DETECTION OF LEAFY SPURGE USING HYPER-SPECTRAL-SPATIAL-TEMPORAL IMAGERY

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PROBLEM ADDRESSED

Leafy spurge (*Euphorbia esula*) is an aggressive invasive species that has invaded large areas of the Northern Plains of the United States. Mapping leafy spurge has been identified as a critical stage for management [4], and numerous attempts have been made to do so using hyperspectral imagery (e.g., [2], [5], [6]). The most successful attempts have only mapped presence or absence, although density is an important attribute for management purposes. Further, success in several previous studies might be a function of collecting imagery when leafy spurge was in bloom, although in many cases it will be found at varying phenological stages at scales relevant for management purposes [5].

A seasonal time series of hyperspectral imagery might be able to overcome limitations of previous studies with respect to identifying small infestations and overcoming phenological variability. High costs associated with hyperspectral imagery, however, have limited the ability to collect multiple images within a season in all but rare cases (e.g., [3]. [7], [8]). The development of very low cost, light weight sensors that can be flown on small airplanes, UAVs, or radio controlled model planes, however, makes multiple collections feasible. The Pika II hyperspectral sensor, developed and manufactured by Resonon Incorporated, is such a sensor (http://www.resonon.com). It is a compact pushbroom instrument that records the spectrum from 400-940 nm in up to 148 bands. We sought to determine whether a seasonal time series of imagery from the Pika II could accurately detect varying densities of leafy spurge.

METHODS

A 1.15-ha study area was selected on private property immediately adjacent to the Madison River, Montana, USA. Images were collected on average 10 days apart and span from May 29, 2009 thru August 29, 2009. Vegetation surveys were conducted at random locations concurrently with image collection and included percent leafy spurge cover, numbers of leafy spurge stems, percent cover other species, percent dead or senesced vegetation cover, and percent cover of bare ground. Vegetation surveys were conducted using four, 1-m^2 sampling frames around each reference point. Percent cover was estimated based on Daubenmire's cover classes [1]. Images were georeferenced with a combination of ray tracing and polynomial corrections and accuracy (all RMSE < 2 m) was confirmed with GPS referenced tarps on the ground (Figure 1).

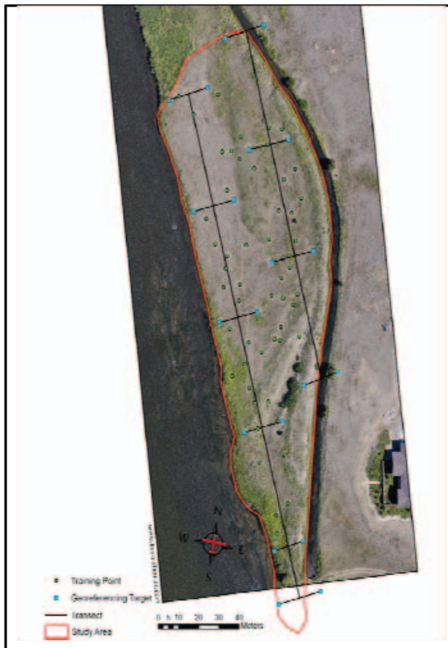

Figure 1. Study area with reference plots and tarp locations.

Classification was conducted both for individual image dates and for all images combined. The random forest algorithm, which had been previously used to successfully map leafy spurge with hyperspectral imagery [5], was used for all classifications. Random forest, in addition to being a strong classifier, enables all reference data to be used for classification while producing an internal accuracy assessment that is equal to an independent accuracy assessment, assuming the reference data are unbiased. Reference data locations were selected randomly, enabling the use of this accuracy assessment approach.

CONCLUSIONS

Single date classification achieved between 73% and 90% estimated accuracy with kappa values between 0.61 and 0.86 (Figure 2). The highest estimated accuracy achieved was 90.45% (kappa = 0.86) on June 3, 2009, while the lowest accuracy was obtained on June 19, 2009 with an accuracy of 73% (kappa = 0.61). Classification accuracy as the growing season progressed remained relatively constant, with the highest accuracies occurring early in the growing season and accuracy values fluctuating for the rest of the summer. The variable importance plots showed high amounts of importance was placed in the 500 to 600 nm portion of the spectrum, and, depending on the date, in the 700-750 nm portion of the spectrum.

Combining the spectrum from the all of the data collected over the summer into a single classification resulted in significant accuracy improvements over single date classifications (p-value < 0.01). The multiple date classification achieved 97% accuracy with a kappa value of 0.95. User's accuracies range between 92% and 100% accuracy. High user's accuracies are important for noxious weed detection because high commission errors may result in overestimation of the amount of an invasive plant species being present. Variable importance indicated the most important dates in the multiple date classification were July 16 and July 23. Within these dates, the bands between 500-650 nm held the highest importance. Importance decreased substantially between dates often approaching zero, indicating that the change between dates held little importance and rather the green to red portion of the spectrum of each image was the basis for classification.

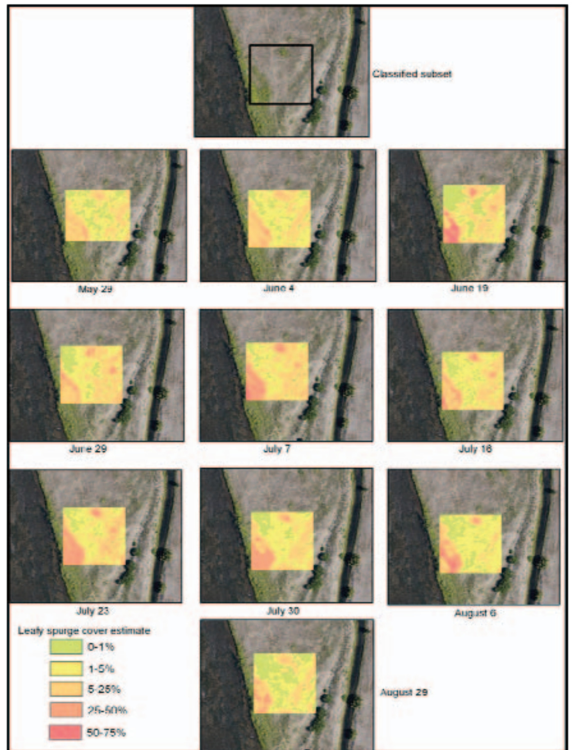

Figure 2. Classification results of a subset of the data.

While not directly comparable, the single date classifications are similar to previous leafy spurge hyperspectral classifications. The classification accuracy from multiple dates of 97% was higher than reported in previous studies. This was especially notable considering previous studies mapped only presence and absence and used much more expensive sensors, while this study mapped leafy spurge density with one of the most economical hyperspectral sensors available.

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