# FEASIBILITY AND ACCURACY OF MODIS 250M IMAGERY FOR FOREST DISTURBANCE MONITORING

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## ABSTRACT

Landsat Enhanced Thematic Mapper Plus (ETM+) images were compared to Terra-MODIS imagery for detecting forest changes in northern Maine's industrial forest. Advantages of MODIS imagery compared to medium spatial resolution imagery, like Landsat TM or ETM+, are its temporal frequency, its low data volume to cover large forest regions and, the data are free to download over the Internet. The objective of the study was to compare MODIS NDVI (250m) to ETM+ (30m) forest change images and determine detection accuracy and feasibility for using MODIS to detect forest disturbance hot spots.

## **INTRODUCTION**

Forest land cover change is an important input for modeling ecological and environmental processes at various scales. Medium spatial resolution (~20–30 m) satellite images, such as those from Landsat and *Satellite Pour Observation De La Terre* (SPOT), are well suited for forest disturbance monitoring on a landscape and regional scale (Bauer et al., 1994; Cohen et al., 1998; Collins & Woodcock, 1996; Franklin et al., 2002; Sader et al., 2003; Skakun et al., 2003; Coppin et al., 2004; Jin and Sader, 2005b). However the cost of obtaining medium spatial resolution images for large areas, and problems with cloud cover due to infrequent coverage can hinder forest monitoring at regional and global scales (Wulder et al., 2004). Coarse resolution sensors (e.g., 250-1000m) may overcome these limitations by providing cost effective, frequent (e.g., monthly) coverage of the earth's surface.

The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor has 36 spectral bands extending from the visible to the thermal infrared wavelengths (between 0.405 and 14.385 µm). The MODIS land bands have a heritage related to the Landsat Thematic Mapper (TM), with additional spectral capabilities added in the short-wave and long-wave infrared (Justice et al., 1998). The first seven bands are designed primarily for remote sensing of the land surface with spatial resolutions of 250 m (band 1 and 2), and 500 m (bands 3 to 7), which are centered at 648 nm, 858 nm, 470 nm, 555 nm, 1240 nm, 1640 nm, and 2130 nm, respectively (Zhan et al., 2002). The Normalized Difference Vegetation Index (NDVI), a normalized ratio of the NIR (841-876 nm, band 2) and red (620-670 nm, band 1) bands, is one of the standard products of MODIS.

The objective of the study was to compare MODIS NDVI (250m) to ETM+ (30m) forest change images and determine detection accuracy and feasibility for using MODIS to detect forest disturbance hot spots. The study area is located in northwestern Maine, USA (Figure 1 and 2). Like most of the land in northern Maine, the study area is privately owned and managed primarily for wood products. This Acadian forest type occupies the northern boundary of temperate forest and southern edge of boreal forest (Loo and Ives 2003). The area is relatively flat to rolling with occasional low mountains, abundant lakes, ponds, streams and associated wetland vegetation and essentially no urban development (Hepinstall et al. 1999). The mainly private forests have been actively logged for over 150 years (Seymour, 1992). Clearcutting (complete or nearly complete canopy removal) was the major forest harvesting practice prior to the 1990s, however partial harvesting became dominant in the 1990s and 2000s (Maine Forest Service, 1999, McWilliams et al. 2005).



Figure 1. Landsat and MODIS RGB-NDVI color composites near Munsungan Lake, Maine.

#### **METHODS**

MODIS images were browsed on the USGS web site: (<u>http://edcimswww.cr.usgs.gov/pub/imswelcome</u>) to find relatively cloud free imagery during the summers of 2000, 2001 and 2002. The MODIS scenes were selected to be as close as possible to the Landsat data for the same years that were available in the Maine Image Analysis Laboratory (MIAL) data archive (Table 1).

|       | Spatial Resolution    | 250m   |
|-------|-----------------------|--|
| MODIS | Index Used            | NDVI (Normalized Difference Vegetation Index)                        |
|       | Three Dates           | 8/27/2000-8/27/2001-8/27/2002  |
|       | Classification Method | (Three Dates RGB) Unsupervised Classification and Image Segmentation |
|       | Spatial Resolution    | 30m  |
| ETM+  | Index Used            | NDMI (Normalized Difference Moisture Index)                          |
|       | Three Dates           | 9/27/2000-5/25/2001-7/4/2002   |
|       | Classification Method | (Three Dates RGB) Unsupervised Classification and Image Segmentation |
|       |                       | Note: NDMI=(NIR (4)-SWIR(5))/(NIR (4)+SWIR(5))                       |

| Tuble It 110D Ib and Landbar Little auta attributes | Table 1. | MODIS | and | Landsat | ETM+ | data | attributes |
|---|----------|-------|-----|---------|------|------|------------|
|---|----------|-------|-----|---------|------|------|------------|

The method employed in change detection can be described as time-series RGB-NDVI (Sader and Winne, 1992; Sader et al., 2003). The normalized difference vegetation index (NDVI) was computed at each date of imagery for MODIS and the normalized difference moisture index (NDMI) for Landsat ETM+ using equation 1. We used Landsat NDMI forest change maps (rather than NDVI) as a reference source for evaluating MODIS forest change maps because earlier studies in Maine indicated the accuracy of the NDMI forest change was slightly higher than NDVI (Wilson and Sader, 2002; Sader et al. 2003). Annual imagery at 250m (MODIS) and 30m (ETM+) was selected to provide the best temporal and spatial resolution practical for both sensors.

$$NDMI = \frac{(NIR - MIR)}{(NIR + MIR)} \tag{1}$$

where; NIR is the near infrared spectral band 4 of the Landsat images, and MIR is mid infrared spectral band 5 of the Landsat images.

MODIS were geo-referenced using matching control points that could be located in each date of imagery. The process was repeated for the three dates of Landsat. Clouds and water features were masked to reduce false positive changes that were not associated with forest change events. The MODIS imagery was already radiometrically calibrated and the Landsat images were "haze corrected" using the minimum value subtraction method (Jensen, 1996).

Following the calculation of the single date NDVI and NDMI, the images were layer-stacked in chronological order to create three layer images for both MODIS and Landsat datasets. The cloud and water masks were applied to each dataset. Visual color composites were prepared and an unsupervised (Isodata clustering) classification of MODIS and Landsat RGB-NDMI datasets was performed. The cluster classes were named using visual interpretation of Landsat RGB-453 (2000-01-02) single date color composites as a guide (Cohen et al 1998, Sader et al 2003) 2000 color infrared aerial photos and 2001 IKONOS 4m multispectral data were available for most of the study area to assist in the change class labeling process. After recoding the classified images into forest change and no change classes, a 3x3 majority filter was applied to TM change detection maps to eliminate isolated pixels.

# 2000-01-02 TM NDMI and MODIS NDVI RGB Color Composite



**Figure 2.** MODIS and Landsat ETM+ RGB composites (left side) and classified change detection images (right side). Green in the classified change images indicate non disturbed forest at both dates.

# **RESULTS AND DISCUSSION**

The visual comparisons of RGB-NDVI (2000-01-02) images are provided in Figure 1. Figure 2 is a comparison of the visual composites next to a classified image of the 3 date forest changes after application of a 3x3 majority filter. Areas in red in the visual RGB-NDVI color composites indicate forest biomass decrease between 2000 and 2001. Areas in yellow are forest biomass loss between 2001 and 2002. In some areas the MODIS image indicates red whereas the Landsat ETM+ change composite indicates a yellow color. This does not represent an error in either case. The difference in color simply reflects the different months of the year that the MODIS versus ETM+ images were recorded. For example, all 3 dates of MODIS are August 27, but the Landsat dates are September 2000, May 2001 and July 2002. An area that is red on MODIS but yellow on ETM+ indicate the harvesting occurred after May 25, 2001 (ETM+) and but before August 27, 2001 (MODIS). The ETM+ detected the change between 2001 and 2002 images while MODIS detected the same change event between the 2000 and 2001 dates.

Many of the changes detected by Landsat ETM+ can also be seen on MODIS (Figure 1). It is apparent from both the visual change detection composites (Figure 1) and the classified images (Figure 2) that some of the smaller disturbances (smaller areas) were not effectively resolved by MODIS. This is expected due to the much coarser pixel size of MODIS. MODIS can effectively detect the larger area disturbance, even on some ligher partial harvest sites when annual images are available.

In a related study (Jin and Sader, 2005b), MODIS 250m single day surface reflectance (MOD09GQK) and 16day composite gridded vegetation-index data (MOD13Q1) were used to detect forest harvest disturbance between 2000 and 2004 in northern Maine. A Landsat TM/ETM+ change detection map was developed as a reference to assess the effect of disturbed forest patch size on classification accuracy (agreement) and disturbed area estimates of MODIS. The MODIS single day and 16-day composite data showed no significant difference in overall classification accuracies. However, the 16-day NDVI change detection map had marginally higher overall classification accuracy (at 85%), but had significantly lower detection accuracy related to disturbed patch size than the single day NDVI change detection map (Table 2). The 16-day composite NDVI data achieved 69% detection accuracy and the single day NDVI achieved 76% when the disturbed patch size was greater than 20 ha. The detection accuracy increased to approximately 90% for both data sets when the patch size exceeded 50 ha. The R<sup>2</sup> (range 0.6 to 0.9) and slope (range 0.5 to 0.9) of regression lines between Landsat and MODIS data (based on forest disturbance percent of township) increased with the mean disturbed patch size of each township.

| Method          | Class  | Producers<br>accuracy | Users accuracy | Overall accuracy | Overall<br>Kappa |
|-----------------|--------|-----------------------|----------------|------------------|------------------|
| 16 day-NDVI     | C0004  | 74.00%                | 72.55%         | 85.50%           | 0.627            |
|                 | C0004  | 89.33%                | 67.21%         |                  |                  |
| Single day-NDVI | NC0004 | 83.33%                | 93.98%         | 83.00%           | 0.600            |

Table 2. Accuracy (agreement) assessment of MODIS change detection maps with Landsat change detectionmap (200 stratified random points; NC0004 = forest no change between 2000 and 2004; C0004 = forestchange between 2000 and 2004). Table modified from Jin and Sader (2005b).

MODIS 250m NDVI imagery, single date or 16 day mosaics, show promise as an "alarm" or "hot spot" detection system (Achard et al., 2002; Zhan et al., 2002) and may have some potential when applied in change monitoring using a multi-phase or multi-sensor (and resolution) sampling scheme for statewide and regional forest monitoring.

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ASPRS 2006 Annual Conference Reno, Nevada + May 1-5, 2006