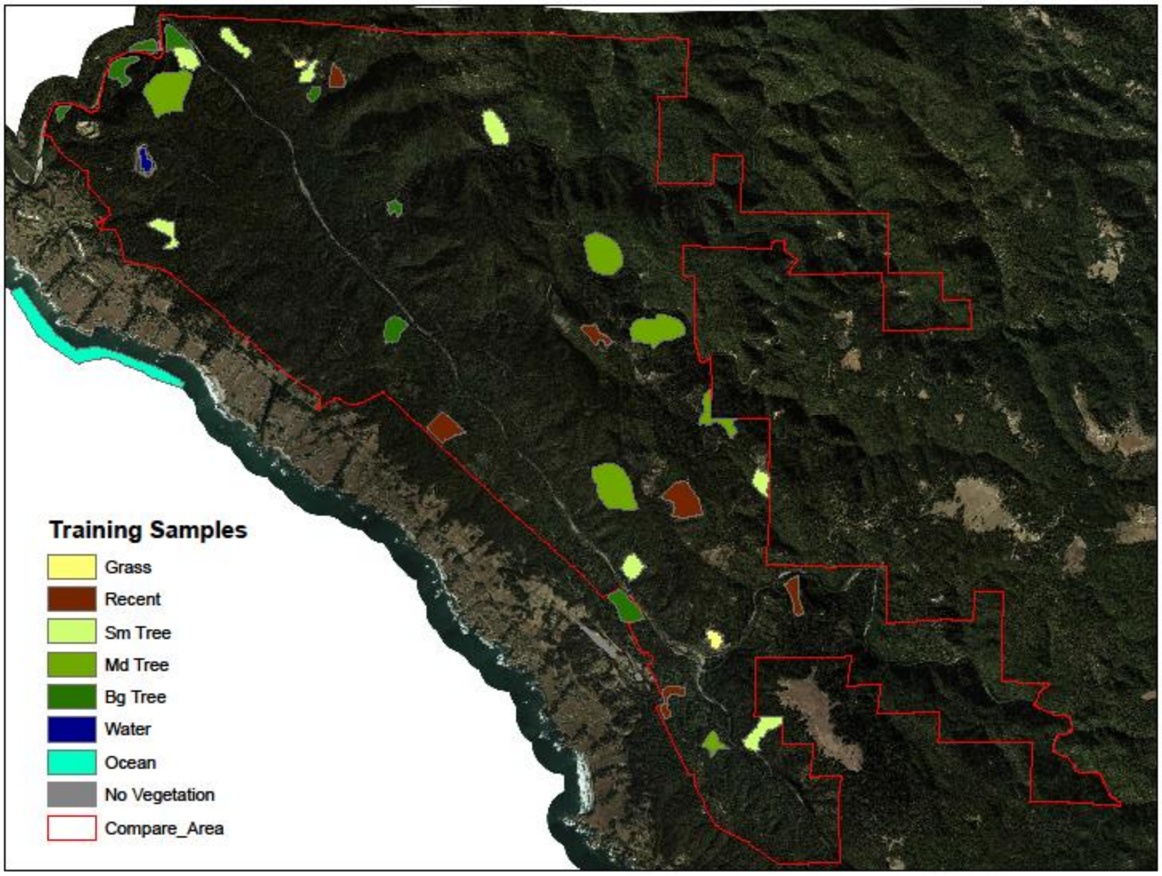
Exact date of LIDAR data was not available. It was described as Late 2013.

1-meter Canopy Height Raster (Vegetation Height Raster)



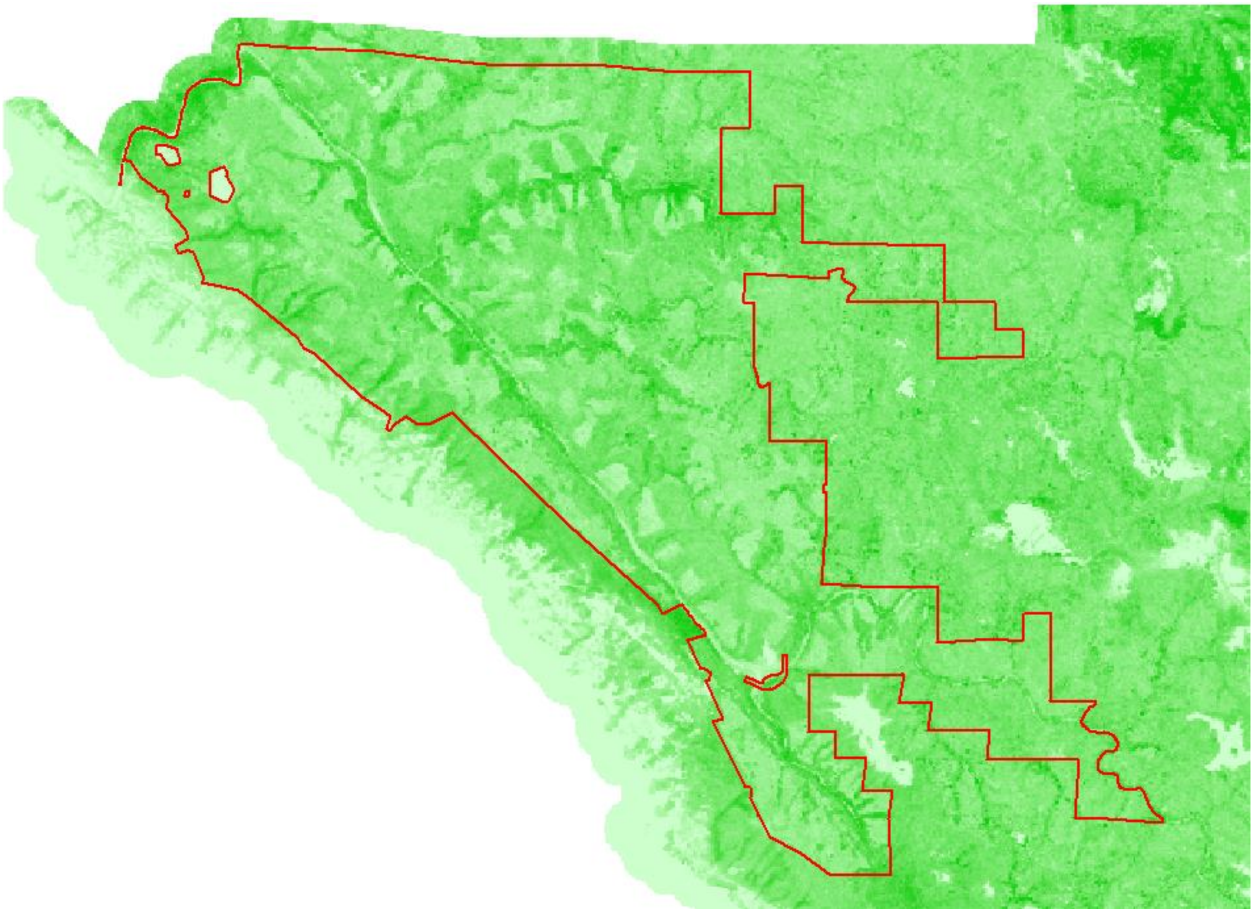
Description of the image processing tasks and methods used to create the outputs

A classification scheme of Grass, Recent (recently disturbed), Small Tree, Medium Tree, Big Tree, Water, Ocean, and No Vegetation was used. A training set was developed by digitizing sample areas from high resolution natural color imagery.



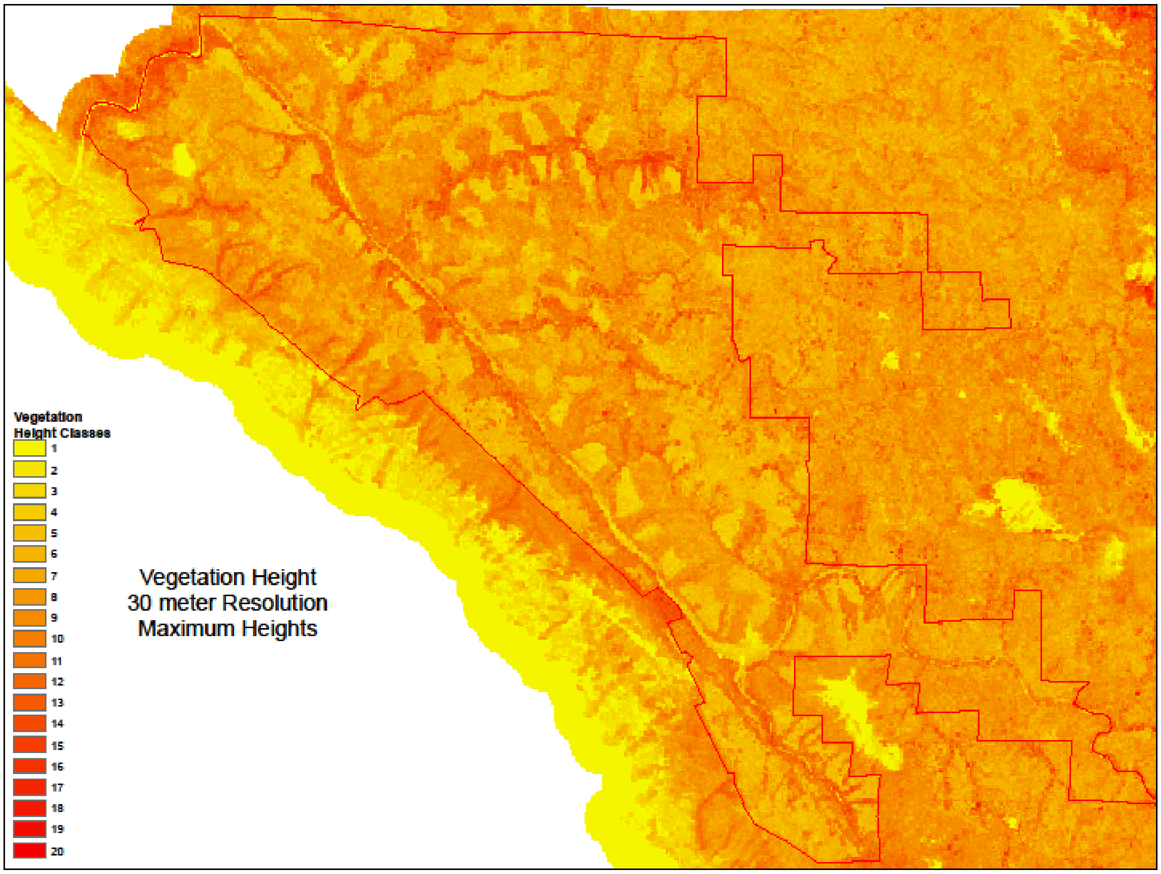
The Sonoma Veg Map Project's vegetation height raster was problematic due to file size. The image was resampled by aggregating the pixels to approximately 30 meter resolution. In order to emphasize trees in the classification pixels were assigned the maximum value for the aggregated area.

Aggregated to 30 meter Maximum Heights

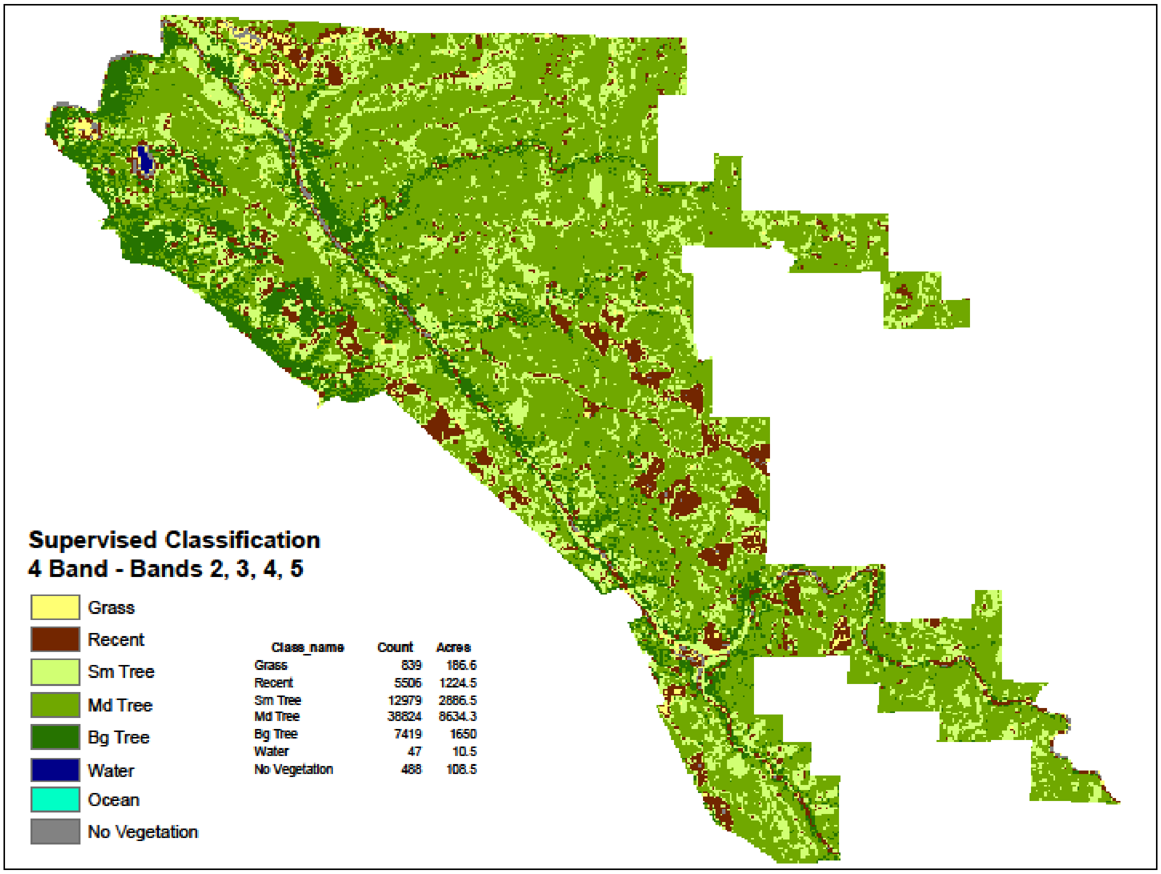


Since the Vegetation Height Raster contained floating point values and to speed processing, I reclassified the image to approximately 10 foot value increments.

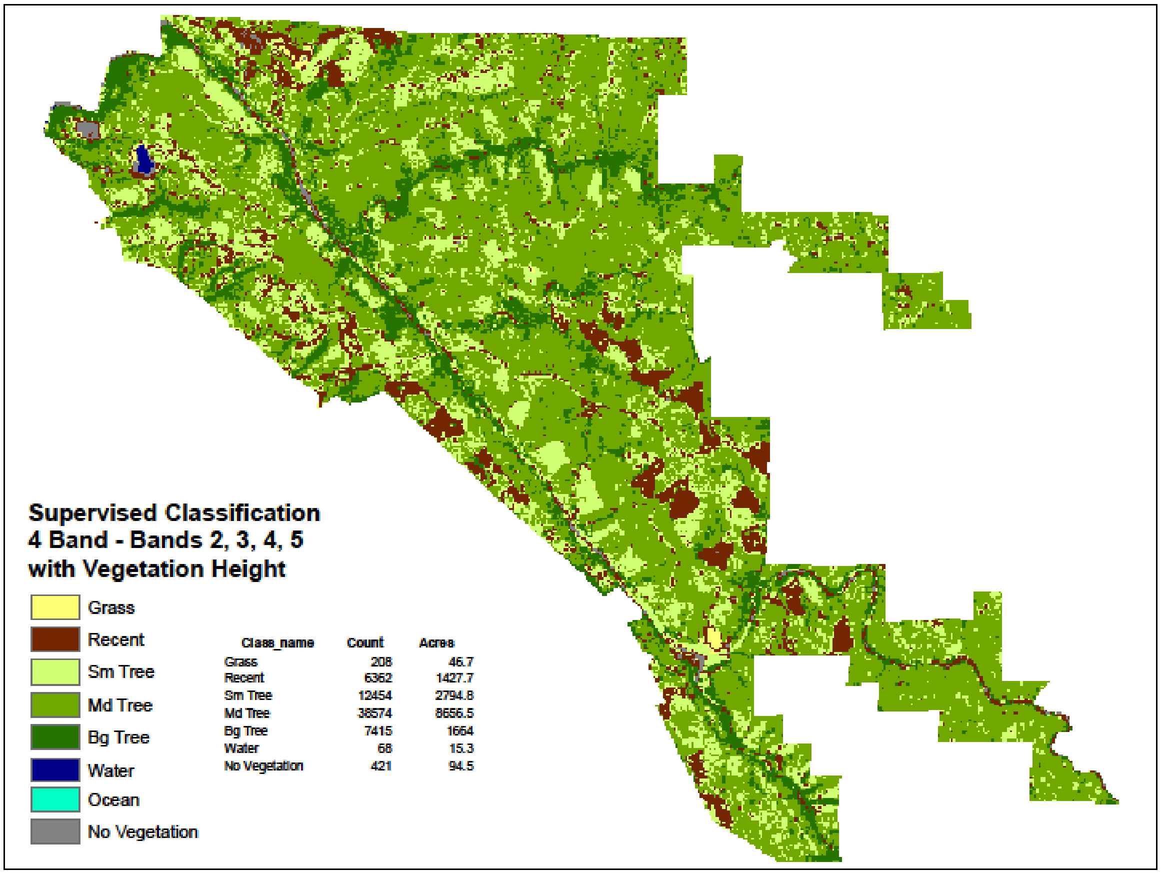
Vegetation Height - Aggregated to 30 meters Maximum Heights Reclassified to 10 foot Increments.



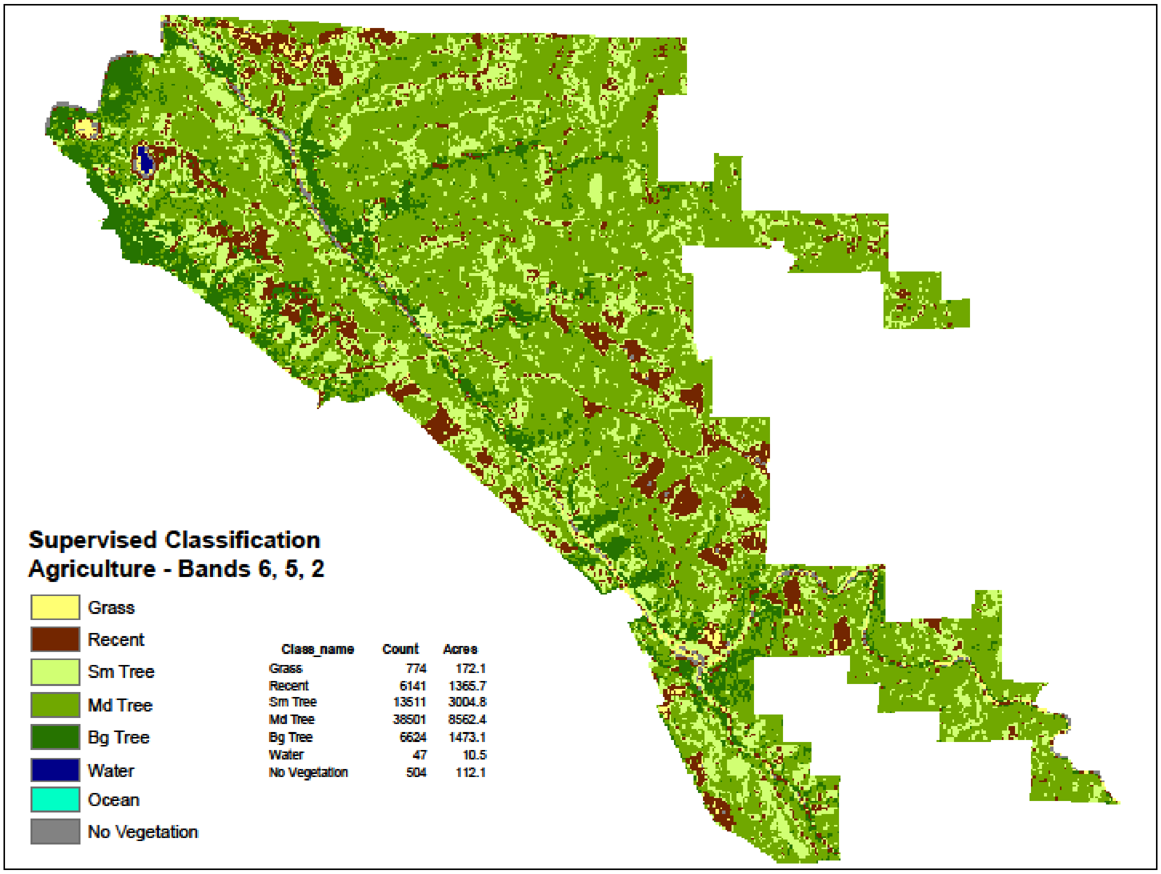
A maximum likelihood supervised classification of the seven Landsat 8 band combinations was conducted. In addition the same supervised classification was applied to the vegetation height raster. The seven Landsat 8 band combinations were composited with the aggregated and reclassified vegetation height raster. The same maximum likelihood supervised classification was applied to each. Acreage in each class was calculated.



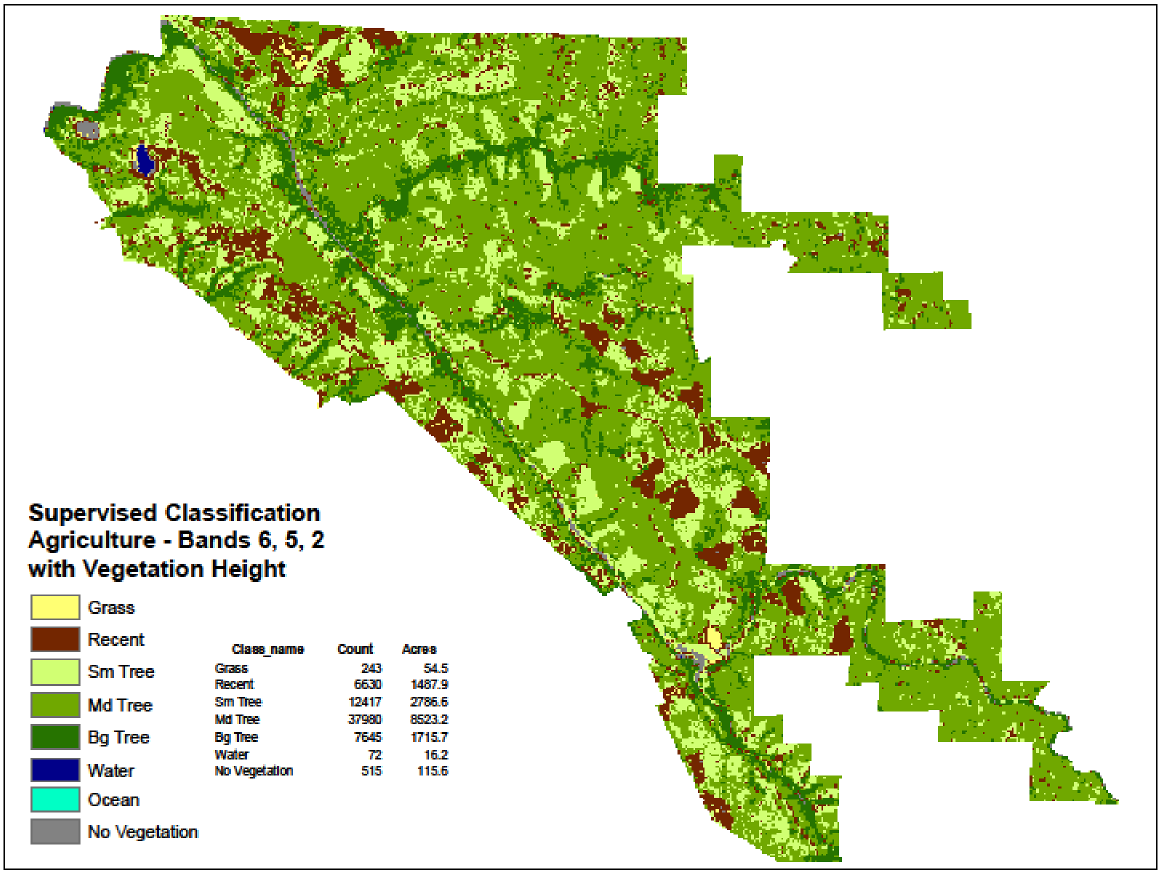
Class_name	Count	Acres
Grass	839	186.6
Recent	5506	1224.5
Sm Tree	12979	2886.5
Md Tree	38824	8634.3
Bg Tree	7419	1650
Water	47	10.5
No Vegetation	488	108.5



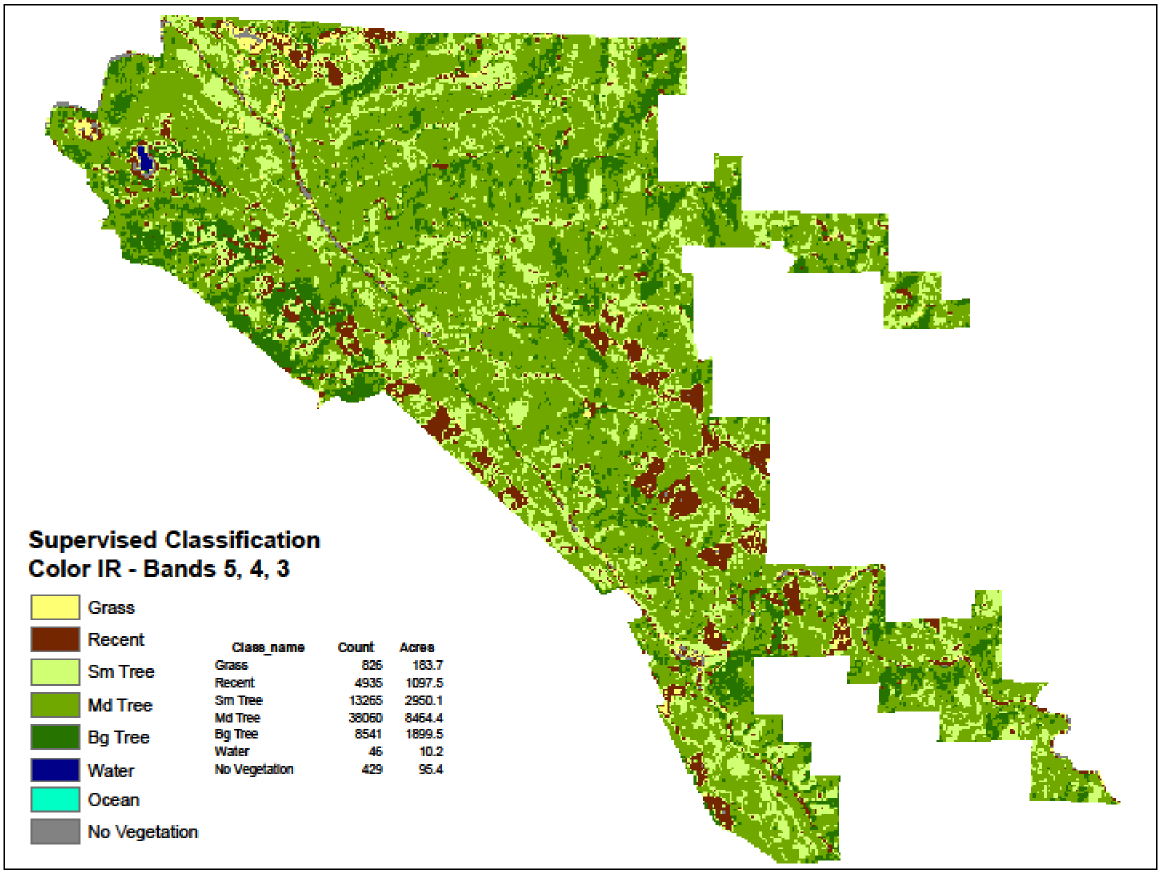
Class_name	Count	Acres
Grass	208	46.7
Recent	6362	1427.7
Sm Tree	12454	2794.8
Md Tree	38574	8656.5
Bg Tree	7415	1664
Water	68	15.3
No Vegetation	421	94.5



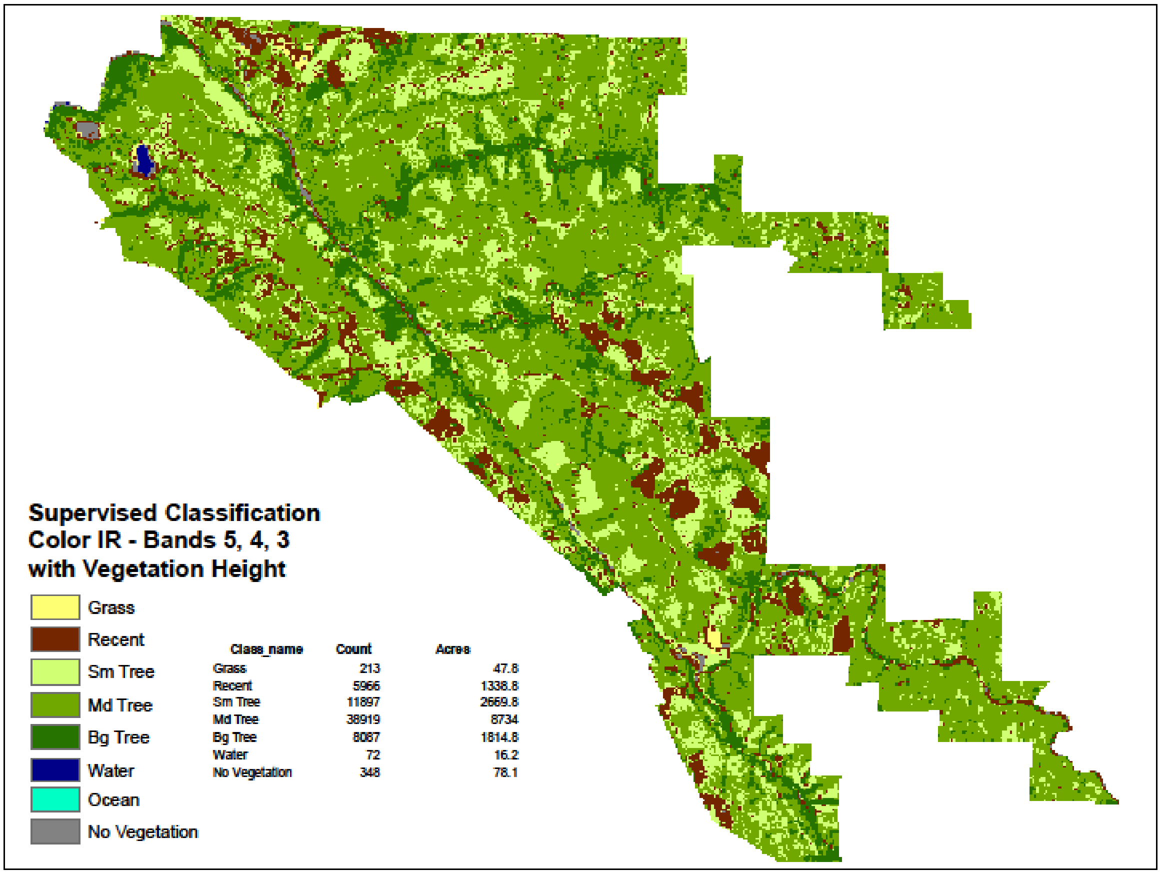
Class_name	Count	Acres
Grass	774	172.1
Recent	6141	1365.7
Sm Tree	13511	3004.8
Md Tree	38501	8562.4
Bg Tree	6624	1473.1
Water	47	10.5
No Vegetation	504	112.1



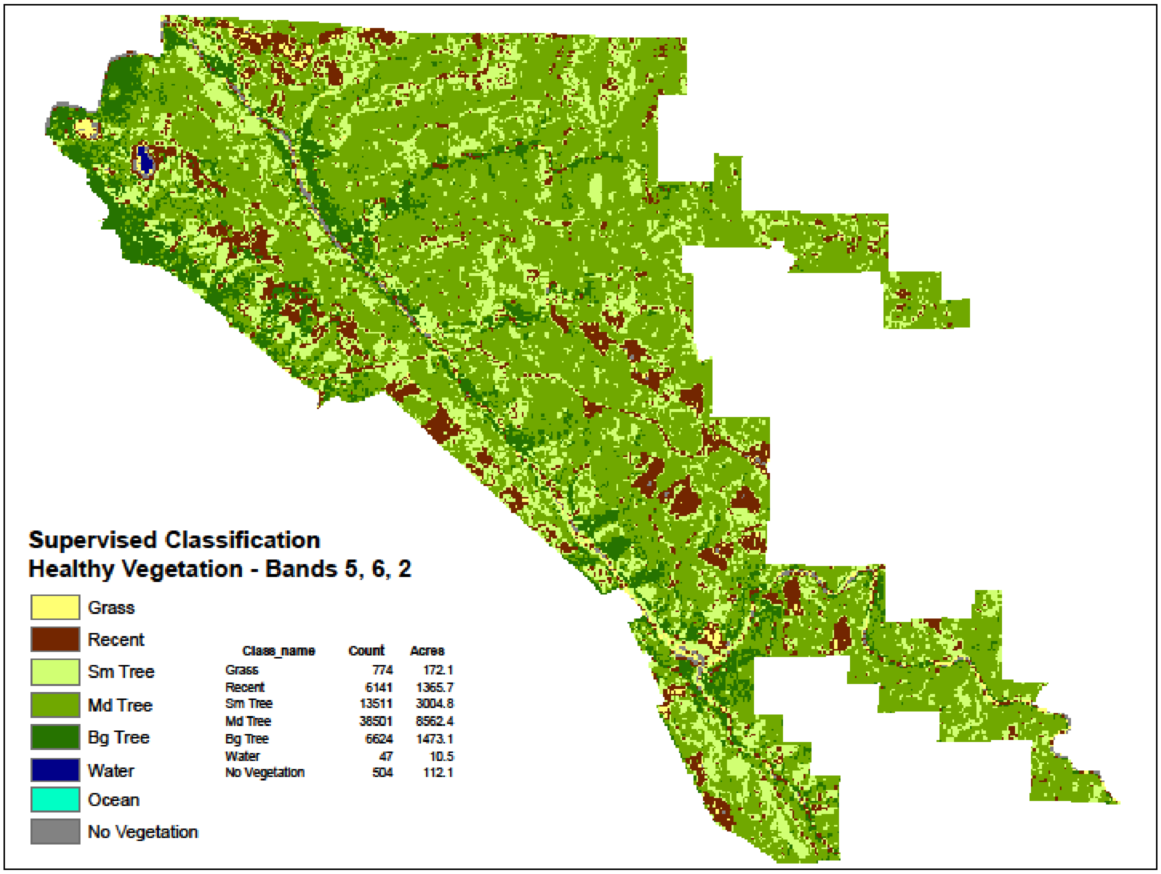
Class_name	Count	Acres
Grass	243	54.5
Recent	6630	1487.9
Sm Tree	12417	2786.6
Md Tree	37980	8523.2
Bg Tree	7645	1715.7
Water	72	16.2
No Vegetation	515	115.6



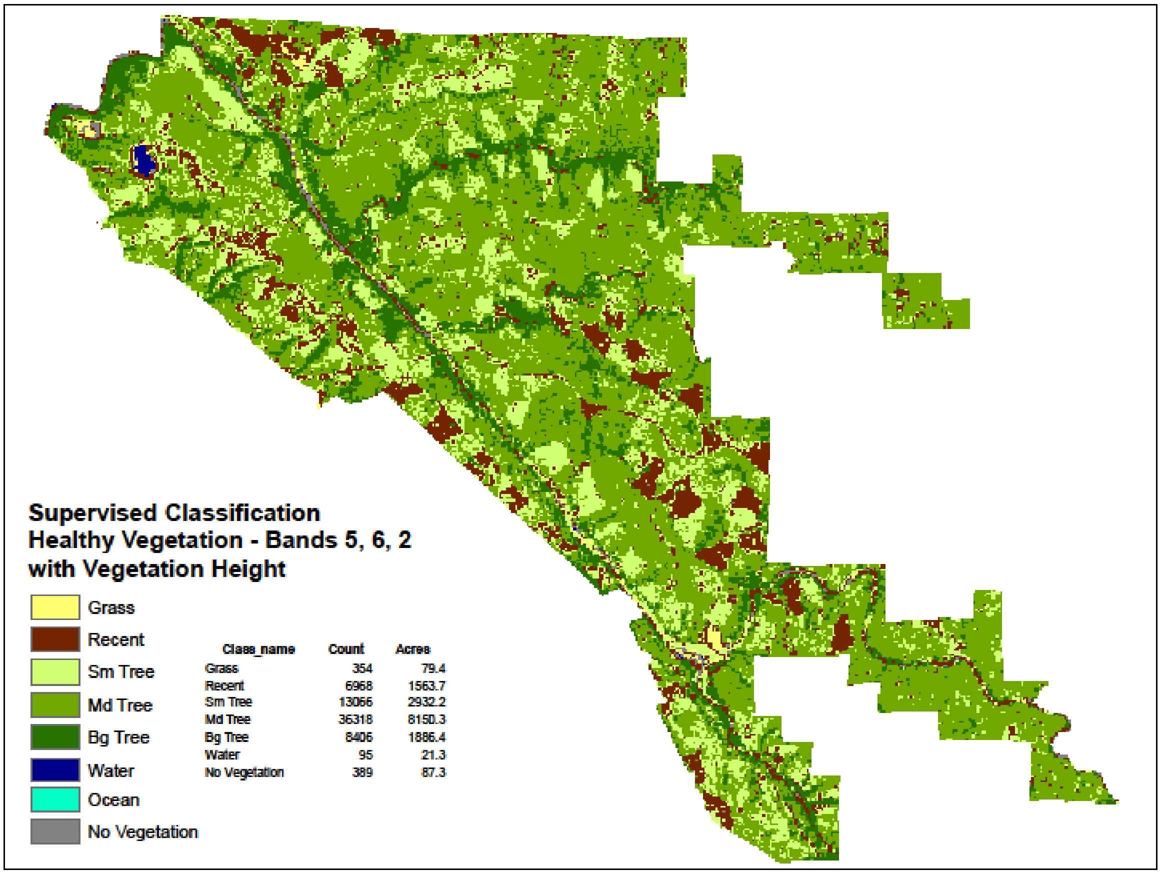
Class_name	Count	Acres
Grass	826	183.7
Recent	4935	1097.5
Sm Tree	13265	2950.1
Md Tree	38060	8464.4
Bg Tree	8541	1899.5
Water	46	10.2
No Vegetation	429	95.4



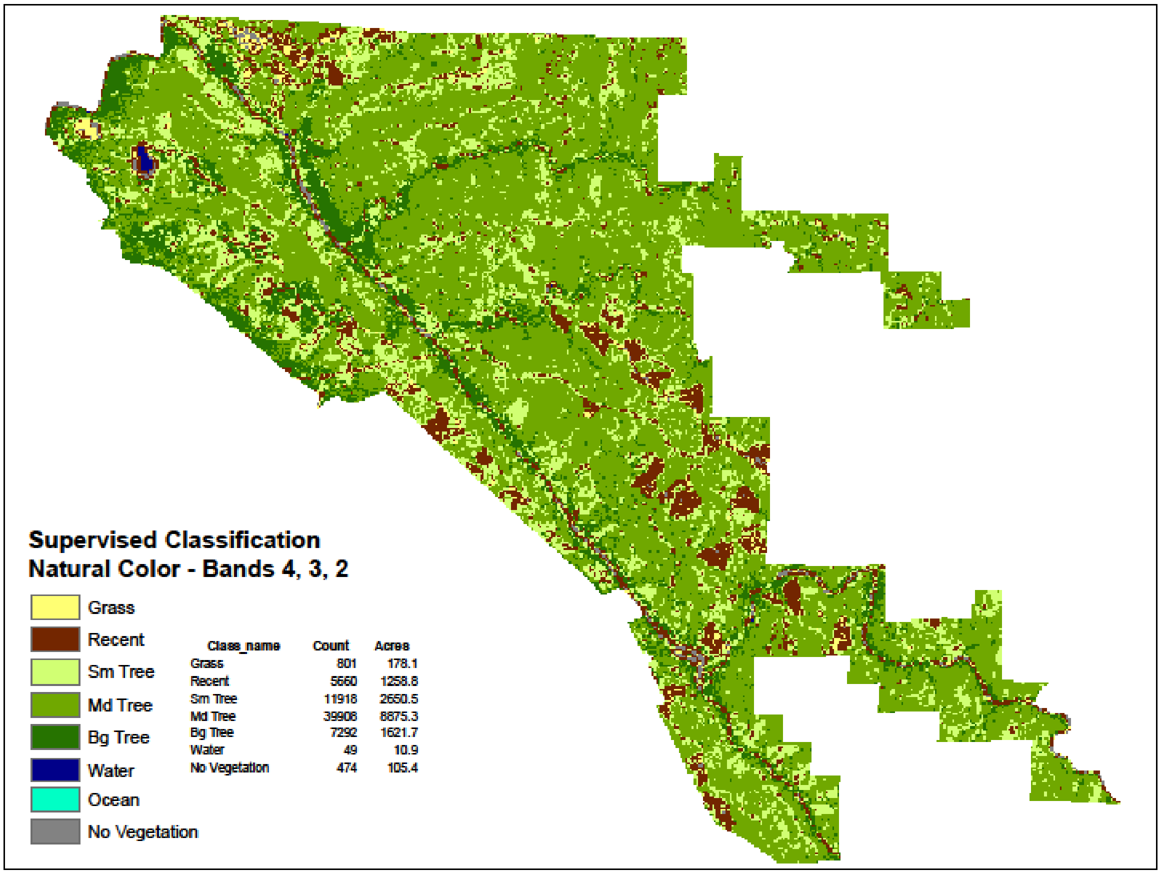
Class_name	Count	Acres
Grass	213	47.8
Recent	5966	1338.8
Sm Tree	11897	2669.8
Md Tree	38919	8734
Bg Tree	8087	1814.8
Water	72	16.2
No Vegetation	348	78.1

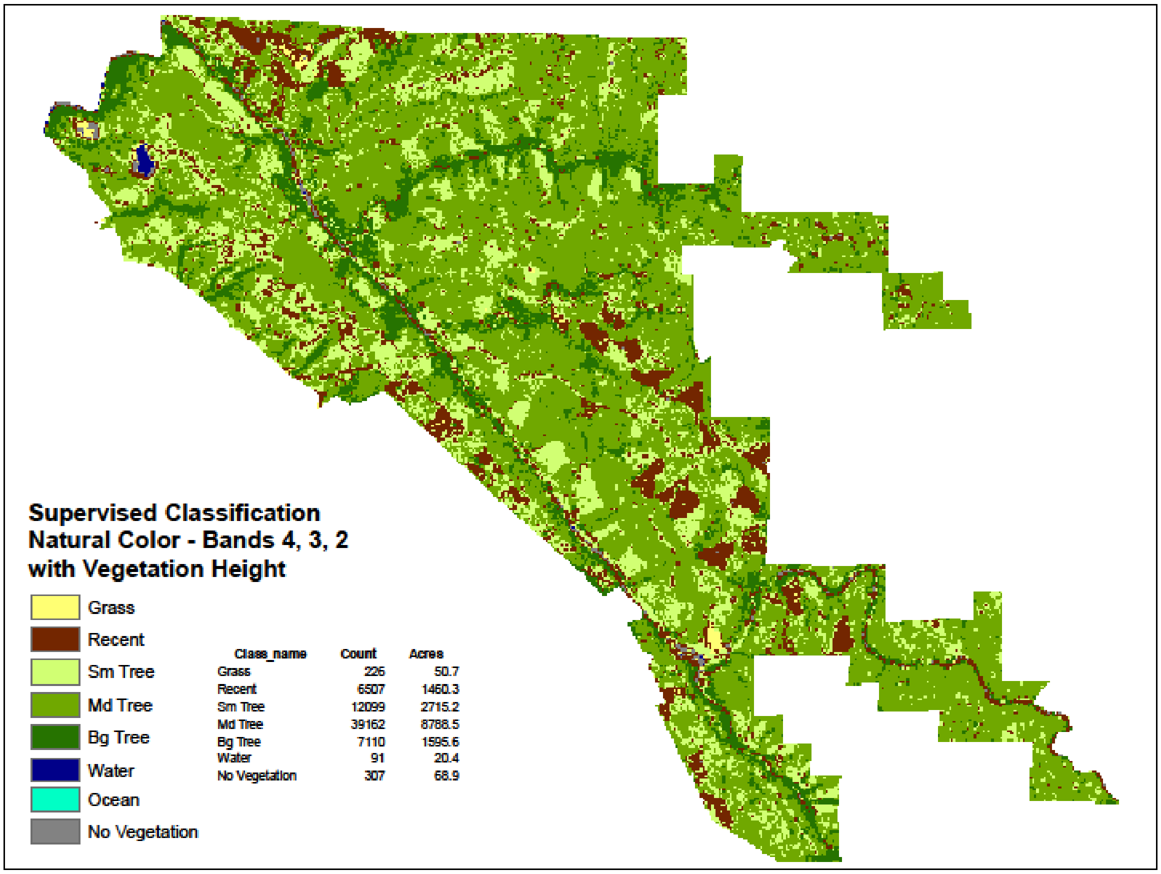


Class_name	Count	Acres
Grass	774	172.1
Recent	6141	1365.7
Sm Tree	13511	3004.8
Md Tree	38501	8562.4
Bg Tree	6624	1473.1
Water	47	10.5
No Vegetation	504	112.1

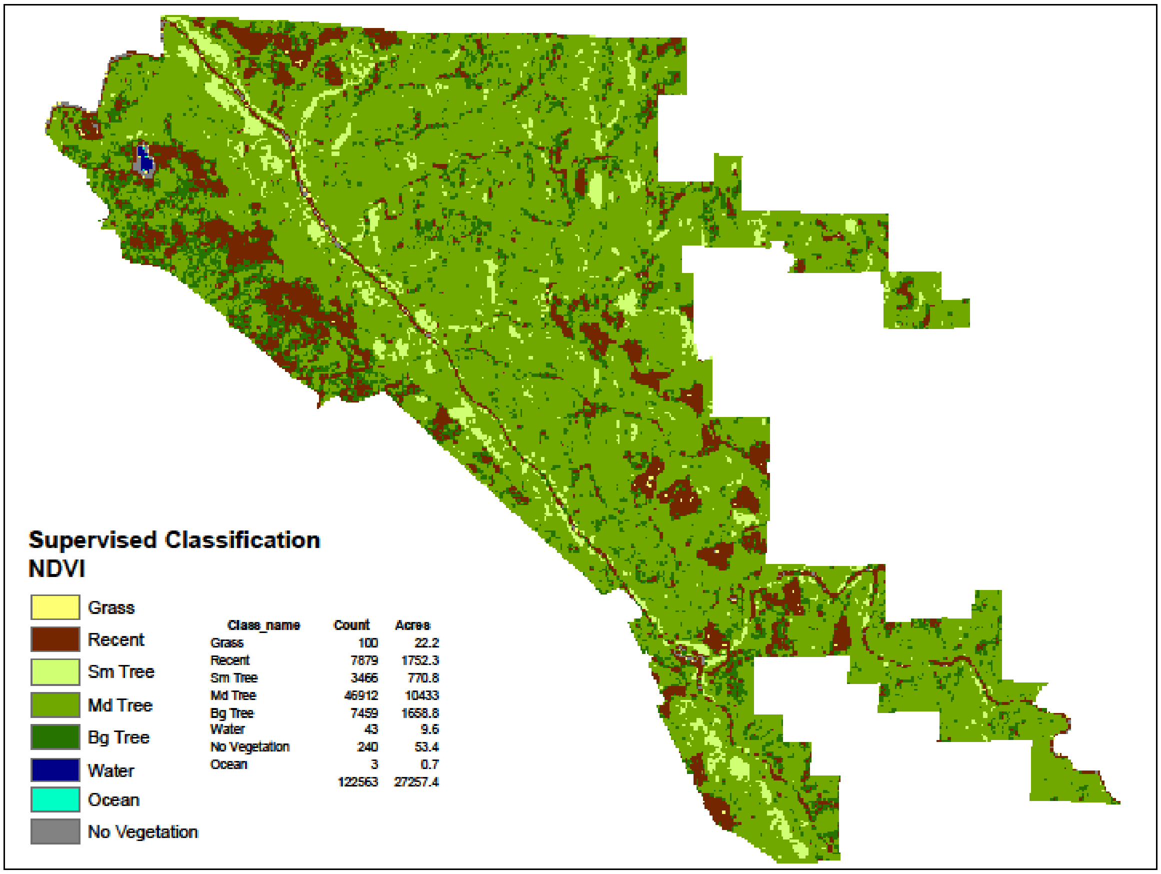


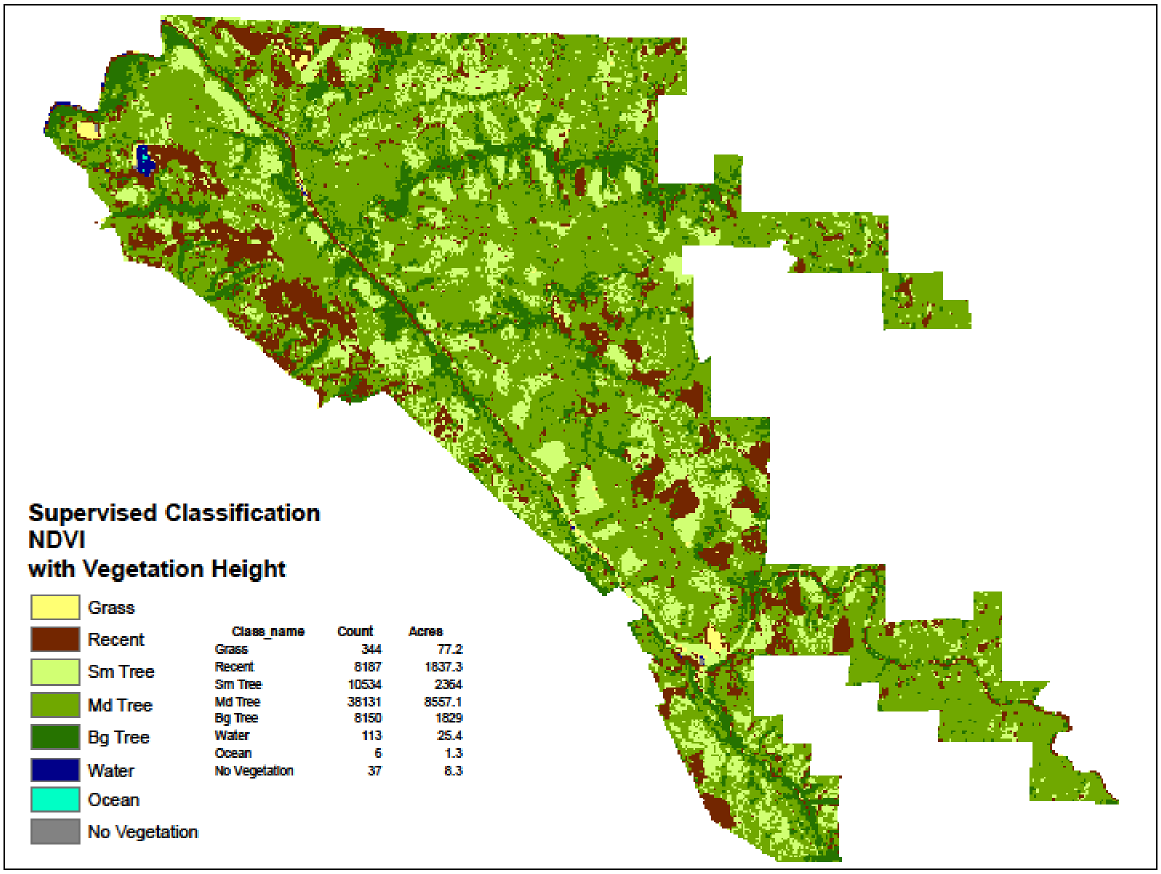
Class_name	Count	Acres
Grass	354	79.4
Recent	6968	1563.7
Sm Tree	13066	2932.2
Md Tree	36318	8150.3
Bg Tree	8406	1886.4
Water	95	21.3
No Vegetation	389	87.3


Supervised Classification
Natural Color - Bands 4, 3, 2
Grass
Recent
Sm Tree
Md Tree
Bg Tree
Water
Ocean
No Vegetation
Class_name Count Acres
Grass 801 178.1
Recent 5660 1258.8
Sm Tree 11918 2650.5
Md Tree 39908 8875.3
Bg Tree 7292 1621.7
Water 49 10.9
No Vegetation 474 105.4

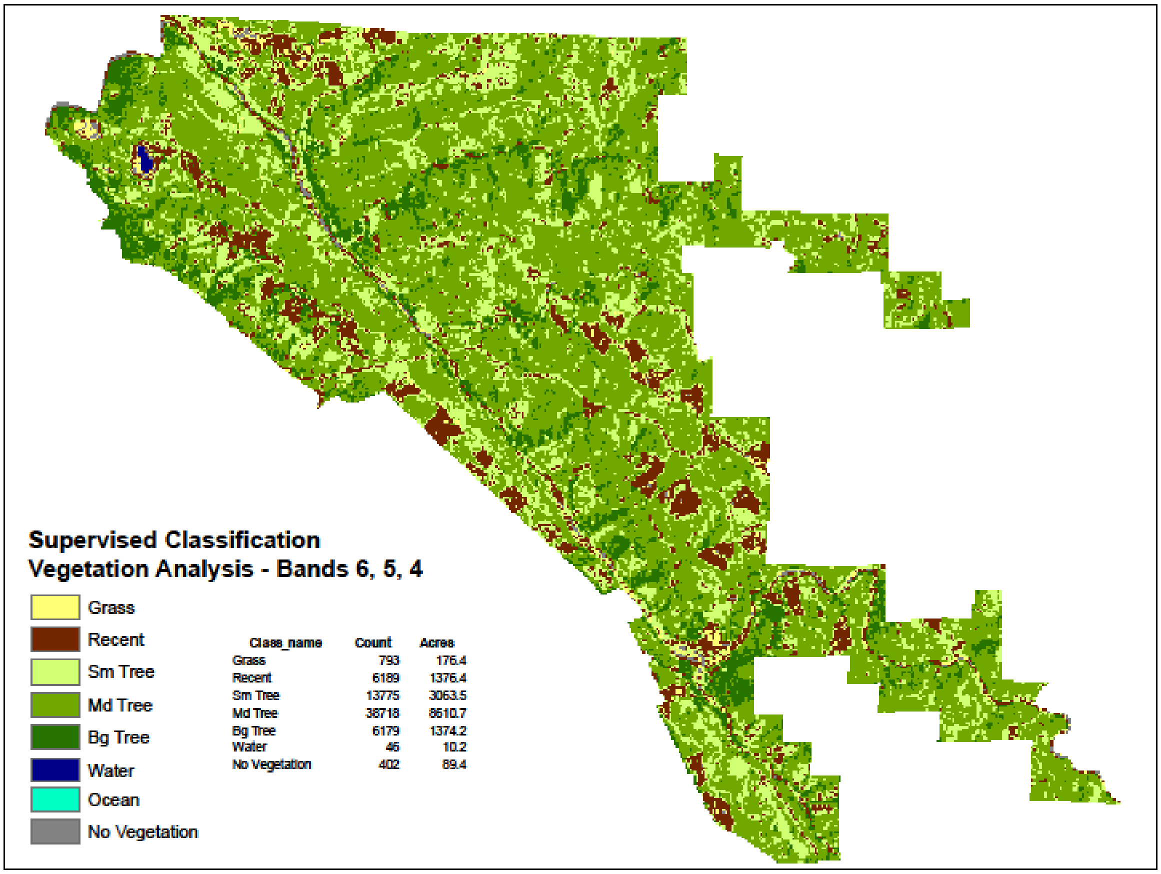


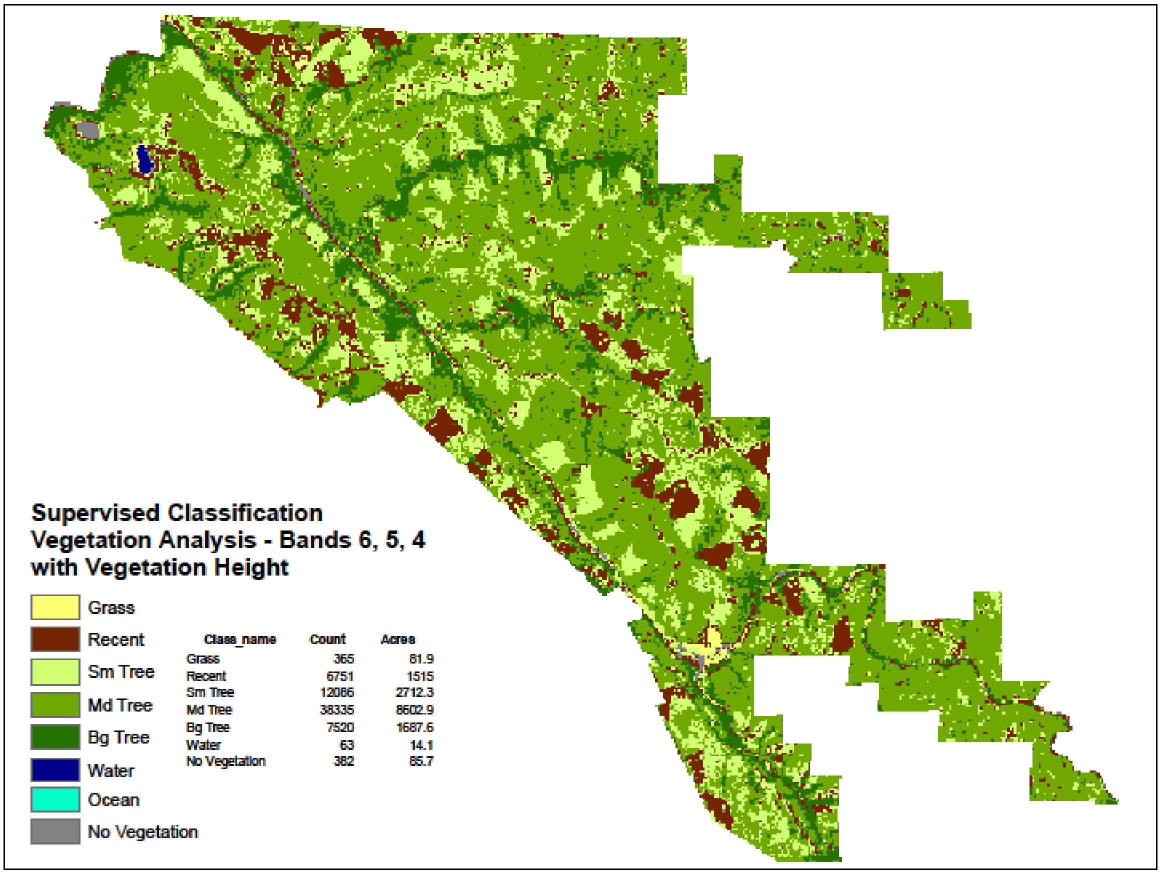
Class_name	Count	Acres
Grass	226	50.7
Recent	6507	1460.3
Sm Tree	12099	2715.2
Md Tree	39162	8788.5
Bg Tree	7110	1595.6
Water	91	20.4
No Vegetation	307	68.9


Supervised Classification
NDVI
Grass
Recent
Sm Tree
Md Tree
Bg Tree
Water
Ocean
No Vegetation
Class_name Count Acres
Grass 100 22.2
Recent 7879 1752.3
Sm Tree 3466 770.8
Md Tree 46912 10433
Bg Tree 7459 1658.8
Water 43 9.6
No Vegetation 240 53.4
Ocean 3 0.7
122563 27257.4

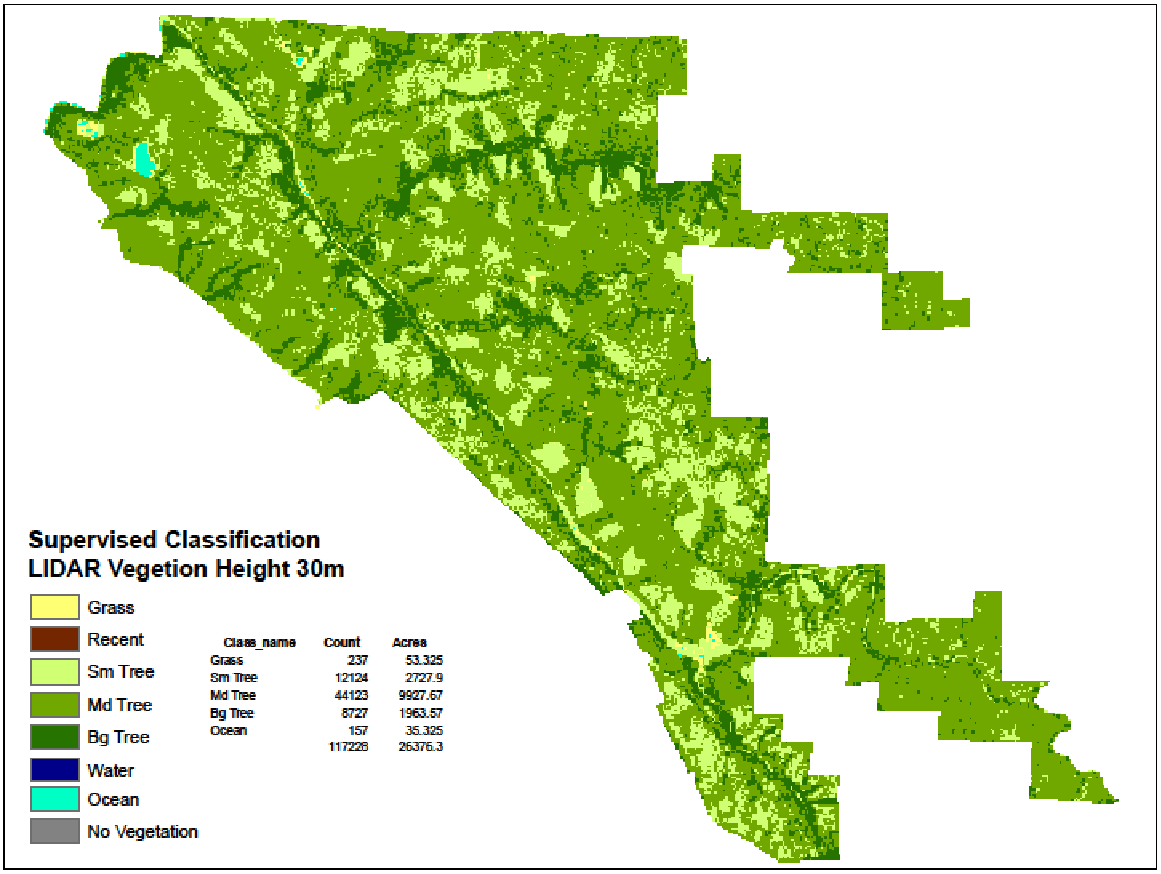


Class_name	Count	Acres
Grass	344	77.2
Recent	8187	1837.3
Sm Tree	10534	2364
Md Tree	38131	8557.1
Bg Tree	8150	1829
Water	113	25.4
Ocean	6	1.3
No Vegetation	37	8.3


Supervised Classification
Vegetation Analysis - Bands 6, 5, 4
Grass
Recent
Sm Tree
Md Tree
Bg Tree
Water
Ocean
No Vegetation
Class_name Count Acres
Grass 793 176.4
Recent 6189 1376.4
Sm Tree 13775 3063.5
Md Tree 38718 8610.7
Bg Tree 6179 1374.2
Water 46 10.2
No Vegetation 402 89.4



Class_name	Count	Acres
Grass	365	81.9
Recent	6751	1515
Sm Tree	12086	2712.3
Md Tree	38335	8602.9
Bg Tree	7520	1687.6
Water	63	14.1
No Vegetation	382	85.7


Supervised Classification
LIDAR Vegetion Height 30m
Grass
Recent
Sm Tree
Md Tree
Bg Tree
Water
Ocean
No Vegetation
Class_name Count Acres
Grass 237 53.325
Sm Tree 12124 2727.9
Md Tree 44123 9927.67
Bg Tree 8727 1963.57
Ocean 157 35.325
117228 26376.3

Discussion of any difficulties/issues encountered and how you resolved them

There were numerous issues in this process. It was a learning experience. The first issue was trying to deal with high resolution data. Pixel sizes of 1 meter or smaller add up to large files and bog the processes down. Rather than reduce the size of my project area, I decided to use lower resolution imagery. I used Landsat 8, instead of 1 meter 4 band data. I also resampled the vegetation height data from 1 meter to 30 meters.

The LIDAR data is very high resolution. Much of the image included the ground between trees. Since I didn't want an average height that included the ground layer, when I aggregated to 30 meters I chose maximum values. This was intended to over represent height and accentuate trees.

The Sonoma Veg Map data is in feet. The Landsat data is meters. When I aggregated the Vegetation Height data, I tried to reconcile this difference. I don't think I got an exact match. When I calculated acreage I had to use different factors to deal with differences in cell size.

When searching for Landsat Data many images were obscured by clouds. Fortunately the 16 day temporal resolution of Landsat allowed many opportunities to find clear coverage.

I first tried to use fall 2013 Landsat images since this would match the time frame of LIDAR acquisition. Unfortunately all the images had long shadows (and clouds). I eventually chose a June 29, 2014 image because it was close the solstice and shadows were shorter.

The initial classification raster image attribute tables did not contain cell counts. I had to use the Build Raster Attribute Table tool to get the information.

Discussion of the output, the interpretation(s) made on the output and/or intermediate image files.

Results

The following tables summarize the results. Since the raster cell sizes were not exactly the same, I calculated acreage for the classified images rather than reporting cell count.

Classification Results in Acres

Acres								
Raster Combination	Grass	Recent	Small Trees	Medium Trees	Big Trees	Water	Ocean	No Vegetation
4Band	186.6	1224.5	2886.5	8634.3	1649.9	10.5	0.0	108.5
4Band + Veg Ht	46.7	1427.7	2794.9	8656.5	1664.0	15.3	0.0	94.5
Agriculture	172.1	1365.7	3004.8	8562.4	1473.1	10.5	0.0	112.1
Agriculture + Veg Ht	54.5	1487.9	2786.5	8523.2	1715.6	16.2	0.0	115.6
Color Ir	183.7	1097.5	2950.1	8464.3	1899.5	10.2	0.0	95.4
Color Ir + Veg Ht	47.8	1338.9	2669.9	8734.0	1814.8	16.2	0.0	78.1
Healthy Vegetation	172.1	1365.7	3004.8	8562.4	1473.1	10.5	0.0	112.1
Healthy Veg + Veg Ht	79.4	1561.5	2927.9	8138.4	1883.7	21.4	0.0	87.3
Natural Color	178.1	1258.8	2650.5	8875.3	1621.7	10.9	0.0	105.4
Natural Color + Veg Ht	50.7	1460.3	2715.2	8788.5	1595.6	20.4	0.0	68.9
NDVI	22.2	1752.2	770.8	10433.0	1658.8	9.6	0.7	53.4
NDVI + Veg Ht	77.2	1837.3	2364.0	8557.1	1829.0	25.4	1.3	8.3
Veg Analysis	176.4	1376.4	3063.5	8610.7	1374.2	10.2	0.0	89.4
Veget Analysis + Veg Ht	81.9	1515.0	2712.3	8602.9	1687.6	14.1	0.0	85.7
Vegetation Ht	53.3	0.0	2727.9	9927.7	1963.6	0.0	35.3	0.0

Total Acreage 14700.

I was interested in the difference between the classification of spectral images and spectral images with vegetation height data. So I constructed a table of differences between the paired images. The pair being the spectral only image and the same image in a composite with the vegetation height raster.

Influence of Adding Vegetation Height Raster to Classification (differences in acres)

	Grass	Recent	Small Trees	Medium Trees	Big Trees	Water	Ocean	No Vegetation
4Band	-139.9	203.2	-91.6	22.3	14.1	4.8	0.0	-14.1
Agriculture	-117.6	122.1	-218.2	-39.2	242.5	5.7	0.0	3.5
Color Infrared	-135.9	241.3	-280.2	269.6	-84.6	5.9	0.0	-17.3
Healthy Veg	-92.7	195.8	-76.9	-424.0	410.6	10.9	0.0	-24.8
Natural Color	-127.4	201.5	64.7	-86.8	-26.1	9.5	0.0	-36.5
NDVI	55.0	85.0	1593.2	-1875.9	170.1	15.8	0.7	-45.1
Vegetation Analysis	-94.4	138.6	-351.2	-7.8	313.4	3.9	0.0	-3.7

(Supervised Classification without Vegetation Height)-(Supervised Classification with Vegetation Height)

Discussion of Results

Although I found this process interesting, the results were not spectacular. The classification of land cover is a zero sum game. Adjustments to improve one class will change another class, or all other classes. I thought that adding the vegetation height data would improve classification but that would be hard to discern from the results since most of the differences were in the range of 1 to 2 percent or less. I did draw some conclusions, not all of them can be fully explained.

With the exception of NDVI, the addition of the vegetation height data reduced the amount of area classified as Grass. NDVI was a single band image and its results did not parallel the results of the other band combinations.

The addition of vegetation height data increased the amount of area classified as Recent (recently logged or disturbed). These areas probably have a lot of grass in them and residual height structure. So the height reduced the influence of the grass in the classification.

With the exception of NDVI and Natural Color, the addition of vegetation height data decreased the amount of area classified as Small Trees. The addition of height appears to have shifted some of NDVI's medium trees to small trees. I did not expect the Natural Color image to work well since it has no infrared component. I have no theories on the reshuffling of the Natural Color classification due to height.

Aggregating the vegetation height raster to 30 meters to match Landsat resolution probably obscured cover types that only occurred in small or narrow areas. In this case the non-forest classifications. Most of the grass and no vegetation classes shrank with the addition of height data. These areas included small forest opening, gravel bars along rivers and streams, roads, and houses. The 30 meter maximum height pixel probably resulted in an under classification of low height classes.

The classification of water was consistent across all spectral data only images, the addition of the vegetation height raster resulted in higher acreage classified as water. Not sure why this occurred since the vegetation height data was aggregated by maximum to exaggerate trees.

All band combinations probably under classified the amount of area in big trees. The classification of the vegetation height only raster had the highest count of big trees. These trees are taller than all other objects in the image there should be no confusion with other classes. Experiments with reclassification of the vegetation height raster could solve this problem.