SPECIES AND CANOPY COVER MAP DEVELOPMENT USING LANDSAT ENHANCED THEMATIC MAPPER IMAGERY FOR GRAND CANYON NATIONAL PARK

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ABSTRACT

Overstory vegetation maps of species and canopy cover were developed from Landsat 7 Thematic Enhanced Thematic Mapper satellite imagery. Ecosystem Monitoring plot data, collected during the 1997-2001 field seasons, were used as training sites for the image classification. Sixty-two species classes and four canopy cover classes were mapped. The maps will be used to support a Joint Fire Science Program funded project to model long-term fire regimes and ecological change using fire history, climate, and forest structure data. The calibrated model will then be used to assess fire behavior under current fuel conditions and to evaluate and compare future fuel treatments that may include prescribed burning and thinning.

INTRODUCTION

We developed landscape-scale information on forest species composition (vegetation type) and canopy characteristics in support of a larger study on ecological changes in forest structure and fire regime. In most southwestern forests, fire ecology research has focused on ponderosa pine and lower mixed conifer forests, where well-preserved fire scars are used to reconstruct detailed histories of surface fire. This method stands in contrast to the research approach usually applied in boreal forests, where maps of forest stands that originated after stand-replacing fires form the base data for reconstructing fire history. In this study, we had the opportunity to combine both methods to reconstruct changes over an elevational gradient from ponderosa pine forest, with a surface fire regime, to spruce-fir and aspen forests, with a mixed fire regime that included stand-replacing burns. Remotely sensed data, combined with extensive systematic ground sampling, were necessary for creating the large-scale coverages for analysis.

Fire regime characteristics of high-elevation forests on the North Rim of the Grand Canyon, Arizona, were reconstructed from fire scar analysis, remote sensing, tree age, and forest structure measurements (Fulé et al, 2002 and in review). Analysis of fire scar samples indicates that surface fires were common from 1700 to 1879 in the 4,400 ha site, especially on S and W aspects. Fire ignition point data for a portion of the study area, collected by the National Park Service between 1924 and 1996 (Figure 1), shows that fires, both lighting and human caused, are quite frequent. Fire dates frequently coincided with fire dates measured at study sites at lower elevation, suggesting that pre-1880 fire sizes may have exceeded 50,000 ha. Currently the forest is predominantly spruce-fir, mixed conifer, and aspen. In contrast, dendroecological reconstruction of past forest structure showed that the forest in 1880 was very open, corresponding closely with historical (Lang and Stewart 1910) accounts of severe fires leaving partially denuded landscapes. Severe fires were not unprecedented in the pre-1880 forest, but the exclusion of frequent surface fires in the mixed conifer and ponderosa pine forests has led to a more homogenous landscape where the extent and severity of contemporary fires may exceed pre-1880 patterns.

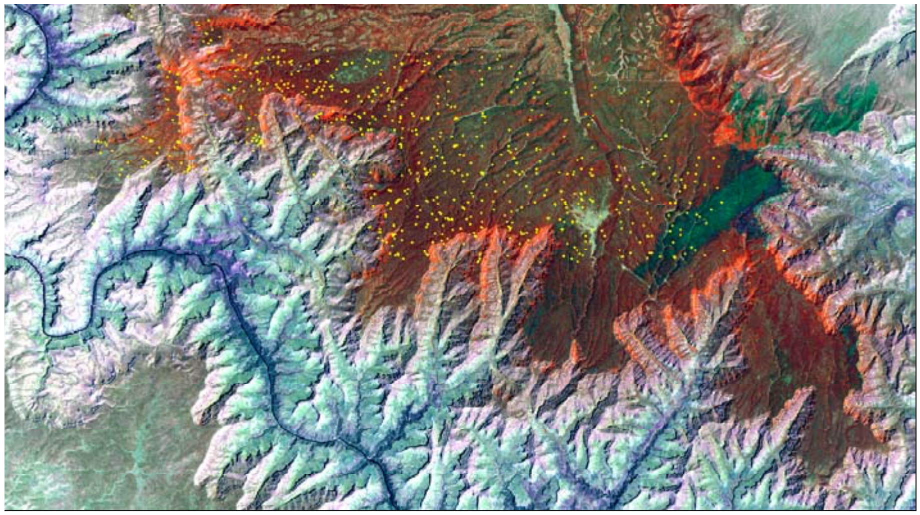

Figure 1; Fire ignition points

METHODS

Study Area

The study site (Figure 2) was a portion of the South Rim, a section of the Canyon itself, and the entire North Rim area located within the National Park. A portion of the North Kaibab National Forest, just north of the Park boundary, was also included. The main focus of this project was the North Rim portion of the study area. This portion of the site completed a transect of study sites described by Fulé et al. (2002). The lower transect ranged from Powell Plateau , Fire Point, and Rainbow Plateau, each ~2,300 m elevation, through Swamp Ridge (~2,500 m). While the complete transect ran west-east along the northern border of Grand Canyon National Park, the prevailing fire season winds are from the southwest. Therefore we added a new study site, Galahad Point, at the base of Kanabownits Canyon (~2,350 m elevation). The Galahad site lay directly downcanyon and upwind from Little Park, allowing us to test whether fire dates differed among low-elevation sites southwest vs. due west of the high-elevation site.

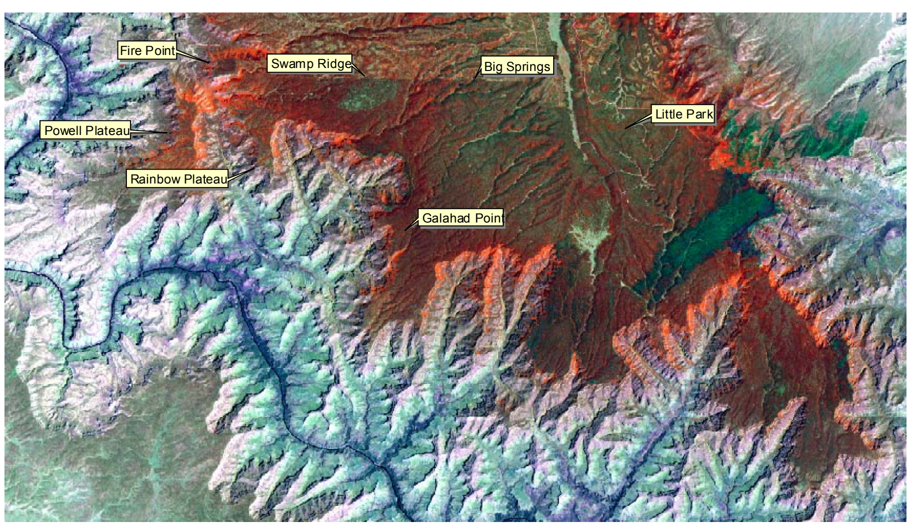

Figure 2; Study site

The average January temperature is -2° C and the average July temperature is 17° C. Precipitation occurs during the winter months, in the form of snow, and during the summer monsoonal season. Average precipitation is 64 cm and the average snowfall is 318 cm (Warren et al. 1982).

Forests in the lower elevation areas of the study site, such as Galahad Point and Powell Plateau, were dominated by ponderosa pine with Gambel oak (*Quercus gambelii*) and New Mexican locust (*Robinia neomexicana*). At Little Park and Big Springs, tree species included ponderosa pine (*Pinus ponderosa*), aspen (*Populus tremuloides*), white fir (*Abies concolor*), and subalpine fir (*Abies lasiocarpa*). Two spruce species were encountered: Engelmann (*Picea engelmannii*) and blue spruce (*Picea pungens*). Both species were combined as "spruce" in this study because of difficulties in distinguishing young trees (Moore and Huffman in review) and our observation of trees at the study site that had characteristics intermediate between the two species.

Dataset

For this project, a Landsat 7 Enhanced Thematic Mapper (ETM) image, acquired 6 June 2000, was used. TM imagery has been shown to be the best product for consistently mapping vegetation for large land areas (Keane et al. 2000). Landsat Thematic Mapper imagery has been used extensively for vegetation mapping projects (Golden 1991, Congalton et al. 1993, Muldavin et al. 1998, Vanderzanden et al. 1999, Keane et al. 2000).

The aerial photography for the study area is National High Altitude Photography program (NHAP) 1:40,000 color infrared prints. A digital elevation model (DEM), with 30 m spatial resolution, was used as a tool to refine the vegetation classification.

Preprocessing

The project area, with a buffer, was clipped from the ETM imagery to reduce processing time and storage space. A ratio band of band 3 (visible red) with band 4 (near infra-red) was created and added to the original six reflective bands. This particular ratio has proven to be useful for minimizing shadow effects in satellite image classifications (Vanderzanden et al. 1999). The Texture module in Imagine was used to create a texture file using band 4. This band was added to the ETM dataset.

An unsupervised classification with 75 classes was run to identify non-forest and below rim areas. The DEM was used to separate below rim areas that were confused with above rim areas. No large water bodies or developed areas exist in the project area that needed to be masked from the imagery. The non-forest classes were given the appropriate labels (grass, grass-shrub, etc.) and masked from the imagery. They were not included in the remainder of the processing. This was done to reduce the spectral variation within the image.

Training Site Selection

Training sites are areas on the ground used to represent a particular cover type or structural stage category (Lachowski et al., 1995). The Ecosystem Monitoring (EM) plot data collected in the 1997-2001 field seasons was used as training sites for the classification process. The EM plot centers are 300 m apart and are a subset from a plot grid that covers the entire study area. A total of 202 20 x 50 m plots were established and 188 were used as training sites (Figure 3).

These plots were not established with the intention of being utilized as training sites for image classification but the data collected for each plot does make them well suited for this purpose. Overstory tree data collected includes species, dbh, dsh for a subset of the trees, and tree height. Tree canopy cover, as well as understory vegetation data, are collected on the two 50 m plot edges and fuels data are collected on four 25 m transects that originate from the centerline (long axis) of the plot. Understory tree data are collected for ¼ of the plot. Slope and aspect are recorded for all plots. Plot elevations were taken from the DEM.

All image classification and analysis was done using Erdas Imagine. The training sites were digitized directly on the ETM imagery to create a supervised training site signature file. Each training site polygon included at least 10 pixels including the pixel or pixels that corresponded with each EM plot center. Each training site was given a species classification label after it was digitized.

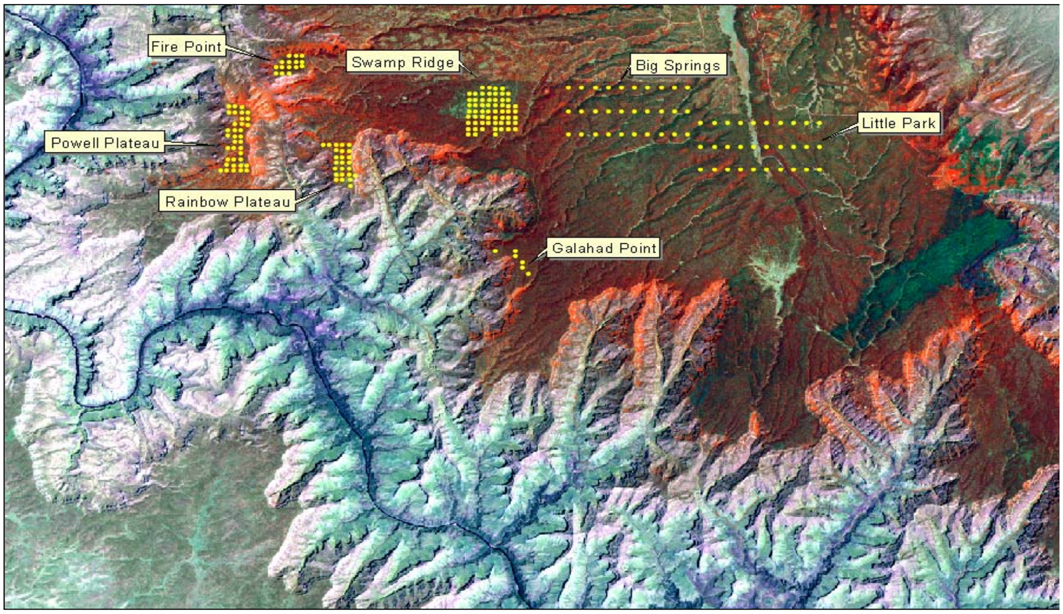

Figure 2; Training site locations

Classification scheme

The classification scheme for this project was developed so that it would fit within the National Vegetation Classification Standards (NVCS) framework. The NVCS has been developed through the USGS-NPS Vegetation Mapping Program in association with USGS/BRD, EPA, National Park Service, The Nature Conservancy, Ecological Society of America, and others (USGS, 2000). The goal of the NVCS is to provide a consistent national vegetation classification system

The EM plot data were analyzed to determine the species labels that were assigned to each of the training sites. The species label for each training site was based on 'importance value' (Taylor 2000) calculated as the sum of the relative frequency (percent stems) and relative abundance (percent basal area) for each species. The labels were arranged to reflect the dominant species for each training site. A total of fifty-three species classes were created using the described method**.** Nine additional classes were added to account for the below rim vegetation and the burned area from the 2001 Outlet Fire. These sixty-two classes were collapsed into ten classes (Table 1) to facilitate the analysis.

Mixed Conifer
Spruce-fir
Ponderosa Pine
Aspen
Gambel Oak
Pinyon-Juniper
Burn
Mohave Desert
Scrub
Meadow
Grass-Shrub

Table 1; Species and landcover classes

Spectral Analysis

The unsupervised and supervised training site signature files were combined and input into a statistical software package and clustered. Clusters that included two or more supervised signatures with similar labels were retained. Clusters that included a supervised signature and an unsupervised signature were also retained. Supervised signatures, with dissimilar labels, that clustered together, indicated that one or both of the signatures needed to be reevaluated. Spectral confusion between signatures may be due to topographic effects, mislabeling of one or both of the signatures, or a placement error made during the digitizing process. It is also possible that the signatures may not be statistically separable. Erdas Imagine has programs that were used to determine signature separability. Two or more unsupervised signatures that clustered together indicated areas within the study area whose spectral parameters were not captured with the supervised training sites. This may be due to an actual vegetation variable that was not sampled in the field or it may be due to topographic effects. These polygons were then digitized onto the imagery. The final set of signatures from this spectral analysis process were used for image classification.

Supervised Classification and Editing

A classification using a minimum distance algorithm was run using the combined training site signature set. The classified image was checked using the aerial photographs. Individuals familiar with the area assisted in reviewing and refining the classification. Any signatures that were consistently classifying correctly were masked from the image and not used for further processing. Signatures that consistently misclassed the image were evaluated to determine if they had to be removed from the signature set. Training sites were sometimes redigitized in an attempt to improve the classification. They were also sometimes relabeled to reflect the cover type that they were classifying.

A model was developed in Imagine, using the DEM, to assist in the identification of misclassed pixels. Vegetation types such as Gambel Oak and New Mexico Locust do not occur at the higher elevations of the study area. The model "flagged" these vegetation types if they occurred above 2250 m. These pixels were then edited to reflect the correct vegetation type. Mixed conifer pixels below 2200 m were also identified and edited.

Canopy cover was mapped, into four forested classes and four non-forested classes (Table 2), using training sites that were photo-interpreted from the 1:40,000 aerial photography. During the supervised classification process, training sites were added as needed to refine the classification. A total of fifty-eight training sites were used to develop the supervised classification.

11-25%
26-40%
41-70%
71-100%
Below Rim Vegetation
Burn
Meadow
Grass/Shrub

Table 2; Canopy cover class

Results and future work

Table 3 shows the areas and relative areas for the ten species and landcover types. Pinyon-juniper was the most common type because of the large amount of below rim vegetation within the mapped area. Ponderosa pine, mixed conifer, and spruce-fir are the most common vegetation types on the North Rim.

Cover Type	Area (ha)	Percent of Area	Fuel Model
Mixed Conifer	5,375	3.5%	8
Spruce-fir	2,450	1.6%	10
Ponderosa Pine	35,892	23.4%	9
Aspen	3,820	2.5%	8
Gambel Oak	3,810	2.5%	9
Pinyon-Juniper	94,920	61.8%	6
Burn	3,033	2.0%	11
Mohave Desert Scrub	2,100	1.4%	5
Meadow	880	0.6%	1
Grass-Shrub	1,250	0.8%	2
total	153,530		

Table 3; Total area, relative area, and Anderson fuel model type of the species and landcover types

Plans for future work include using the data layers as inputs to fire behavior simulation models. The species coverage has already been recoded to their corresponding Anderson (1982) fuel models. The models will be used to evaluate alternative future fuel treatments.

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