Remote Sensing of Leafy Spurge (*Euphorbia esula* L.):
Spectral and Spatial Detection Limits

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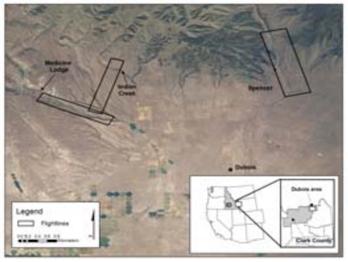
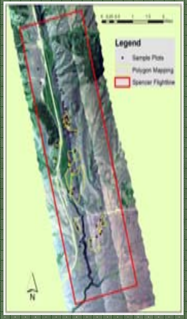
Abstract: Invasive species can alter ecosystem functions in a number of ways, including the devaluation of land; the reduction of agricultural productivity and rangeland; the diminishment of native habitat; the decline of species diversity; and the alteration of fire regimes and soil dynamics. Leafy spurge (*Euphorbia esula* L.) is listed as a noxious weed in the western United States and Canada, where widespread infestations necessitate a combination of continued monitoring and adaptive, long-term management strategies. Leafy spurge is spectrally distinct from surrounding vegetation during peak phenology and hyperspectral imagery can successfully discriminate nascent populations with cover as low as 10% within a 3.5m^2 area. A heavily infested demonstration area in southeast Idaho was used to extend remote sensing of leafy spurge research in two directions: 1) coarse regional scale detection for broad monitoring purposes and predictive modeling, and 2) fine scale detection for abundance mapping using matched filter scores (pixel-based estimates of subpixel target abundance produced from the hyperspectral classification method mixture-tuned matched filtering). The results presented herein address the coarse scale direction and focus on assessing the suitability of using Landsat TM5 for invasion history mapping and regional monitoring. Combining distribution and abundance mapping w/ ground measurements of species diversity can be used to identify sensitive areas that are susceptible to invasion (endemic, rare, or biodiverse "hotspots").

Introduction

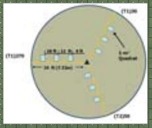
The study area is ~7,700 ha of sagebrush steppe, just south of the Continental Divide, in the Centennial Mountains of Clark County, Idaho. The area has a long history of leafy spurge invasion – first introductions likely occurred by way of the Union Pacific railroad in the late 1800's.

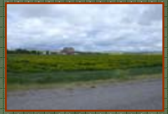


Hyperspectral image acquisitions occurred on June 28, 2006 using a HyMap sensor to collect radiance data in 126 near-contiguous spectral bands (0. 45 – 2.48 µm) at a spatial resolution of 3.3m x 3.3m.

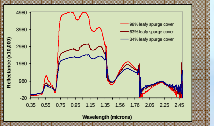


The sampling plot is a modified version of the Beyond North America Weed Mapping Association (NAWMA) design (Stohlgren et al.,1995). This sampling scheme was chosen To maximize the predictive power of the data collected at presence and absence locations. Measurements and estimations were made at the quadrat and plot levels. At the quadrat level, a Daubenmire frame was used to estimate leafy spurge canopy cover to the nearest percent. Similar cover estimations were made for shrub, bare ground, and rock. In addition, leafy spurge height was measured, individual species within the plots were identified and the total # of species recorded. At the plot level, ocular estimates of leafy spurge, shrub, bare ground, and rock were recorded and a walking species search was conducted to identify any new plant species not previously identified during the quadrat sampling. Additional ancillary information was also collected at each location, including slope, aspect, elevation, distance from road, and distance from water.



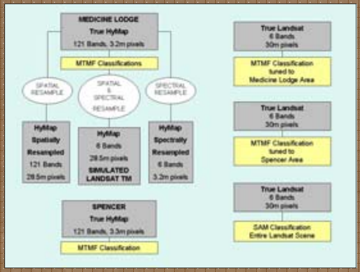


To assess the spectral characteristics of leafy spurge ground cover data at varying percent covers, a field spectroradiometer was used to measure the spectral signatures of leafy spurge at three locations (34%, 63%, and 98% canopy cover) in the Spencer study area .

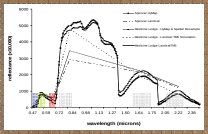


Methods

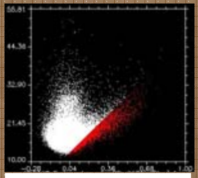
The hyperspectral classification method mixture-tuned matched filtering (MTMF) was applied to HyMap mosaics of the Medicine Lodge and Spencer study sites (Boardman, 1998). This classification method was also applied to spatial subsets within the Landsat image, and to resampled HyMap images. A spectral angle mapper (SAM) classification was applied to the entire Landsat scene using noise transformed bands as input.



A spectrally pure leafy spurge pixel within each image was used for MTMF classification. Final endmember selections presented here are performance based.

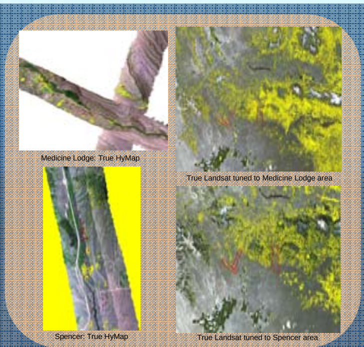


The MTMF classification generates two data sets: a matched filter (MF) band and an Infeasibility band. MF scores provide estimates of subpixel target abundance, where a value of 1 indicates a perfect match. Infeasibility values are used to constrain false positives. Scatterplots of MF scores (x) vs Infeasibility values (y) are generated and thresholds are interactively determined. For weed management purposes, over prediction is favored, as there is a greater risk associated with overlooking a new infestation than with falsely identifying leafy spurge presence.


MF score vs Infeasibility values

Results

The true Medicine Lodge MTMF classifications (HyMap and Landsat spatial subsets) outperformed the true Spencer classifications. This is likely due to less spectral contrast in the Spencer area between the target and background, which resulted in greater confusion in riparian and mixed shrub areas. There is greater spectral contrast in the Medicine Lodge area because wildland fire burned the entire site in 2003. Leafy spurge re-established quickly and shrub cover remains low (average field estimates are 8% vs 29% in Spencer).


Medicine Lodge: True HyMap
True Landsat tuned to Medicine Lodge area
Spencer: True HyMap
True Landsat tuned to Spencer area

Classification	Med. Lodge HyMap	Med. Lodge area Landsat TM5	Spencer HyMap	Spencer area Landsat TM5	Entire Landsat TM5 image using SAM and MNF transformed input bands
User's Accuracy (Present)	100%	89%	90%	72%	96%
User's Accuracy (Absent)	60%	35%	40%	22%	30%
Produer's Accuracy (Present)	80%	59%	64%	31%	30%
Produer's Accuracy (Absent)	100%	75%	77%	62%	96%
Overall Accuracy	85%	62%	67%	38%	46%
Kappa	0.70	0.36	0.43	0.16	0.33

An Incremental Cover Evaluation (Mundt et al., 2005) was applied to each classified Medicine Lodge image to quantify the minimum percent cover of leafy spurge necessary to detect leafy spurge under various resolution scenarios. The spectrally resampled image (6 bands, 3.3m pixels) performed better than the true HyMap (121 bands, 3.3m pixels) and the spatially resampled HyMap (121 bands, 3.3m pixels). The HyMap mosaic that was resampled to simulate Landsat TM5 (6 bands, 28.5m pixels) performed better that the true Landsat classification.

Medicine Lodge - MTMF Classifications										
N	53	51	49	44	41	37	34	29	24	15
LSC (>)	0	10	20	30	40	50	60	70	80	90
HyMap (121 Bands, 3.2m pixels)										
Producer's Accuracy	80%	85%	89%	88%	93%	96%	100%	100%	100%	100%
Overall Accuracy	85%	84%	92%	91%	95%	97%	100%	100%	100%	100%
Kappa	0.70	0.76	0.83	0.83	0.91	0.95	1.00	1.00	1.00	1.00
HyMap Spectral Resample (6 bands, 3.2m pixels)										
Producer's Accuracy	88%	92%	95%	97%	97%	96%	96%	94%	92%	75%
Overall Accuracy	89%	92%	94%	98%	98%	97%	97%	97%	96%	93%
Kappa	0.75	0.82	0.86	0.95	0.95	0.95	0.95	0.94	0.94	0.92
HyMap Spatial Resample (121 bands, 28.5m pixels)										
Producer's Accuracy	49%	51%	91%	56%	59%	64%	68%	76%	67%	33%
Overall Accuracy	62%	61%	61%	64%	66%	70%	74%	79%	75%	73%
Kappa	0.42	0.41	0.40	0.44	0.48	0.54	0.59	0.69	0.67	0.69
HyMap TM Simulation (6 bands, 28.5m pixels)										
Producer's Accuracy	73%	77%	78%	84%	86%	84%	91%	88%	83%	100%
Overall Accuracy	75%	80%	82%	86%	88%	86%	91%	90%	88%	93%
Kappa	0.53	0.63	0.65	0.74	0.77	0.77	0.85	0.84	0.83	0.92
True Landsat TM (6 bands, 28.5m pixels)										
Producer's Accuracy	59%	56%	57%	53%	55%	64%	68%	71%	67%	33%
Overall Accuracy	62%	61%	61%	59%	61%	68%	71%	72%	71%	67%
Kappa	0.36	0.36	0.37	0.37	0.40	0.49	0.54	0.59	0.60	0.61

Conclusion

True Landsat classification performances of the demonstration area indicate that the sensor would not be suitable for historic invasions mapping and regional monitoring of leafy spurge. If Landsat could not discriminate leafy spurge well enough in this study area, then it is doubtful that the sensor could perform better elsewhere. The simulated Landsat performance, along with a recent leafy spurge study using the Landsat prototype sensor ALI (Stitt et. Al., 2006) suggest that the spectral and spatial dimensions of Landsat, when combined with improved instrumentation, are sufficient for regional mapping purposes. The spectrally resampled HyMap produced unanticipated high performance results that need further validation. The results could be specific to the target, there may be some advantage to having 6broad bands vs 121 narrow bands, or spatial resolution may be more critical to leafy spurge discrimination. Future work may leverage variable information collected in the field to improve multispectral classification results.

References

Boardman, J. W. (1998). Leveraging the high dimensionality of AVIRIS data for improved sub-pixel target unmixing and rejection of false positives: Mixture tuned matched filtering. *Proceedings of the Fifth JPL Geoscience Workshop*. Pasadena, CA: JPL

Mundt, J. T., Streutker, D. R., and Glenn, N. F., (2007). Partial unmixing of hyperspectral imagery: Theory and methods. *Proceedings of the American Society of Photogrammetry and Remote Sensing.*

Stitt, S., Root, R., Brown, K., Hager, S., Mladinich, C., Anderson, G. L., Dudek, K., Ruiz Bustos, M., and Kokaly, R., (2006). Classification of leafy spurge with Earth Observing-1 Advanced Land Imager. *Rangeland Ecology and Management , 59(5), 507-511.*

Stohlgren, T. J., Barnett, D. T., & Crosier, C. S. (2006). Beyond NAWMA-The North American Weed Management Association Standards. Available URL: http://www.niiss.org/cwis438/websites/niiss/FieldMethods/BeyondNAWMA.php , accessed June 01, 2006.

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