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Location and Distribution of Western Juniper (*Juniperus Occidentalis*) within and adjacent to Desolation Wilderness Area, California

Abstract

This is a remote sensing study within and adjacent to the Desolation Wilderness Area, California. The study is specifically centered upon the northeastern corner of Desolation Valley and Lake Aloha, 38°52’30” north latitude, 120°07’30” west longitude. Primary emphasis is placed upon location, classification and symbolization of the small and isolated groves of western juniper trees (*juniperus occidentalis*), in comparison to and in contrast with more common and denser growing tree species, such as lodgepole pine (*pinus contorta*) and red fir (*abies magnifica*). The problem of changes to the limits and distribution of junipers, within arid and semi-arid rangeland, where water and acreage are at a premium, is one example of how such data and studies similar to this may prove quite valuable. Tracking such changes and species at the “margins” of their limits and distribution may also be valuable to those studying the potential effects of climate change. The supervised classification tools in Esri’s ArcMap/ArcGIS software were used in conjunction with four-band digital orthophoto quadrangle maps. This study is concluded with a discussion comparing the supervised classification technique outlined above with other techniques, such as Lidar and hyperspectral sensors, which may prove useful in lieu of, or in combination with, the methods utilized here.

Geographic Locale of Study Area: Desolation Wilderness Area, California

Desolation wilderness is located north of U.S. Highway 50 and southwest of Lake Tahoe. The total acreage is 16,960, or approximately 100 square miles. The centroid lies approximately at 38°55’00” north latitude, 120°10’00” west longitude. Refer to the location map below.

Desolation Wilderness Area is a primitive area administered by the U.S. Department of Agriculture/Forestry Service. Strict limits are placed upon areas officially designated as “wilderness” with uses mainly limited to recreation and livestock grazing. Motorized vehicles and many other items are restricted in such areas. Cars, bicycles and chainsaws are some examples of restricted devices.

Desolation Wilderness Area is characterized by alpine and subalpine terrain, granite peaks and granite-bound lakes. Lodgepole pine (*pinus contorta*) and red fir (*abies magnifica*) are the predominate tree species. The area is substantially higher and steeper that other adjacent areas, such as Lake Tahoe and U.S. Highway 50, with a minimum elevation of approximately 7000 feet and a maximum elevation of 10,000 feet. The extreme elevations and steepness of this area are the primary reasons that construction of permanent dwellings, road construction and large scale commercial logging were never undertaken.

Washoe Indians historically utilized this area seasonally, on occasion, for hunting and gathering activities. Some small scale homesteading and grazing activity did occur throughout the nineteenth century and many geographical features, such as Dicks Peak and Gilmore Lake, still reflect names of these pioneers.

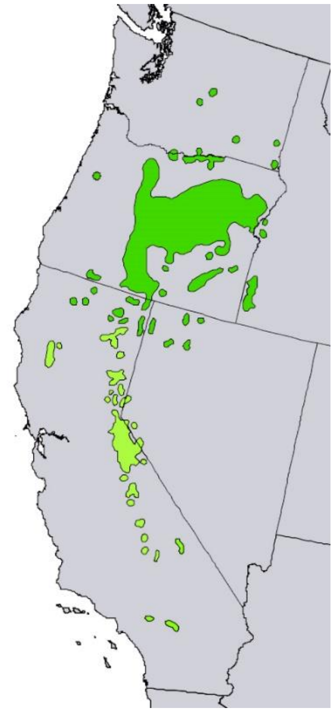
Lake Aloha, within Desolation Valley, in the southern portion of the wilderness area, is one of the most prominent features. This lake is also unusual for being one of the few large manmade structures, since the lake was created by a small and simple concrete dam on its southeastern edge. See photo of Lake Aloha below.

The 2700 mile Pacific Crest Trail, which runs from the Mexican border to the Canadian border, bisects the Wilderness from the southeast corner to the northwest corner.

The Crystal Range of mountains, with Pyramid Peak and Mount Price among them, are also very prominent and run along the southwestern edge of the Wilderness. This is the range that can sometimes be viewed from Sacramento. Please refer to example image below that depicts how these features appear from Sacramento.

One final and specific note upon the location of the Desolation Wilderness regards the location of Angora Lakes and Angora Ridge on the southeastern edge of the Desolation Wilderness Area. This area experienced a serious forest fire in 2007 and the burned acreage is shown on this imagery.

Subject Features: Western Juniper Trees



Special attention was paid in this project in locating and classifying western juniper trees (*juniperus occidentalis*), also known as sierra junipers. This classification needed to differentiate the junipers from other, more dominant, species, such as lodgepole pine (*pinus contorta*) and red fir (*abies magnifica*), within the study area.

Western juniper are distributed mainly along the crest of the Sierra Nevada range in California and much of eastern Oregon. Small and isolated pockets exist throughout California, Oregon, Washington, Nevada and Idaho. Many species of juniper are often found along with species of pinyon pine in a biome called a pinyon-juniper woodland. However, the western juniper is not commonly found in this grouping and our study area would not likely be categorized as such a biome. The areas occupied by the junipers in this study would be better classified as a *krumholtz* formation, which is a particular feature of subarctic and subalpine tree line landscapes. A location map showing distribution of western juniper is shown to the right.

In general, and in contrast to the more common pine species in this study area, western junipers prefer higher elevations (with an ideal elevation of approximately 8000 feet), drier weather and climate, rockier soil and relatively steep slopes. In such locations and habitats, the western junipers will grow in sparse and thin groves usually separated from the foliage of neighboring trees by at least a couple of meters and usually a much greater amount.

Individual specimens of western juniper can live quite long. One specimen, named the Bennett Juniper, is approximately 3000 years old. It is located near U.S. Highway 108 in the Stanislaus National Forest.

These junipers average around 18 meters in height with a drip line of approximately 9 meters in diameter. The foliage of the juniper can be identified by its distinctive scale-like appearance in contrast to needle-like foliage of more common pine trees. A photo of a typical western juniper specimen is shown below/left and close-up of foliage is shown below/right.

There are many more common species of juniper that could be named here, but will not be since this exceeds the scope of this paper. We will mention in passing that most people will be familiar with many domesticated and cultivated species used in landscaping, such as the chinese juniper (*juniperus chinensis*). Also of some interest here is the utah juniper, (*Juniperus osteosperma*) which is a smaller species that shares some overlapping habitat and distribution with the western juniper. The western juniper and utah juniper often cross pollinate and produce hybrid offspring. However, this is unlikely in this study area since utah juniper are more common just to the east, in the Great Basin region. The non-juniper whitebark pine (*pinus albicaulis*) is a more likely neighbor to western junipers in our study area. The close proximity of these two species provides a major challenge to individual classification.

Purpose:

John Muir stated thusly regarding the western juniper:

> A thickset, sturdy, picturesque highlander, seemingly content to live for more than a score of centuries on sunshine and snow; a truly wonderful fellow, dogged endurance expressed in every feature, lasting about as long as the granite he stands on.

My initial interest in this subject was prompted by similar personal and aesthetic experiences with this species and the locales it inhabits. However, there are at least two practical, and interrelated, reasons why a remote sensing study on this species is of high importance.

The first reason is that junipers tend to encroach into rangeland. Junipers may invasively move into adjacent rangeland, removing valuable acreage that feeds livestock, utilizing relatively large amounts of water in arid or semi-arid regions and providing habitat for other invasive flora and fauna. The long-term consequences of such a situation is the transformation of rangeland into a very different habitat, much less suitable for livestock grazing. Information on locations exhibiting this sort of transformation, or prone to such transformations, would prove invaluable in areas such as the Western U.S., where vast acreage is currently utilized for grazing range livestock. Anything that could potentially make these areas less productive would have serious economic consequences. Our research indicates that much remote sensing work is currently performed addressing this issue.

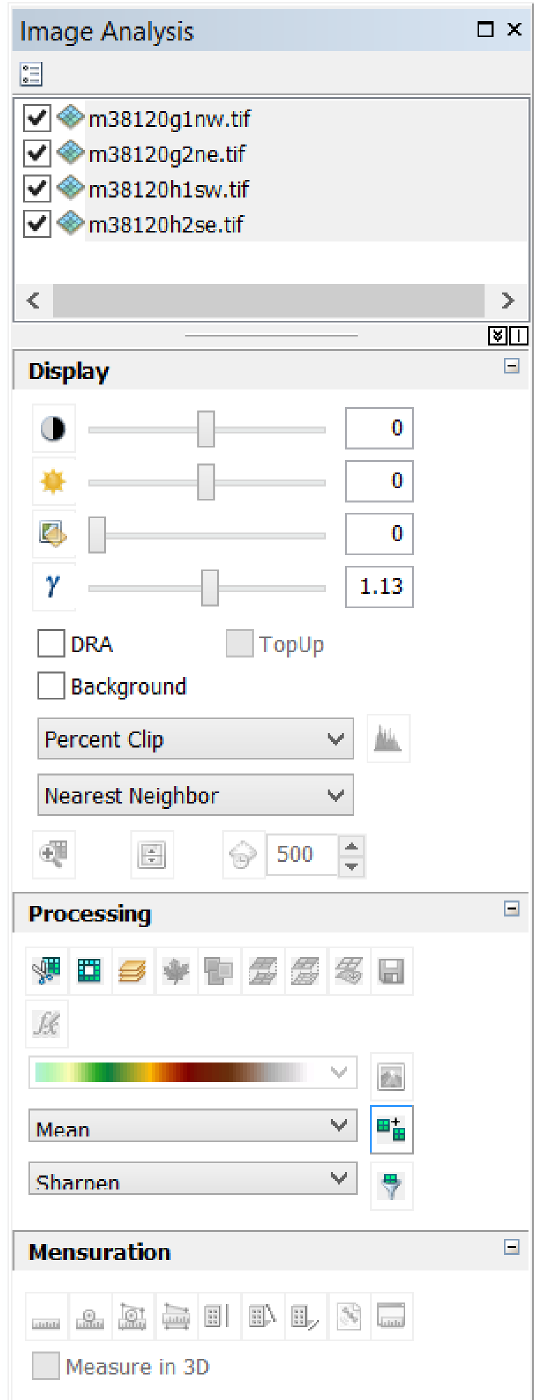
The second, and a related reason to the one above, is that changes in juniper locations and distribution may be indicative of changes in climate. Junipers prefer much drier, rockier, elevated and steeper terrain than most other types of trees. As such, junipers may exist on the fringe of certain habitats and may be well positioned to take early advantage of small changes in climate, especially slightly greater amounts of precipitation. Tracking such changes in distribution and location of junipers may offer some early and concrete evidence of changing local climate patterns. Such research may provide ancillary data and evidence to those studying and documenting global climate change. Our research indicates that much work has been done regarding climate change and invasive plant species in general, but little work has been done regarding climate change and junipers in particular.

Our study area is a forested alpine or subalpine environment that is quite different that the rangelands discussed above. The junipers in our study area are unlikely to be invasive and have probably existed in this locale for a historical or even a geological period of time. Although our study area is quite different that those discussed above, it is worth mentioning here the similarities of subject, purpose and techniques.

Methods Utilized: ArcMap and Digital Orthophoto Quadrangle Maps

ArcGIS/ArcMap 10.2.2 by Esri and digital orthophoto quadrangle maps were the primary tools utilized.

Four digital orthophoto quadrangle maps were the main source of data required. These files, downloaded from the Cal-Atlas Geospatial Clearinghouse, (*http://atlas.ca.gov/imagerySearch.html*) are named m38120g1nw, m38120g1ne, m38120g1sw and m38120g1se. These images are in a georeferenced and orthorectified "TIF" file format with four bands. These bands are red (1), green (2), blue (3) and near infrared (4). These images have a resolution of 1 meter. The images each cover a 00°03'45" latitude by 00°03'45" longitude area and are arranged in a 00°07'30" latitude by 00°07'30" longitude total area with a center location of 38°52'30" north latitude, 120°07'30" west longitude. The images are spatially referenced and projected using NAD 83 and UTM Zone 10N with units being meters. The imagery was collected in 2009 and an image mosaic was created for the said images using the mosaic tool, with the "mean" option, in the Image Analysis window, in order to facilitate classification. This is depicted at the right.



Although the image area does not represent a complete and perfect coverage of Desolation Wilderness Area, it is a good approximation for the purposes of this study. The center of Desolation Valley and Lake Aloha, which is the primary subject area because it's high proportion of junipers, lies at the same approximate center of the images. Furthermore the shape of Desolation Wilderness is approximately rectangular with similar proportions to the total area covered by the images. See the location map in the Geographical Locale section in this paper for the approximate shape of Desolation Wilderness area.

The supervised classification method via the "Image Classification" toolbar, the "Training Sample Manger" dialog box and the "Maximum Likelihood Classification" tool, all of which reside within the ArcMap program, were the main software tools required. Examples of these are provided on the next page.

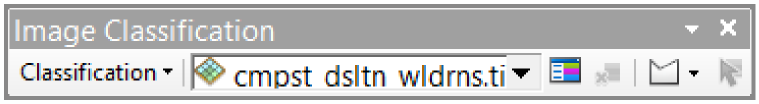
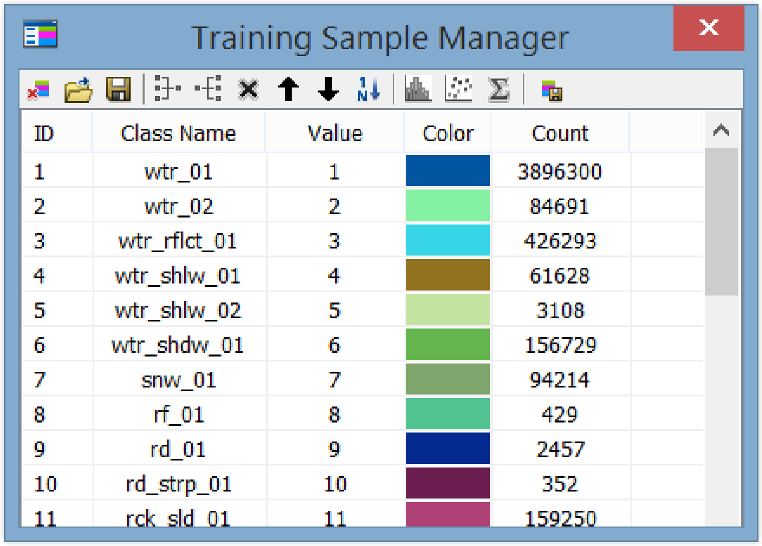
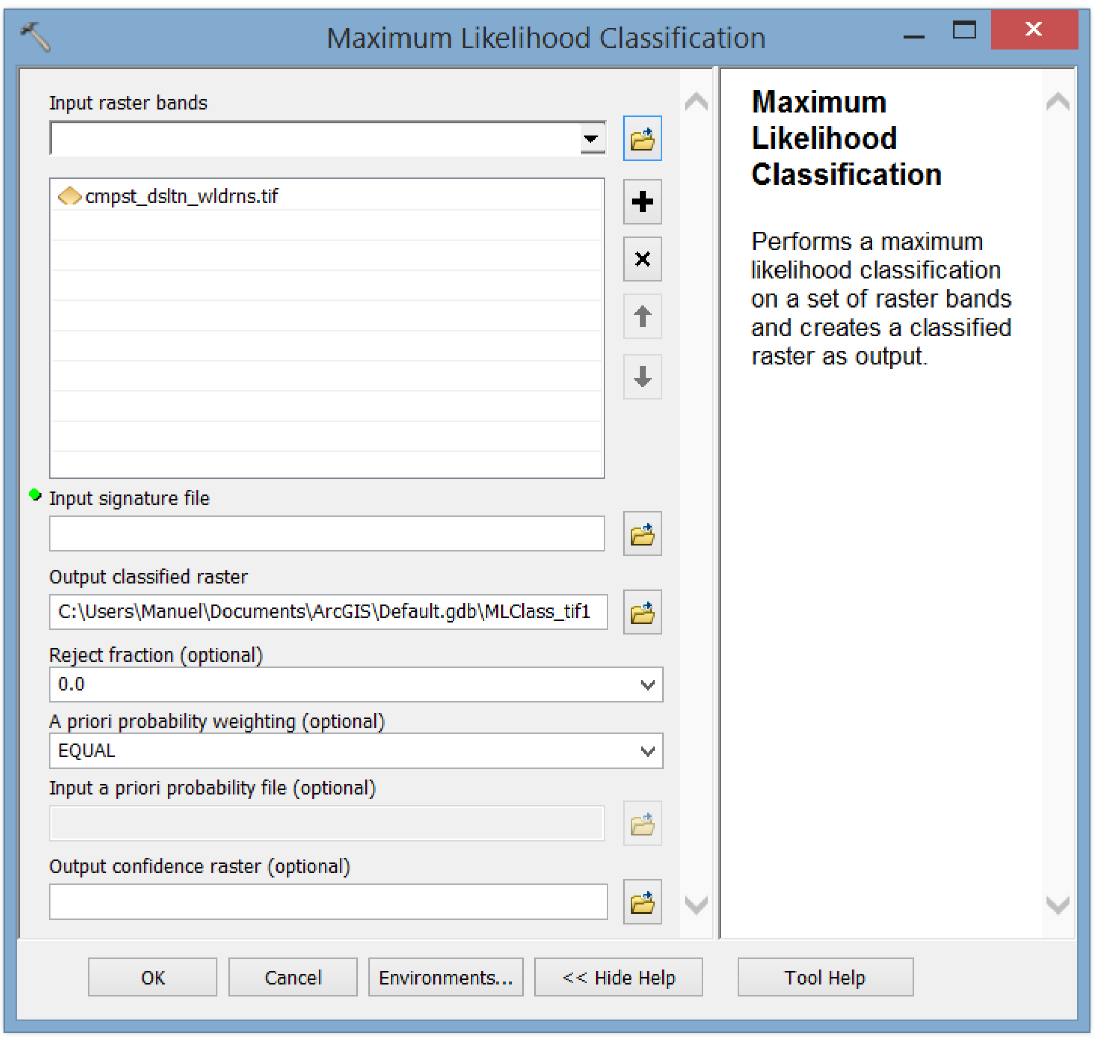
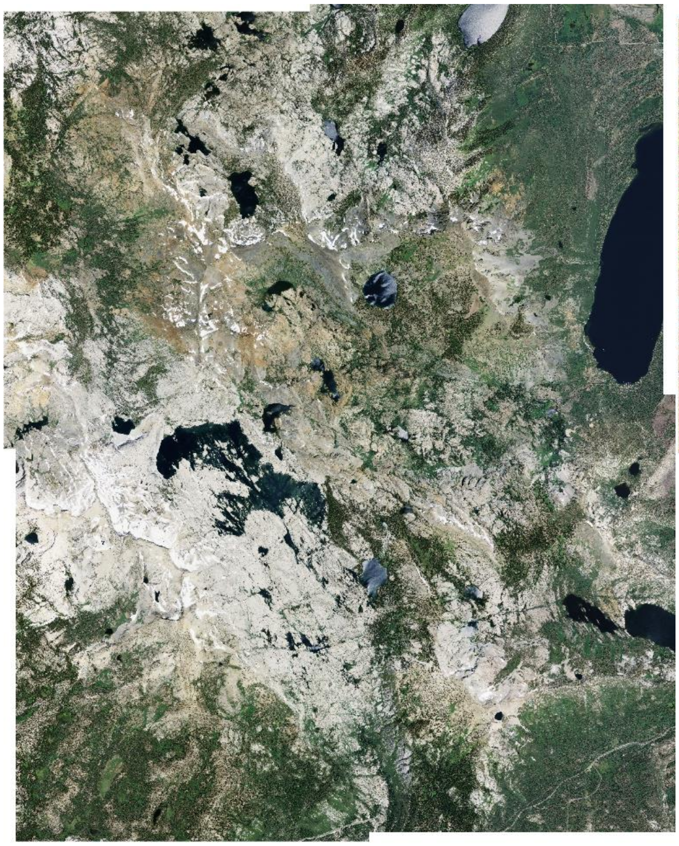


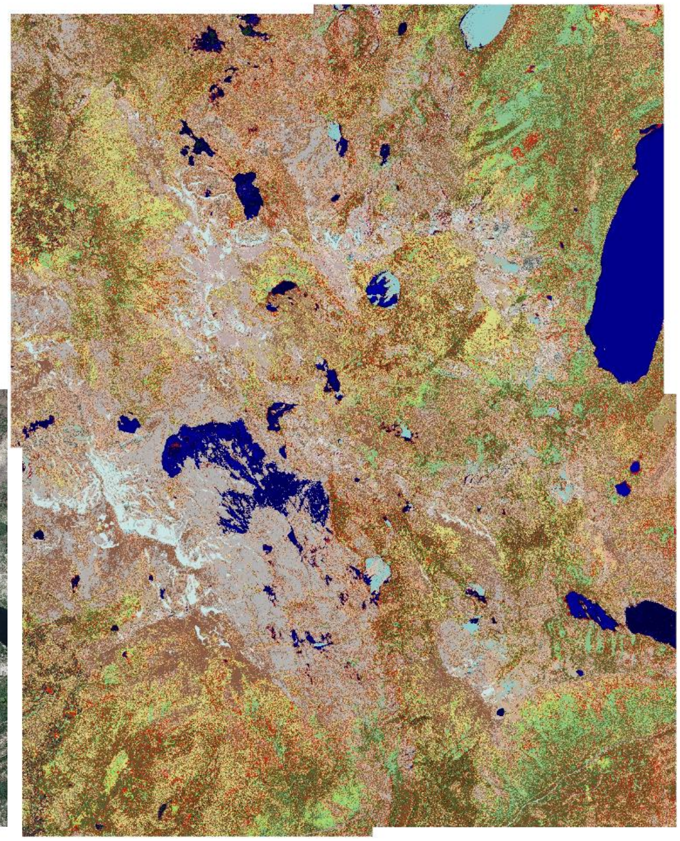
Image Classification
Classification
cmpst_dsltn_wldrns.ti


Training Sample Manager
ID | Class Name | Value | Color | Count
1 | wtr_01 | 1 | | 3896300
2 | wtr_02 | 2 | | 84691
3 | wtr_rflct_01 | 3 | | 426293
4 | wtr_shlw_01 | 4 | | 61628
5 | wtr_shlw_02 | 5 | | 3108
6 | wtr_shdw_01 | 6 | | 156729
7 | snw_01 | 7 | | 94214
8 | rf_01 | 8 | | 429
9 | rd_01 | 9 | | 2457
10 | rd_strp_01 | 10 | | 352
11 | rck_sld_01 | 11 | | 159250


Maximum Likelihood Classification
Input raster bands
cmpst_dsltn_wldrns.tif
Input signature file
Output classified raster
C:\Users\Manuel\Documents\ArcGIS\Default.gdb\MLClass_tif1
Reject fraction (optional)
0.0
A priori probability weighting (optional)
EQUAL
Input a priori probability file (optional)
Output confidence raster (optional)
OK
Cancel
Environments...
<< Hide Help
Tool Help
Maximum Likelihood Classification
Performs a maximum likelihood classification on a set of raster bands and creates a classified raster as output.

Classified Data and Image Examples

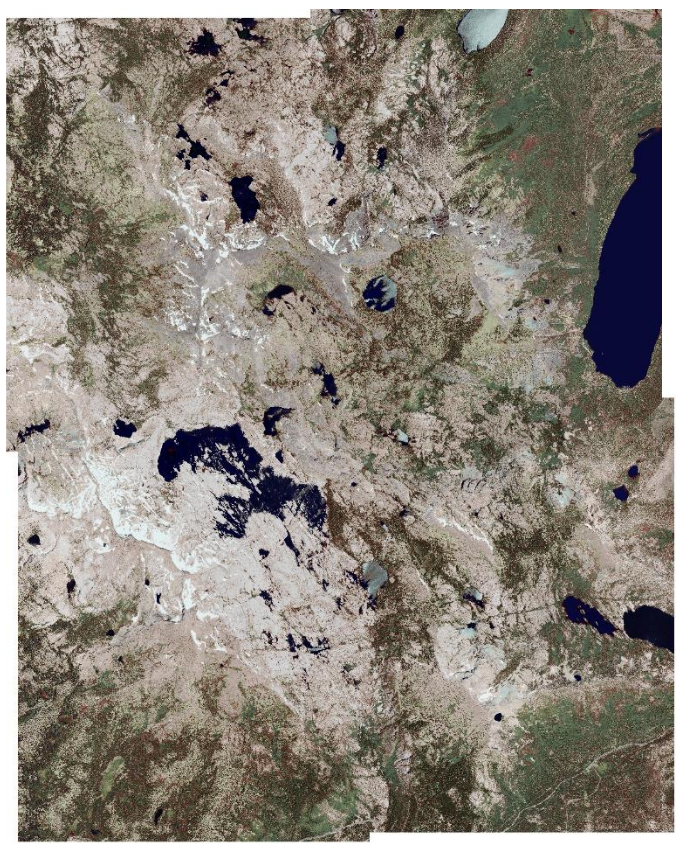


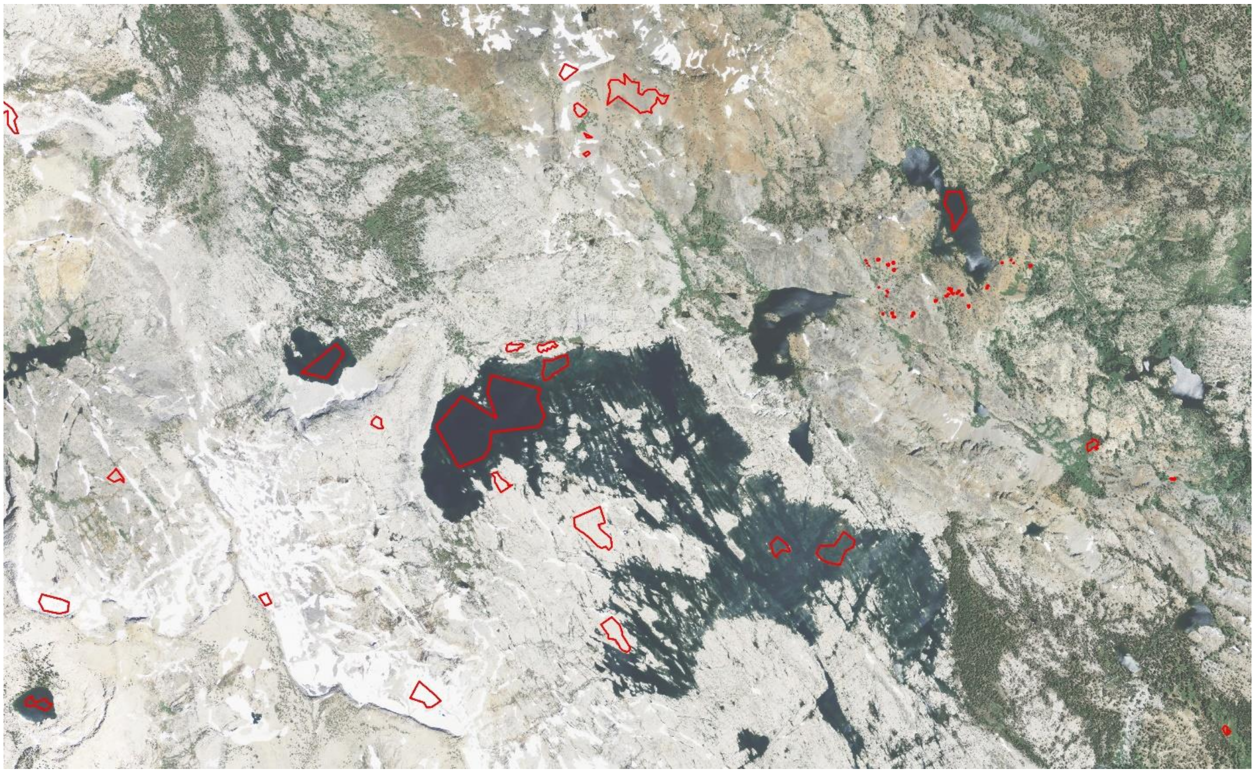


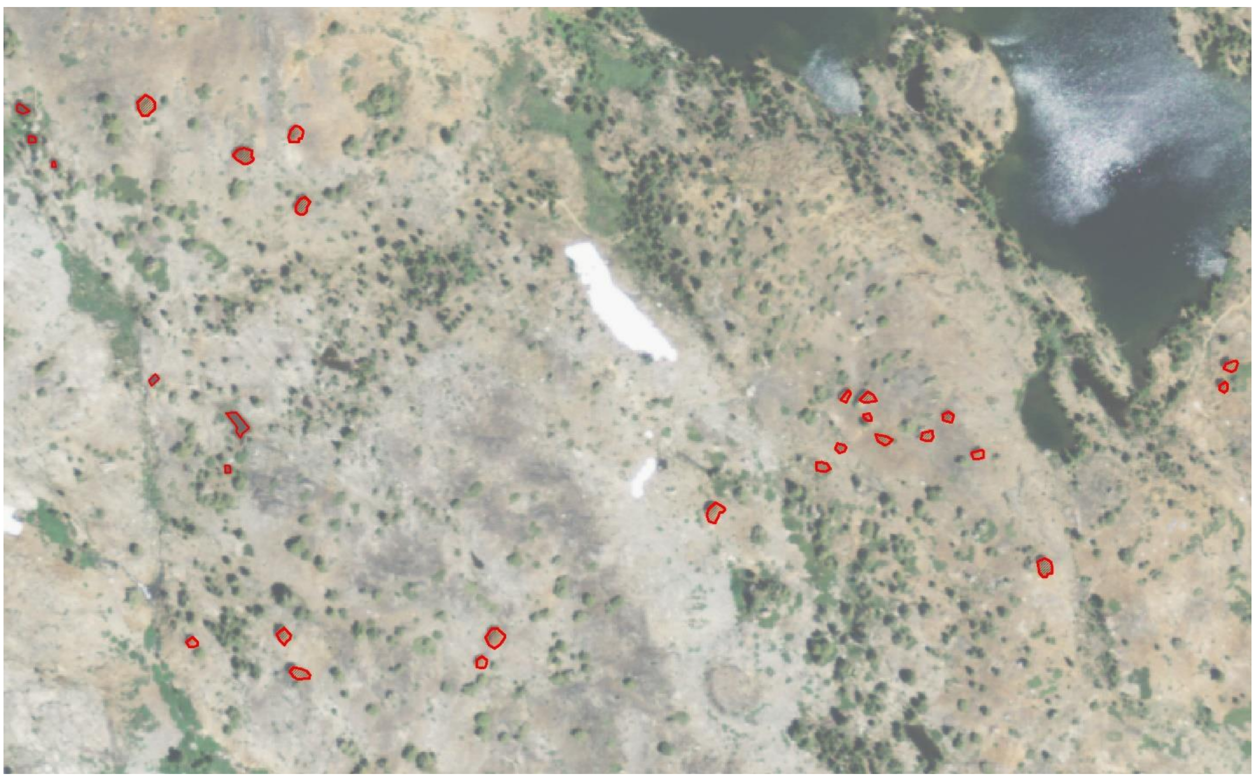
The image above is the mosaicked digital orthophoto quadrangle map that we started with.

The image above/right represents the fully classified and symbolized image. Red is the only warm and bright color used in this image and represents the location of our subject junipers. A legend of all of the colors and features classified and depicted is shown on page 9.

The image at right is our preferred method of displaying the classified and symbolized data. The original orthophoto quadrangle map is in the foreground, with a transparency applied and changed to grayscale. This symbolized and classified image is below. With this scheme, the red junipers are the only bright and warm color used. This is not readily apparent here, but enlarged images are shown on pages 9 and 10 along with a legend of all of the colors and features classified and depicted.

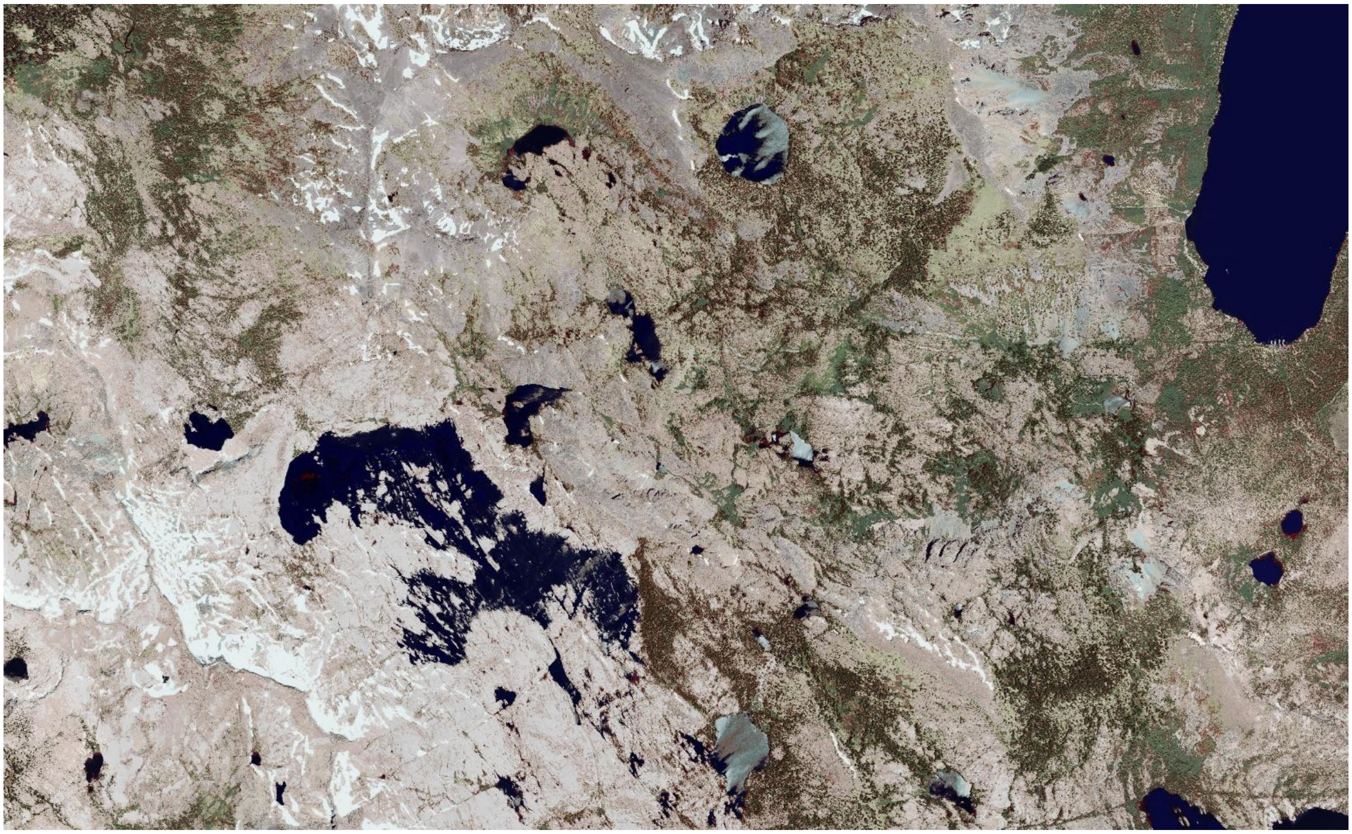






The images above depict two examples of training areas with features to be classified. A slight transparency has been applied to the mosaicked digital orthophoto quadrangle map in order to emphasize the red training areas.

The top image includes many non-juniper features and training areas near Lake Aloha. The bottom image shows many juniper features and training areas near Susie Lake, which is in the approximate center of our study area.



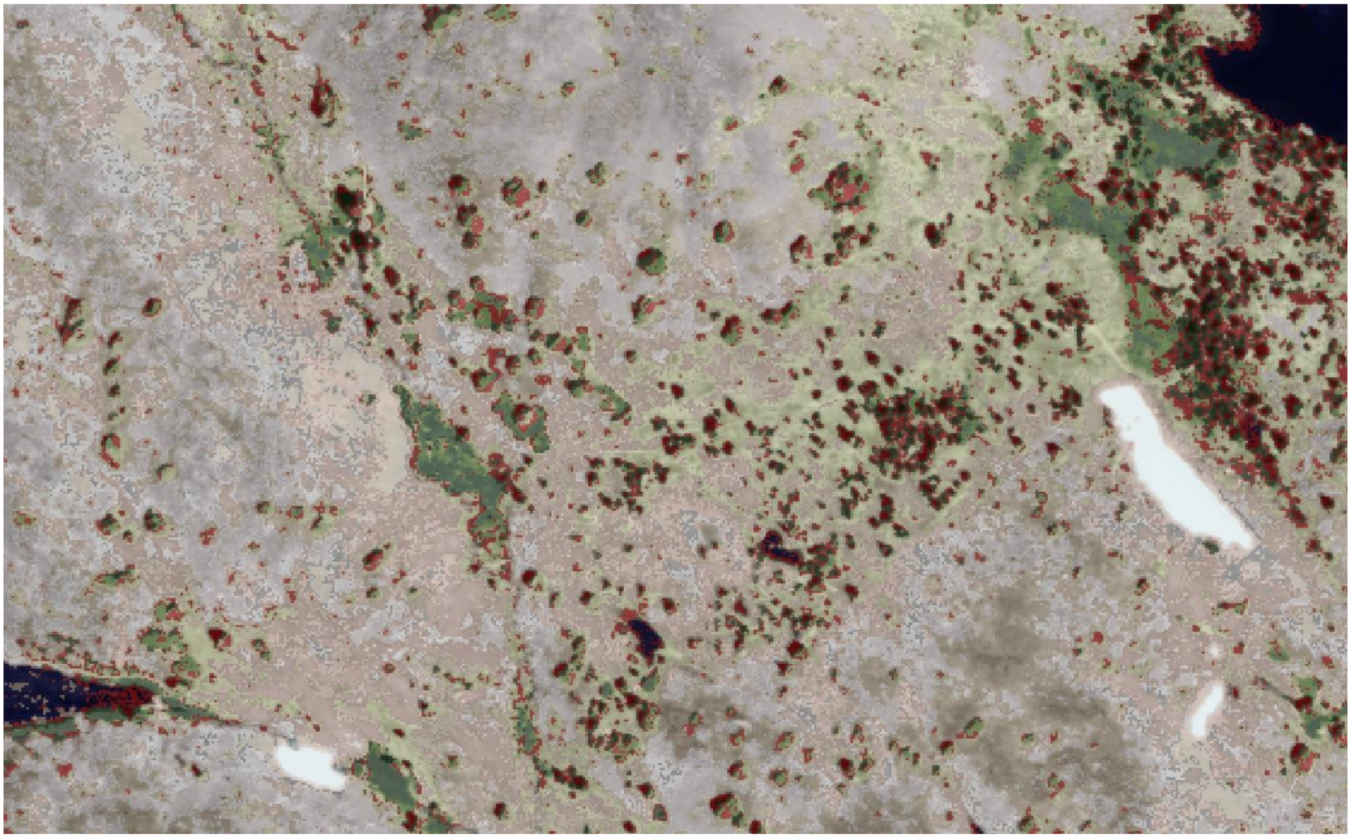
The image above represents an enlarged and subset area of our final classified and symbolized study area. Again, the red areas indicate locations of western juniper.

Shown to the right is the legend of all of the colors and features classified and depicted on our final classified and symbolized study area.

The top image on the next page represents an enlarged and subset area of our final classified and symbolized study area. The area depicted is between Heather Lake and Susie Lake, near the center of our study area, which has many groves of junipers. Again, the red areas indicate assumed locations of western juniper.

The bottom image on the next page represents another enlarged and subset area of our study area. The area depicted is near U.S. Highway 50. This area has little to no junipers and a greater amount of other tree species.

Please note that the assumed junipers on the top image are not consistently and completely red while the bottom image contains some partially red areas that are unlikely to be junipers. This is most likely caused by limitations of the methods used and lack of 100% certain "ground truth" data on juniper locations versus non-juniper tree locations, to be used as training area. This will be discussed in greater detail in the "Conclusions" section at the end of this paper.



Conclusions

The digital orthophoto quadrangle maps provided proper coverage of our study area and the one meter resolution was well suited to the average size of the junipers to be located, classified and symbolized. The greatest limitation of these images was that they only have four bands. A greater amount of infrared bands would have been useful. Three bands of infrared, such as that available with Landsat images, or hyperspectral data, would likely have assisted in preventing or limiting the fragmentation of the assumed juniper areas. This issue is shown in the images on the previous page, where the red areas are not completely coincident with locations of junipers. Our research shows that hyperspectral sensors have been used by others in the past to locate, classify and symbolized junipers.

Lidar has also been used in the past to locate junipers. However, this technique is better suited to flat or rolling terrain in arid or semi-arid rangeland, such as that of the Great Basin region. In such locations the junipers will often be the tallest features on the terrain. Such a method would not be very useful for a mountainous and forested location, such as our study area.

We also relied heavily our knowledge of "ground truth" of juniper locations and distribution throughout our study area. Actual G.P.S. points and/or polygonal areas indicating coordinates of juniper and non-juniper trees would also have proved useful in limiting or preventing the symbolization fragmentation documented above. Such G.P.S. coordinates could have been used as training areas to provide nearly 100% certainty of locations of both junipers and non-juniper trees. This would have greatly prevented the problem of whitebark pines mixed in with western junipers.

Lastly, this project might have benefited from other software, in addition to, or in lieu of, ArcGIS/ArcMap 10.2.2 by Esri. The object-based analysis program eCognition is one such example of such software.