Final report, Joint Fire Science Program AFP 2000-1-3-01

Project Title: The use of Landsat 7 (ETM+) and AVIRIS data to map fuel characteristic classes in western ecosystems

Project Location: Yosemite National Park, California; Devils Postpile National Monument, California; Lassen Volcanic National Park, California; Great Basin National Park, Nevada; and Glacier National Park, Montana.

Principal Investigators: Jan W. van Wagtendonk (PI), Ralph R. Root (deceased), Carl H. Key.

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This final report details the status of the project, findings to date, and proposed and accomplished deliverables. Details on the study background, objectives, and methods are available in the study proposal.

STATUS OF PROJECT

As it was originally intended, this project was going to produce fuel model maps for the five parks using both Landsat ETM+ and AVIRIS imagery. Some aspects of the project were not completed due to problems obtaining AVIRIS imagery and the unfortunate death of one of the principal investigators. However, many relevant products were produced, and the data and imagery have been provided to other investigators who have produced additional products.

AVIRIS Imagery. New AVIRIS imagery was obtained for Yosemite National Park in 2001 but had to be reflown in 2002 because of clouds and miscalibration of one of the sensors. Previously flown AVIRIS imagery for Lassen Volcanic National Park could not be used because the imagery did not cover the area where the field data had been collected. AVIRIS imagery for Theodore Roosevelt National Park was not used because the field data were not available because they were to have been collected by the deceased co-PI. AVIRIS missions were scheduled for Great Basin and Glacier national parks in 2003 but had to be cancelled because of bad weather in both parks. In 2004, we had a successful collection at Great Basin, but smoke obviated any flights over Glacier. As a result, we were only able to obtain useful AVIRIS data at Yosemite and Great Basin. However, since Devils Postpile National Monument was within the Yosemite imagery window and field data existed for the area, we were able to add it to the project in lieu of Theodore Roosevelt.

Field Data. Fuels data collection was completed for Great Basin National Parks(267 plots), and leveraged datasets were available for Lassen Volcanic (347 plots), Yosemite (1313 plots), and Glacier (723 plots) national parks and Devils Postpile National Monument (57 plots). Data from all areas were entered, checked for errors, and placed in

accessible data bases. All of these data sets were made available to the National Landfire Project, and the Yosemite and Devils Postpile data sets were provided to the Gradient Nearest Neighbor Project (01-1-4-09).

Analysis. Because the analysis of the AVIRIS imagery and the application of spectroscopic imaging algorithms to temporal data sets were to be conducted by the deceased PI, those analyses will not be accomplished. Instead, these tasks will be part of a doctoral dissertation by a student at the University of California, Santa Barbara. We were able to use the two AVIRIS flights in Yosemite for a comparison with Landsat ETM+ imagery for burn severity analyses and for fuel moisture determinations.

Future Work. Upon completion of the Landfire project and the doctoral dissertation, the principal investigator will conduct workshops at each of the parks to explain the use, accuracy, and limitations of the products. These workshops will not require additional Joint Fire Science Program funds.

SUMMARY OF FINDINGS

Satellite imagery has the potential to map fuel models at the national and local levels.

- Landsat. The Landfire project has shown that Landsat 7 (ETM+) data are useful for mapping fuels at the national level. Critical to developing accurate maps are data collected in the field on fuels and vegetation. At Yosemite, both the Gradient Nearest Neighbor Project and the combination of vegetation maps with Landsat data have produced reliable fuel model maps that have been accepted by managers and are in use today.
- AVIRIS. Although it was thought that the higher spectral and spatial resolution of AVIRIS data would improve the accuracy and quality of fuel model maps, the difficulty in obtaining the imagery and its high cost precludes its use. If hyperspectral data become readily available at a reasonable cost, it would be instructive to reinitiate a project to compare the two image sources. This would be particularly true for local applications.

AVIRIS imagery compares well with Landsat for detecting fire severity, but has distinct limitations.

- AVIRIS imagery proved equal to ETM+ for detecting burn severity. Unfortunately, use of AVIRIS in multi-temporal differencing may be limited by the complexity of mission planning and the high cost of data acquisition. Moreover, AVIRIS is not continuously flown and coverage is not geographically contiguous. There are also issues of complexity in the georectification necessary for temporal differencing, especially with multiple flight lines and terrain exhibiting high topographic relief. Until orbital imaging spectrometers with the capability of capturing data at regular intervals are in routine use, it is doubtful such data are currently practical for making burn assessments.

DELIVERABLES

The following tables include the following: (1) deliverables specifically listed in the project proposal, (2) additional publications that were not specifically listed in the study proposal, (3) datasets used in other projects related to fuels and fire severity mapping, (4) publications by other authors using field data collected as part of this project or a leveraged project, and (5) presentations and proposed workshops.

Deliverables specifically listed in the project proposal	
Annual progress reports	Annual progress reports completed
Published peer-reviewed articles using AVIRIS and Landsat ETM+ data collected as part of this project.	• van Wagtendonk, J. W., and R. R. Root. 2003. The use of multi-temporal Landsat Normalized Difference Vegetation Index (NDVI) data for mapping fuels in Yosemite National Park, USA. International Journal of Remote Sensing 24(8): 1639-1651. • van Wagtendonk, J. W., R. R. Root, and C. H. Key. 2004. Comparison of AVIRIS and Landsat ETM+ detection capabilities for burn severity. Remote Sensing of Environment 92(3): 397-408.
Future publications using ground-based and remotely-sensed data collected for this project.	• van Wagtendonk, J. W., and K. A. van Wagtendonk. Cumulative fire severity effects of multiple fires over a 35-year period using MSS, TM, and ETM+ imagery (in preparation) • Hooke, J., K. A. van Wagtendonk, and J. W. van Wagtendonk. Dynamic mapping the new 40 fuel models using aerial photography-derived vegetation maps and satellite imagery. (in preparation)
Future publication using AVIRIS data for spectroscopic imaging algorithms of temporal data sets (in lieu of proposed product).	• Peterson, S. Relationships between ground-based vegetation amount and live fuel moisture measurements for fire fuels research and remotely sensed data of varying spatial resolution. PhD. Dissertation, Univ. California, Santa Barbara. (in preparation)

Additional publications that were not specifically listed in the study proposal.	
Published peer-reviewed proceedings using AVIRIS and Landsat ETM+ data collected as part of this project.	• Roberts, D. A., S. Peterson, P.E. Dennison, J. Rechel, and J.W. van Wagtendonk. 2005. Fine spatial, spectral and temporal characterization of wildfire fuels through the integrated analysis of imaging spectrometry and coarser resolution broad band data. Pages 85-90 *in:* De la Riva, J., Pérez-Cabello, F., and Chuvieco, E. (eds) Proceedings of the 5th International Workshop on Remote Sensing and GIS Applications to Forest Fire Management: Fire Effects Assessment. Universidad de Zaragoza, Spain. 290 p. • Rechel, J. L., S. H. Peterson, D. A. Roberts, and J. W. van Wagtendonk. 2005. Predicting seasonal fuel moisture in the western United States using endmember fractions at multiple spatial and spectral resolutions. Pages 245-248 *in:* De la Riva, J., Pérez-Cabello, F., and Chuvieco, E. (eds) Proceedings of the 5th International Workshop on Remote Sensing and GIS Applications to Forest Fire Management: Fire Effects Assessment. Universidad de Zaragoza, Spain. 290 p.
Other publications that provide context for mapping fuels using satellite imagery	• van Wagtendonk, J. W., Z. Zhu, and E. L. Lile. 2004. Prefire risk assessment and fuels mapping. P. 49-52 in: Livingston, R. K., (ed.). Third U. S. Geological Survey Wildland Fire-Science Workshop. USGS Scientific Investigations Report 2004-5005. 67 p. • Keane, R. E., R. E. Burgan, and J. W. van Wagtendonk. 2001. Mapping wildland fuels for fire management across multiple scales: integrating remote sensing, GIS, and biophysical modeling. Int. J. Wildland Fire 10(3&4): 301-319. • van Wagtendonk, J. W., and R. R. Root. 2000. Hyperspectral analysis of multi-temporal Landsat TM data for mapping fuels in Yosemite National Park. P. 224-228 *in:* Neuenschwander, L. F., and K. C. Ryan (tech. eds.). Proc. Joint Fire Sci. Conf. and Workshop, Vol. I. Univ. Idaho and Int. Assoc. Wildland Fire. 298 p. • van Wagtendonk, J. W. 1998. Use of thematic mapper imagery to map fuel models. Proceedings 13th Conf. on Fire and Forest Meteorology. International Assoc. Wildland Fire. 13: 215-224.

Datasets used in other projects related to fuels and fire severity mapping.	
Datasets including data collected directly as part of this project	• Pleszewski, R., P. E. Moore, and J. W. van Wagtendonk. 2005. Fuels and vegetation mapping program data/output: Great Basin National Park. Version 1.0. USGS Western Ecological Research Center, Yosemite Field Station, El Portal, CA
Datasets including data collected through leveraged projects	• Pleszewski, R., P. E. Moore, and J. W. van Wagtendonk. 2005. Fuels and vegetation mapping program data/output: Yosemite National Park. Version 1.0. USGS Western Ecological Research Center, Yosemite Field Station, El Portal, CA • Pleszewski, R., P. E. Moore, and J. W. van Wagtendonk. 2005. Fuels and vegetation mapping program data/output: Devils Postpile National Monument. Version 1.0. USGS Western Ecological Research Center, Yosemite Field Station, El Portal, CA • Farris, C, R. Pleszewski, and J. W. van Wagtendonk. 2005. Fuels and vegetation mapping program data/output: Lassen Volcanic National Park. Version 1.0. USGS Western Ecological Research Center, Yosemite Field Station, El Portal, CA • Lansing, C., R. Pleszewski, and J. W. van Wagtendonk. 2005. Fuels and vegetation mapping program data/output: Glacier National Park. Version 1.0. USGS Western Ecological Research Center, Yosemite Field Station, El Portal, CA

Publications by other authors using field data collected as part of this project or a leveraged project.	
Gradient Nearest Neighbor Project	• Pierce, K., J. L. Ohmann, M. C. Wimberly, J. S. Fried, and M. J. Gregory. Mapping wildland fuels and forest structure to support management and simulation modeling. Ecological Applications. (in preparation) • Pierce, K. B., Jr., C. K. Brewer, and J. L. Ohmann. Moderate resolution data and gradient nearest neighbor imputation for regional-national risk assessment. Advances in Threat Assessment Conference Proceedings, Boulder, CO July 18-20, 2006, USDA Forest Service Southern Research Station. (in press) • Ohmann, J. L, M. J. Gregory, and T. A. Spies. In press. Influence of environment, disturbance, and ownership on forest composition and structure of coastal Oregon. Ecological Applications. (in preparation) • Ohmann, J. L., M. C. Wimberly, J. S. Fried, K. B. Pierce Jr., and M. J. Gregory. 2005. A novel approach to regional fuel mapping: linking inventory plots with satellite imagery and GIS databases using the Gradient Nearest Neighbor method. Final peport to the Governing Board, Joint Fire Science Program Project 01-1-4-09.
Burn Severity Project	• Zhu, Z.; C. Key; D. Ohlen; N. Benson. 2006. Evaluate Sensitivities of Burn-Severity Mapping Algorithms for Different Ecosystems and Fire Histories in the United States. Final Report to the Joint Fire Science Program, Project JFSP 01-1-4-12.
LANDFIRE Project	• Forest Service. 2006. Environmental site potential. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center. • Forest Service. 2006. Biophysical settings. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center. • Forest Service. 2006. Existing vegetation cover. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center.

	• Forest Service. 2006. Existing vegetation type. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center. • Forest Service. 2006. Existing Vegetation height. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center. • Forest Service. 2006. Existing Fuel loading models. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center. • Forest Service. 2006. Fuel characteristics classification system. Landfire geospatial data products, Forest Service, Rocky Mountain Research Station, and USGS EROS Data Center.

Workshops and presentations	
Presentations using data collected as part of this project	• Rechel, J. L., S. H. Peterson, D. A. Roberts, and J. W. van Wagtendonk. 2005. Predicting seasonal fuel moisture in the western United States using endmember fractions at multiple spatial and spectral resolutions. 5th International Workshop on Remote Sensing, GIS, and Fire Management; Zaragoza, Spain, June 16-18, 2005. • Roberts, D.A., S. H. Peterson, P. E. Dennison, J. L. Rechel, and J. W. van Wagtendonk. 2005. Fine spatial, spectral and temporal characterization of wildfire fuels through the integrated analysis of imaging spectrometry and coarser resolution broad band data. 5th International Workshop on Remote Sensing, GIS, and Fire Management; Zaragoza, Spain, June 16-18, 2005. • van Wagtendonk, J W., J. L. Rechel, and D. Roberts. 2004. Mapping fuels in Sierra Nevada forests using AVIRIS hyperspectral data. American Society for Photogrammetry and Remote Sensing 2004 Annual Conference; Denver, Colorado. May 23-28, 2004. • van Wagtendonk, J. W., R. R. Root, and C. H. Key, 2003. Burn severity detection enhancement using AVIRIS hyperspectral data. 4th International Workshop on Remote Sensing, GIS, and Fire Management; Ghent, Belgium, June 5-7, 2003. • van Wagtendonk, J. W., and R. R. Root. 2001. The use of multi-temporal Landsat Normalized Difference Vegetation Index (NDVI) data for mapping fuels in Yosemite National Park, USA. 3rd International Workshop on Remote Sensing, GIS, and Fire Management; Paris, France, May 17-18, 2001. • van Wagtendonk, J. W., and R. R. Root. 2000. Hyperspectral analysis of multi-temporal Landsat TM data for mapping fuels in Yosemite National Park. Joint Fire Science. Conf. and Workshop, Int. Assoc. Wildland Fire; Boise, Idaho, June 15-17, 1999. • van Wagtendonk, J. W. 1996. Use of Thematic Mapper imagery to map fuel models. 13th Conference on Fire and Forest Meteorology; International Association of Wildland Fire, Lorne, Australia, October 27-31, 1996.

Future workshops to will be conducted to present fuel model maps to managers, and explain the use of the maps and their values and limitations.	• 2007 Yosemite National Park – Jan van Wagtendonk • 2007 Devils Postpile National Monument – Jan van Wagtendonk • 2007 Glacier National Park – Carl Key • 2008 Lassen Volcanic National Park – Jan van Wagtendonk • 2008 Great Basin National Park – Jan van Wagtendonk

Published peer-reviewed articles using AVIRIS and Landsat ETM+ data collected as part of this project.	• van Wagtendonk, J. W., and R. R. Root. 2003. The use of multi-temporal Landsat Normalized Difference Vegetation Index (NDVI) data for mapping fuels in Yosemite National Park, USA. International Journal of Remote Sensing 24(8): 1639-1651. • van Wagtendonk, J. W., R. R. Root, and C. H. Key. 2004. Comparison of AVIRIS and Landsat ETM+ detection capabilities for burn severity. Remote Sensing of Environment 92(3): 397-408.
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e.g.: ***2 peer-reviewed publications re ground-based vs. remotely sensed data***	• Peterson, S. Relationships between ground-based vegetation amount and live fuel moisture measurements for fire fuels research and remotely sensed data of varying spatial resolution. PhD. Dissertation, Univ. California, Santa Barbara. (in preparation)