FOREST SERVICE
REMOTE SENSING TIPS
RESOURCE MANAGEMENT

Characterizing Upland Meadows with Multitemporal Landsat Thematic Mapper Remote Sensing

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Overview

This project evaluated the utility of remotely sensed data to characterize wet meadow vegetation in the Wallowa Whitman and Umatilla National Forests. Of particular interest was the ability to differentiate species of sedge that are strong indicators of meadow groundwater conditions. We used the tasseled-cap transformation (Kauth and Thomas 1976) on a temporal series of Landsat Thematic Mapper (TM) images to characterize meadows. This approach provided high-resolution data to identify meadow vegetation and can be used to characterize the composition of plant species in meadows, including sedge indicators.

Introduction

There is a demand for better methods to characterize the physical and biological attributes of riparian/wetland areas on national forest land (figure 1). This information is essential for a variety of activities, including forest-level planning, watershed assessments, and designing site-specific restoration projects. Methods are needed to identify meadows that are degraded from past management activities. Of particular interest are meadows that can provide cool subsurface water to streams that support federally listed species like Chinook salmon and bull trout.

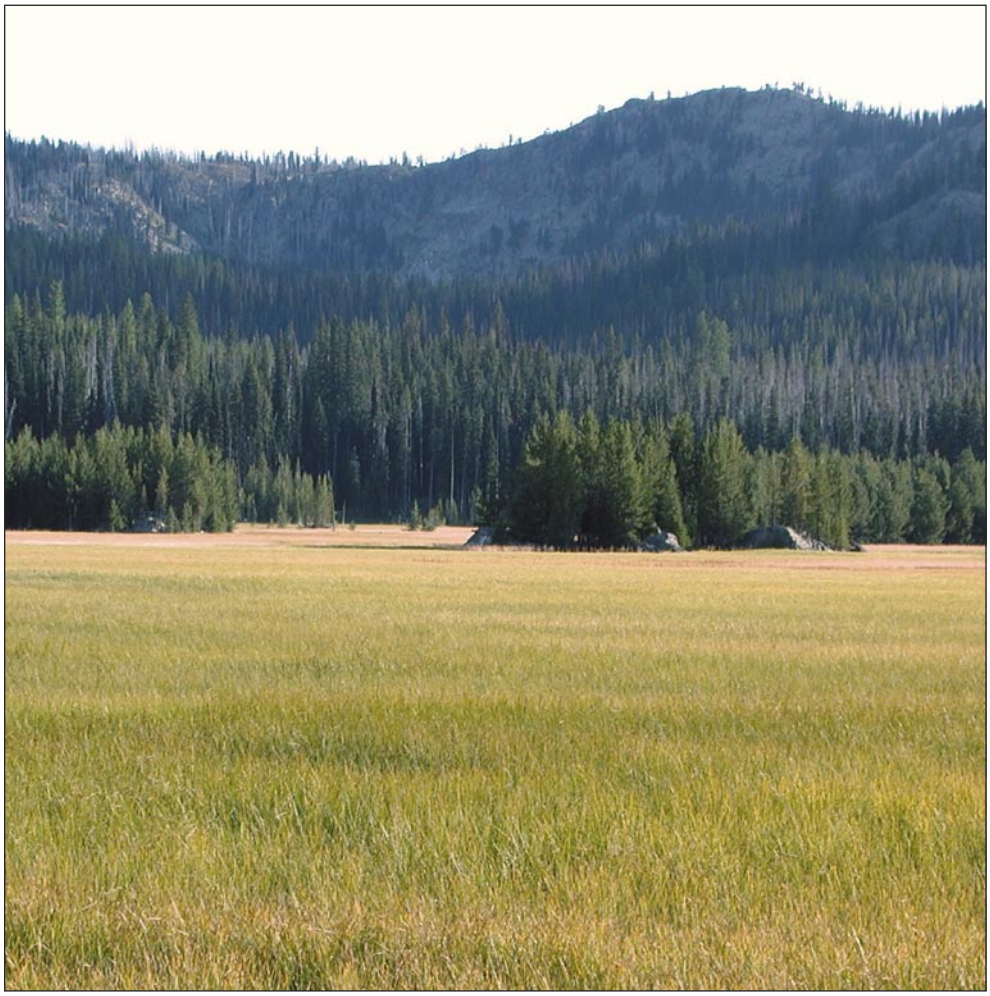

Figure 1—Example of a wetland meadow in the Blue Mountains of Oregon.

Disturbances like grazing and road building can downcut streambanks within wet meadows, causing a number of successional changes, including 1) variations in the composition of plant species; 2) lowered below-ground biomass, and 3) loss of hydrologic function. The changes in plant species are typified by a reduction of certain aquatic sedges. As a first step toward applying remote sensing methods to detect changes in meadow vegetation, we examined how well a temporal series of satellite images could differentiate meadows with different plant compositions.

Study Area

The meadows evaluated were sampled from the LaGrande Ranger District of the Wallowa Whitman National Forest and the North Fork John Day Ranger District of the Umatilla National Forest (figure 2). The meadows represent a range of vegetative types and moisture conditions. Meadow vegetation in this area ranges from xeric bunchgrass to perennially wet, sedge-dominated communities. A number of the meadows were known to have experienced overgrazing and other practices that have changed vegetative composition over the past 20 to 40 years. A total of 32 meadows were included in the study.

Meadows were chosen based on minimum-size criteria (more than 5 acres) and the absence of intermittent shrub or forest vegetation. Using a preexisting geographic information system (GIS) coverage of plot locations collected in the field, the meadows were digitized onscreen using digital orthophotos (DOQs) as a backdrop (figure 3). Boundaries were digitized approximately 15 meters from the meadow edge to eliminate the influence of adjacent, nonwetland areas.

Five dates of TM imagery collected throughout the 2000 growing season were used for the project (path 43, row 29). The dates were April 9, June 16, July 2, August 3, and September 20. Although initial analyses were performed with all five dates of imagery, the June and August dates were dropped because clouds obscured several key meadows.

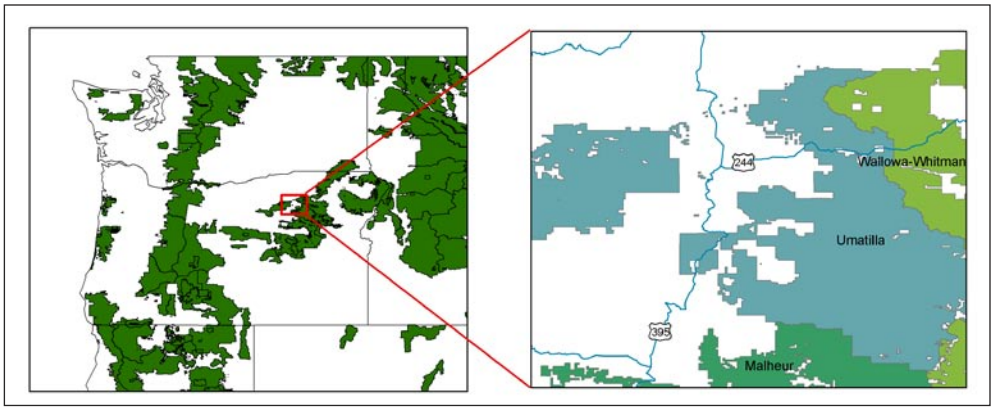

Figure 2—The study area is located in the Upper Grande Ronde HUC4 subbasin, near LaGrande Oregon. The area is 430,000 acres, of which 310,000 are U. S. Department of Agriculture (USDA) Forest Service lands administered by the LaGrande District of the Wallowa Whitman National Forest.

Soil and Vegetation Information

The tasseled-cap transformation (Kauth and Thomas 1976; Crist and Cicone 1984) was applied to each date of the TM data. This transformation is commonly used to generate soil and vegetation indices.

Using predefined coefficients, the tasseled-cap operation transforms Landsat TM data into three new components related to scene brightness, greenness, and wetness. The brightness component is a weighted average of all the bands. The greenness component weights the bands most correlated to vegetation: near-infrared (IR) and red. The wetness component is related to soil moisture and weights the mid-IR bands most heavily. The most useful components for detecting phenological and hydrological characteristics in meadows are the greenness and wetness ones (figure 4).

Using the digitized meadow polygons, the tasseled-cap greenness and wetness zonal means for each polygon were extracted from the time series of images and analyzed further for any patterns.

Data Analysis and Results

Plots of this data were first examined to look for patterns of greenness and wetness over time. Seasonal greenness and moisture "signatures" were identified and appeared to correspond well with plant associations and their seasonal patterns of green-up and decline (figure 5). Plant associations are very good indicators of water-table levels throughout the growing season and therefore become an indirect means of characterizing the hydrologic condition of these meadows.

The mean meadow values from all dates of tasseled-cap images were analyzed using principal-components analysis (PCA) (Rechner 1992). This procedure is a useful way of visualizing multidate greenness and wetness values. Plots of PCA scores were examined to look for groupings of data. Ideally meadows would be grouped together based on their spectral patterns of greenness and wetness across the growing season. The output from this analysis should separate meadows based on their temporal differences in vegetation and wetness, or hydrologic condition, information that may be valuable for classifying unvisited and unknown meadows.

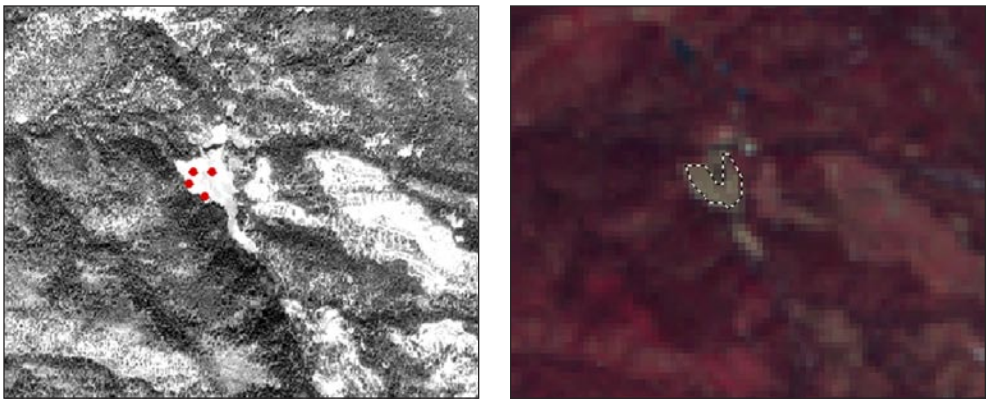

Figure 3—DOQ with field-collected location of meadows displayed *(left)* and corresponding area on the Landsat TM image used for digitizing meadow-boundary polygon *(right)*.

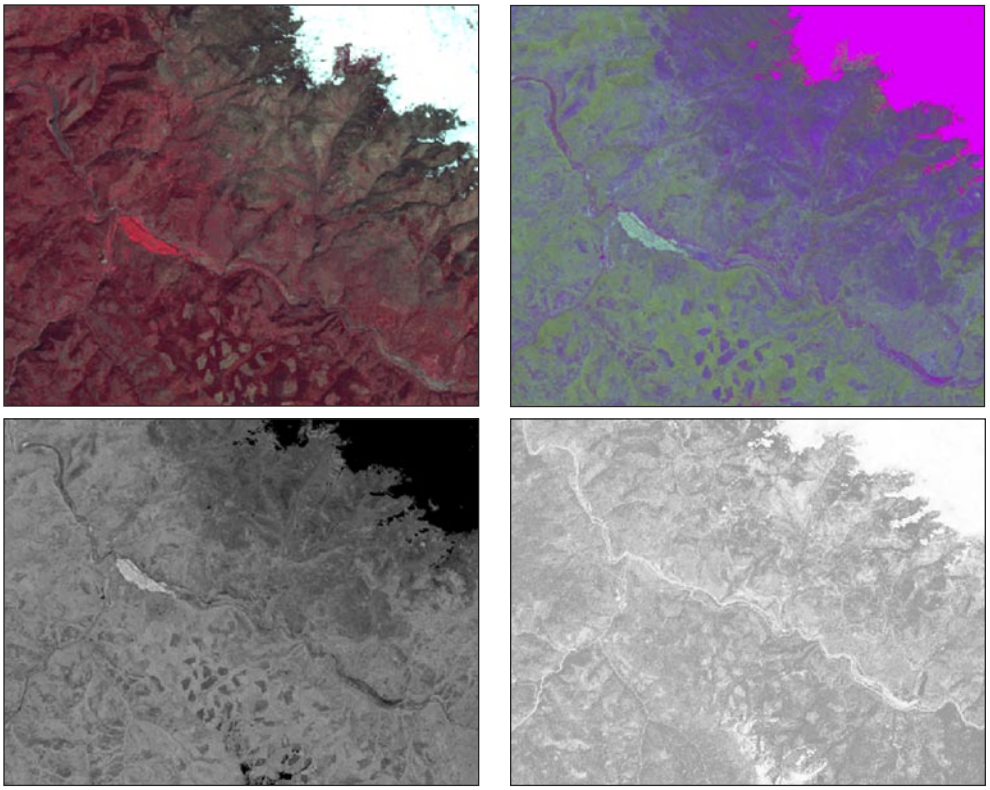

Figure 4—Examples of tasseled-cap-derived images: *(A)* original color-IR image; note the snow in the upper right corner, the river running diagonally, and the harvested patches; *(B)* color composite of brightness, greenness, and wetness; *(C)* greenness in grayscale; *(D)* wetness (soil moisture) in grayscale. Note: Lighter shades of gray indicate higher amounts of greenness and wetness.

Applications

Three potential applications were identified after examining the results of this project. First, in areas where meadow or nonforest vegetation remains unclassified, a relatively small number of training sites can be collected and used to classify meadows and grasslands. This vegetation typing will help prioritize fieldwork for identifying rare and endemic riparian plants and hydrologically important meadows.

Second, the methods developed in this project can be used to screen plant-association data for errors in forests where meadow inventories have been completed.

Finally, these methods can help identify degraded meadows by monitoring changes in PCA scores, or similar measurements, over time. For example, imagery of this study area from 5 and 10 years ago can be compared with current imagery to identify and delineate areas where obligate wetland species have increased or decreased.

The PCA of tasseled-cap-transformed Landsat TM images proved useful for differentiating vegetation and moisture conditions among the sample meadows. Most of the meadows fell neatly into spectral clusters with similar plant composition, although a few outliers cropped up. Some of these problem meadows might have been typed differently if field inspection of their plant compositions had been more thorough.

Classifying different plant species by their association with specific water-table depths enables us to draw conclusions about the groundwater conditions of the meadows (Crowe and Clausnitzer 1997). Further, the response of specific plant species to overgrazing prompts inferences about grazing history.

The analysis did not consider additional principal components, the use of raw Landsat data, or other potential transformations of the data. It is possible that the classification and clustering of meadow data could be improved by including additional input or refining the input selected for this project.

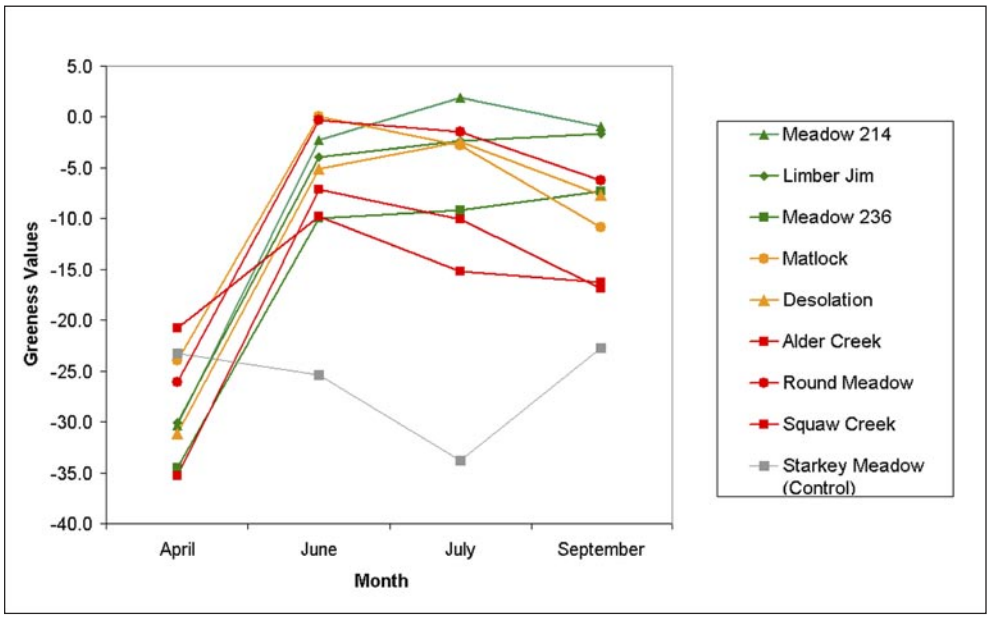

Figure 5—Greenness plots of nine samples demonstrate the potential of using tasseled-cap indicators to characterize meadows. Meadows 214, 236, and Limber Jim are sedge-plant environments, indicators of hydrologically functioning wetlands (high and/or increased levels of greenness at the end of the season). Matlock and Desolation meadows contain tufted hairgrass, an indicator of degraded wetlands (decrease in greenness late in the season). Alder, Round, and Squaw Creek meadows are degraded as a result of overgrazing (decrease in greenness late in the summer). Starkey is a bunchgrass-type meadow that is dry all summer long and greens-up in the fall.

Figure 6—Another wetland meadow in the Blue Mountains of Oregon.

Conclusion

The methods evaluated by this project demonstrate that remote sensing holds great potential to successfully identify and characterize upland meadows in the Western United States (figure 6). Because of the relationship between water-table levels at these sites and the plants that grow there, it is possible to infer hydrological conditions by utilizing a time series of images measuring green-up and drying out over a growing season. The ability to characterize meadows over large areas will help resource specialists conducting watershed assessments and restoration projects by giving them an additional tool to identify and monitor sensitive areas over large distances and saving them time in the field and the office.

References and Suggested Reading

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