OREGON FOREST LAND CHANGE MAPPING

Steven Lennartz, Remote Sensing Analyst
Sanborn Mapping Solutions
Portland, OR 97204
slenartz@sanborn.com

ABSTRACT

The Oregon Department of Forestry (ODF) is using a number of indicators to assess and monitor forest health conditions in Oregon. A critical missing piece of information is related to the location and rate of disturbance on forest land caused by timber harvesting and fire. An earlier project conducted by the US Forest Service (USFS) and Oregon State University (OSU) illustrates the success of utilizing Landsat imagery in identifying change from timber harvesting and fire in western Oregon. The methodology utilized for that study is integrated into the project Sanborn has conducted for ODF.

Sanborn assessed forest disturbance throughout eastern Oregon for a period of over thirty years. The western Oregon project conducted by the US Forest Service and Oregon State University has been updated from 2002 to 2004. The methodology applied to western Oregon has been modified for classification of the sparser density forest types of eastern Oregon. Seven dates of Landsat imagery were used to classify forest land disturbances according to their type and date of origin. Tasseled Cap and other image derivatives were used to generate a difference image using the Simultaneous Image Differencing method. The difference image was then classified using an unsupervised classification. Image segmentation was also applied to the difference image for use in post-classification modeling. The final classification was converted to a vector format for use in ODF GIS databases.

INTRODUCTION

All image change procedures rely on exploiting the correlation between changes on the ground and changes in spectral reflectance. An area that has not changed between the base time and the change time should have the same or similar reflectance values on both images. An area that has changed will have different values between the base and change images. These different values are used to classify areas of “change” and “no change”. Two types of procedures are commonly used, image differencing and unsupervised classification of multi-temporal images. Image differencing works by subtracting reflectance values between two or more dates of imagery to produce an image of difference values for each location of the input images. An unsupervised classification automatically groups, or clusters, pixels of similar spectral values into classes. These pixel clusters are then labeled to their appropriate class. Change detections utilizing the unsupervised classification technique classify each date of imagery independently and then compare the temporal changes. Change detections utilizing unsupervised classification or image differencing techniques each have strengths and weaknesses. Image differencing is better when the change analyzed has a direct, interpretable correspondence to loss or gain of reflectance value, such as forest clearing and regrowth. Unsupervised classification is better when regions of different ground classification happen to have similar difference values or when the changes analyzed may have ambiguous correspondence to loss or gain of reflectance value. Image differencing will be used for this project because there is such a high correlation between changes in forest cover and changes in spectral response. Image differencing involves subtracting the spectral values of the change image from the base image for each pixel. The underlying assumption is that areas where land cover or land use remained constant will be represented by little or no spectral change. Thus, the resulting values of the subtraction in unchanged areas should be close to zero. Difference values in change areas will show either an increase or a decrease in spectral reflectance. The difference in spectral reflectance can then be related to change in land cover or land use.

Cohen et al 1998 examined two methods of change detection utilizing multiple dates of imagery for the purpose of mapping forest land cover change in Oregon. Merged Image Differencing is a method that classifies pairs of temporally consecutive dates of imagery, followed by merging all of these classifications into one. Simultaneous Image Differencing also pairs imagery sharing consecutive dates, but is unique in that this method classifies all of the dates in consideration using a single processing algorithm. Cohen et al 1998 found no significant difference in
thematic accuracy between the two methods, but *Simultaneous Image Differencing* was shown to be considerably more cost effective. *Simultaneous Image Differencing* as applied by Cohen *et al* 1998 was assessed for forest cover change in western Oregon, this method is being modified for application in this project to the sparser density forests of eastern Oregon.

**METHODS**

The objective of this project is to identify and delineate forested land cover changes such as clear-cuts, fire, disease, or other stand replacing disturbances meeting a minimum mapping unit of 5 acres, using a modified *Simultaneous Image Differencing* method. This project consists of several phases: creation of a forest mask, identification of needed imagery and imagery acquisition, imagery geometric correction, data exploration, generation of imagery derivatives, image differencing, unsupervised classification and image segmentation, cluster labeling, and final models and editing.

Creation and use of a forest mask helps simplify image processing, as well as reduce differencing confusion that occurs with non-forest land covers such as agriculture. The forest mask used in this project is the result of a combination of a National Land Cover Dataset 1992 (NLCD 92) and a USGS Gap Analysis Program (GAP) recode for forested land covers (Figure 1, green area).

![Figure 1](image.png)

*Figure 1.* The red boundary delineates the OSU/Forest Service study area that will be updated by Sanborn from 2002 to 2004. The remainder of the state will be classified for forest changes occurring from 1972 through 2004. The green areas indicate forested land cover. The light gray boxes delineate Landsat TM tiles.

All Landsat Multi-Spectral Scanner (MSS) and Thematic Mapper (TM) imagery were provided by the USGS Eros Data Center (EDC). All Landsat Enhanced Thematic Mapper 7 (ETM) imagery was provided by RADARSAT International. Supplemental scenes have been provided by OSU, and also downloaded from the State of California’s CalView project and Landsat.org. These data include imagery from 7 different dates, representing 6 sets of paired change analyses: 1973-1976, 1976-1984, 1984-1988, 1988-1993, 1993-2001, and 2001-2004. Imagery chosen for
each of these dates represents the most comprehensive and technologically advanced Landsat data available for the
time. However, since the Landsat ETM 7 sensor malfunctioned in regard to its Scan Line Corrector instrument
(SLC) in May of 2003, TM 5 data will be used instead for the 2004 date imagery.

For the western Oregon study area (see Figure 1), Sanborn will update the work by the USFS/OSU to 2004.
Only a single date of Landsat TM 5 imagery for western Oregon need be obtained. The imagery for the forested
areas east of the Cascade Mountains consists of six separate time frames consisting of similar dates as utilized by the
USFS/OSU’s project and as well as an update to 2004.

A critical step in any type of change detection analysis is to remove or neutralize any non-change image
differences that may be misinterpreted as changes in land cover. For example, misregistration of multi-temporal
images will result in a map of misregistration rather than a map of change. Seasonal differences in sun angle can
create shadow in one image that are not in the second and may be mistaken as land cover differences. Variations in
atmospheric conditions also can produce radiometric differences between two images acquired on separate dates.
Thus, change detection requires that all variation caused by non-landcover differences be controlled.

Sanborn has controlled the image registration through the acquisition of positionally accurate, orthorectified
ETM 7 imagery that will serve as the base layers for geometrically correcting all of the MSS and TM imagery. This
transformation will be done using the ERDAS Imagine Image Geometric Correction module, polynomial
transformation. In addition to minimize sun-angle or seasonal differences, Sanborn will utilize mid summer imagery.
Imagery atmospheric conditions were assessed for a need to apply an image calibration technique known as Dark
Object Subtraction (Chavez 1996) to each scene.

Once the image data sets are co-registered and calibrated, Sanborn derived tasseled cap bands. TM imagery
produces tasseled cap bands consisting of three separate images; brightness, greenness, and wetness (MSS imagery
only produces Brightness and Greenness bands), that are utilized due to their ability to detect these types of forest
change. As correctly identified by Cohen et al. 1998, forest change due to harvest or burn will result in the
reflectance values increasing in brightness while simultaneously decreasing in greenness and wetness.

Once the respective tasseled cap algorithms are generated for both the early date MSS and the later date TM
images, the MSS images are resampled to 30 meter cells for ease of analysis between the two types of imagery. In
addition, since the MSS tasseled cap algorithm only contains brightness and greenness, the wetness layer will not be
incorporated from TM imagery that shares a consecutive date with MSS imagery. Each pair of consecutive dates of
Tasseled Cap image derivatives are then subtracted from one another yielding a difference image (Figure 2.)

Figure 2. Conceptual flow of image differencing. Tasseled Cap image derivatives are subtracted from one another
to yield a continuous, signed 8-bit image.

The Simultaneous Image Differencing procedure stacks all of the image difference layers from the different date
pairs into an image cube, creating a single output image (i.e. difference bands of brightness, greenness, and wetness
for each date pair, Table 1). The stacked difference image is then clustered statistically by applying an unsupervised
classification. The benefit of this approach is that the time required to process one stack composed of several dates is
considerably more efficient compared to processing each date pair individually followed by merging all of their
resulting classifications. While Cohen et al. 1998 identifies additional error using this process, it was noted that
overall this error was less than 2% between the two methods while still resulting in an overall accuracy above 90%.
Table 1. Example of difference bands stacked into a single image for input into Simultaneous Image Differencing.

<table>
<thead>
<tr>
<th>Band 1: 88-84 Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 2: 88-84 Greeness</td>
</tr>
<tr>
<td>Band 3: 88-84 Wetness</td>
</tr>
<tr>
<td>Band 4: 93-88 Brightness</td>
</tr>
<tr>
<td>Band 5: 93-88 Greeness</td>
</tr>
<tr>
<td>Band 6: 93-88 Wetness</td>
</tr>
<tr>
<td>Band 7: 2001-1993 Brightness</td>
</tr>
<tr>
<td>Band 8: 2001-1993 Greeness</td>
</tr>
<tr>
<td>Band 9: 2001-1993 Wetness</td>
</tr>
<tr>
<td>Band 10: 2004-2001 Brightness</td>
</tr>
<tr>
<td>Band 11: 2004-2001 Greeness</td>
</tr>
<tr>
<td>Band 12: 2004-2001 Wetness</td>
</tr>
</tbody>
</table>

By viewing the unsupervised classification in comparison to the base and change images, initial clusters of forest land cover change will be identified and labeled manually via heads-up image interpretation and image segment modeling.

Image segmentation using Definiens-Imaging’s eCognition software will derive polygons which represent spatially homogenous areas within the difference image. Image segments are derived using several parameters, such as image texture, shape, and size. Image segment polygons are a useful classification derivative as they aid in classification modeling. For instance, a thematic raster classification may have areas that are speckled and heterogeneous. By summarizing the distribution of thematic classes occurring within a particular image segment, the analyst can determine if it is reasonable to recode all of the pixels within that segment polygon to a single class. Image segments will be generated here from the difference image. These polygons will aid analysis for modeling of change areas.

Due to the harvest patterns in eastern Oregon, Sanborn anticipates approximately three forest cover loss classes per time period will be developed in order to account for the clearcuts, fires and other change (such as insect damage, see Table 2). The minimum mapping unit (MMU) for identifying change is 5 acres. While there will be no formal quantitative accuracy assessment for this mapping project, an effort will be made to correlate changes resulting from clearcuts and fire to ODF’s FACTS database along with the ODF and Federal fire occurrence databases. These databases will aid in discerning whether an area was harvested or burned or whether another disturbance occurred (such as insect or disease damage). All of these classes will be attributed to the temporal frame to which they occurred.
Table 2. Classification scheme

- **FOREST** – Woody vegetation with >25% canopy cover and not disturbed between 1973 and 2004

- **FOREST HARVEST** – Woody vegetation that shows >50% change in crown cover
  
  Forest Harvest 1973-1976  
  Forest Harvest 1976-1984  
  Forest Harvest 1984-1988  
  Forest Harvest 1988-1993  
  Forest Harvest 1993-2001  
  Forest Harvest 2001-2004

- **FOREST FIRE**
  
  Forest Fire 1973-1976  
  Forest Fire 1976-1984  
  Forest Fire 1984-1988  
  Forest Fire 1988-1993  
  Forest Fire 1993-2001  
  Forest Fire 2001-2004

- **OTHER FOREST DAMAGE**
  
  Other forest damage 1973-1976  
  Other forest damage 1976-1984  
  Other forest damage 1984-1988  
  Other forest damage 1988-1993  
  Other forest damage 1993-2001  
  Other forest damage 2001-2004

- **NON-FOREST** – Non-woody vegetation, agriculture, bare land, man made features, etc.

**DISCUSSION**

Some of the most important factors in change detection classification of multi-temporal imagery are normalizing atmospheric conditions between dates, and achieving highly accurate levels of geometric correction. After careful analysis of the spectral patterns observed in deep water body targets common between images, reflectance values where found to be minimally influenced by atmospheric interference, and no atmospheric correction was applied to the imagery. Transformation procedures for geometric correction of the imagery were examined with several orders of polynomial transformations and rubber-sheeting. Fourth order polynomial transformations were found to be the most visually accurate method of spatial correction, and all root mean square errors (RSME) averaged under the size of one pixel.

Processing and classifications completed to date indicate an effective application of Simultaneous Image Differencing to eastern Oregon forested land cover. Cluster labeling has been streamlined by summarizing unsupervised clusters based upon image segments. This procedure allows an analyst to identify all of the unsupervised clusters and their percent occurrence in a particular image segment polygon, aiding the analyst to interpret the unsupervised clusters’ potential labels. Preliminary classification results have shown a high level of acceptability when compared to visual interpretation of Landsat imagery.
REFERENCES

