

Tamarisk Mapping and Monitoring Using High Resolution Satellite Imagery

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Abstract—QuickBird high resolution multispectral satellite imagery (60 cm GSD, 4 spectral bands) and calibrated products from DigitalGlobe's AgroWatch program were used as inputs to Visual Learning System's Feature Analyst automated feature extraction software to map localized occurrences of pervasive and aggressive Tamarisk (*Tamarix ramosissima*), an invasive species found along riparian corridors throughout the Western United States. Mapping was carried out along two major river systems known for widespread tamarisk invasions (Colorado River near Grand Junction, CO & Rio Grande River near Albuquerque, NM) using imagery acquired in late Fall, 2003. Mapped tamarisk occurrences were conservative, because only tamarisk vegetation with spatial areas greater than 10 square meters were classified and senesced tamarisk were not taken into account. Classification accuracies were greater than 80 percent based on ground verified data. Overall, these results confirm that high spatial but low spectral resolution remote sensing data coupled with machine learning classifiers can be used effectively for local precision mapping of tamarisk in dominant environments found in riparian landscapes.

Introduction

Tamarisk is a deciduous shrub/small tree that was introduced to the western U.S. in the early nineteenth century from Central Asia and the Mediterranean for use as an ornamental, in windbreaks, and for erosion control. Tamarisk, also known as salt cedar, is well suited to the western U.S., and has displaced much of the native vegetation along low-elevation river and stream banks from Mexico to Canada. Tamarisk is now estimated by some researchers to cover between 1 and 1.5 million acres of land in the western U.S.

Tamarisk is a tenacious plant that has a deep root system (up to 100 feet) and leaves a salt residue in the soil. These characteristics enable it to quickly displace native cottonwoods and willows as well as adjacent upland plant communities; such as bunch grasses, sage and rabbit brush. The resulting tamarisk thickets crowd out streams and rivers; provide poor habitat for livestock, animals, and birds; increase fire hazards; and limit human use of the waterways.

While each of these points is important to one or more constituencies, the single most critical problem is that tamarisk steals water by using more water than native vegetation that it displaces. This non-beneficial user

of the West's limited water resources dries up springs, wetlands, and riparian areas by lowering water tables. Based on average water use values for tamarisk and the native plant species it has replaced, a rough estimate of the non-beneficial consumption of water by tamarisk throughout the West ranges from 2.0 to 4.5 million acre-feet of water per year. These values are above and beyond what the native riparian vegetation would have consumed and represent enough water to supply upwards of 20 million people or the irrigation of over 1,000,000 acres of land. And every year, the problem only continues to get worse.

A key requirement for the effective management of invasive plants is the ability to identify, map, and monitor invasions as well as the invaded plant communities. Hand-mapping in the field or from aerial photos are techniques commonly used in support of eradication efforts, but these methods are labor intensive and limited. Hand-mapping from field observation requires access to the site from the ground, a prospect that is not always practical, safe, or timely, especially on an active military base. Interpretation of aerial photos is extremely time-intensive and often necessitates interpretation of large numbers of photographs. In addition, it can be difficult to distinguish the weed species in the photos even with magnification, making the interpretation process highly

subjective and likely to differ from one analyst to another. Because of these constraints, weed mapping is usually done on an as-needed basis, and comprehensive maps that would support time-series evaluation are not generally made. There is the need, therefore, to develop repeatable and reliable automated techniques for monitoring the spread of weeds and the effects of eradication efforts as well as changes in the habitats being managed. DigitalGlobe has developed a unique set of algorithms that have advanced the capabilities of remote sensing technologies for vegetation assessment. Specifically, they have discovered a method to calibrate the imagery to reflectance at the earth's surface. DigitalGlobe has also developed the capability to remove variation in vegetative indexes caused by differences in soil brightness. This processing step potentially allows for mapping of the invader and surrounding plant communities that cannot be accomplished using more conventional multispectral imagery. Feature Analyst, the flagship automated feature extraction tool of Visual Learning Systems, Inc., is used in this study to exploit the strengths of the high-resolution digital imagery while reducing the extreme variability effects inherent to high-resolution imagery classification.

This study tested the suitability of AgroWatch data and Feature Analyst algorithms for improved mapping of a riparian plant community invaded by Tamarisk. This work will be useful in future decisions about methods for mapping Tamarisk and associated riparian vegetation in other regions.

Technical Objectives

1. Develop methodology to accurately, repetitively, and consistently map tamarisk invasions using:
 - Pan-Sharpener QuickBird Imagery
 - Calibrated AgroWatch Products
 - Advanced COTS Software
2. Test methodology in two study areas along separate riparian corridors within the Southwest
 - Leaf-on and multiple dates
 - Target size ranging from single tree to dense monoculture
3. Assess the accuracy of the classification
 - Collect reference data within each study area

Project Areas

The first study area was a 3.5-mile stretch of the Rio Grande River in Sandoval County, NM. This area recently underwent a tamarisk eradication and riparian

Table 1. Project Area Imagery Comparison.

River System	Colorado River	Rio Grande River
Acquisition Date	October 25, 2003	September 27, 2003
Off Nadir Viewing Angle	12.7°	14.3°
Image Quality	Excellent	Excellent
Cloud Cover	0.0%	0.0%

restoration project completed by the Santa Ana Pueblo. The riparian vegetation in the area was characterized by individual tamarisk plants and monotypic cottonwood stands. The second study area focused on a 5-mile section of the Colorado River in Mesa County, CO. This area is characterized by dense monotypic stands of tamarisk intermixed with native vegetation such as willow and cottonwoods, as well as non-native russian olive. Table 1 compares the QuickBird image parameters for the two project areas.

Classification Methods

Regions of interest (ROIs) were created for use as training sets using a combination of field data, field notes and hand-mapped polygons. ROI polygons were created on an un-georeferenced true-color display of the image data using the field notes as reference by visually matching features in the un-georeferenced and georeferenced images.

The high spatial resolution of these data sets seemed to fit perfectly with the Feature Analyst workflow and analytical capabilities. Feature Analyst allows for a simplified, intuitive classification workflow: Train Learner, Remove Clutter, and Add Missed. The ROIs generated in the field were used to train the Feature Analyst learner on the spectral and spatial characteristics of tamarisk. Using Feature Analyst's Learning Explorer feature and AgroWatch's calibrated vegetation products allowed the learner derived during the first project area to be used directly on the second project area, with only slight modifications regarding the average tamarisk stand size in the latter project area. After a single iteration, results were very promising for tamarisk delineation in both project areas. The results of the accuracy assessment are illustrated in tables 2 and 3.

Conclusions

This study shows that the invasive plant Tamarisk and associated riparian vegetation types can successfully be mapped using QuickBird and AgroWatch data and with advanced machine learning techniques available in the commercial off-the-shelf software, Feature

Table 2. NM Accuracy Assessment Results.

Classification	Reference # Plots	Tamarisk	Other	Totals	User's Accuracy
	Tamarisk	17	2	19	89%
	Other	3	18	21	86%
Totals		20	20	40	
Producer's Accuracy		85%	90%		88%

Table 3. CO Accuracy Assessment Results.

Classification	Reference # Plots	Tamarisk	Other	Totals	User's Accuracy
	Tamarisk	25	6	31	81%
	Other	7	22	29	76%
Totals		32	28	60	
Producer's Accuracy		78%	79%	78%	

Analyst. These techniques show promise as useful tools for evaluating the status of important habitats and the advance (or eradication) of an invasive weed. This is especially applicable in the management of riparian systems because constituent habitat types can change significantly in their spatial extents and distribution in just a few years. More work is needed to discover if learners can be used in images from different years for the same region for development of a sequence of maps that would allow change analysis, since variations from year to year in the timing of plant phenological stages will certainly be a factor.

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