Producing Composite Imagery and Forest Cover and Change Characterizations

South Dakota State University
Geographic Information Science Center of Excellence
2005 United Nations Food and Agriculture Organization Forest Resource Assessment Report

- Africa and South America feature largest forest losses
- Overall rate of forest loss continues to decrease
MODIS-stratified Landsat samples

Sample blocks within change strata:  
- Low
- Medium
- High change

PNAS, in press
Percent forest cover, 2000

PNAS, in press
Percent gross forest cover loss, 2000 to 2005

PNAS, in press
Global gross forest cover loss, 2000 to 2005

Gross forest area loss in Mkm² from 2000 to 2005

PNAS, in press
Data requirements for global forest monitoring

- Systematic global acquisitions
- No/low cost
- Easy access
- Minimal pre-processing required
Monitoring at national scales in the humid tropics – different situations

• Brazil
  – Large-scale change, most of which is located in seasonally cloud-free region, deforestation

• Indonesia
  – Large-scale change, occurring in persistently cloud-affected region, much topography, active forestry

• Democratic Republic of Congo
  – Fine-scale change, occurring in persistently cloud-affected region
MODIS time integrated metrics
MODIS forest cover maps as inputs for automated mapping at finer scales in Central Africa
2000 Global Land Survey
Bias-adjusted
Anisotropy adjusted
Image composite (3-5 images per path/row) and epoch
Landsat forest cover and change
Landsat forest cover and change
Cameroon
forest area loss = 2,002.9 km²
percentage = 1.01%

Central African Republic
forest area loss = 2,860.8 km²
percentage = 4.91%

Equatorial Guinea
forest area loss = 273.6 km²
percentage = 1.14%

Gabon
forest area loss = 2,317.6 km²
percentage = 1.00%

Republic of Congo
forest area loss = 1,723.0 km²
percentage = 0.82%

Democratic Republic of the Congo
forest area loss = 25,589.9 km²
percentage = 2.66%

Congo Basin
forest area = 1,796,708.6 km²
forest area loss = 38,767.9 km²
percentage = 2.16%
Number of images in the USGS/EROS archive

# of images: 10 – 55 – 110
Number of images with < 50 ACCA cloud cover

# of images: 10 – 55 – 110
Number of good observations per pixel for 2003-2005 composite
Different approaches

1) Epochal composites
   - Combine best observations over a given interval to create cloud-free image
   - Cloud-free composites require such a long compositing period that change occurs within the composite interval

2) Time-series characterizations
   - Map each good pixel and create time-series of forest cover estimates in metric space
   - No image composite needed
   - Unequal numbers of cover estimates over the regions (scene overlaps, SLC-off gaps)
Per-pixel time series analysis using all good observations

Forest probability

Likely agro-forestry

Interpretation: 
- Green square = forest
- Red square = no-forest

Year

99 00 01 02 03 04 05 06
Indonesia, 1999 to 2009

6,189 images
Annual forest cover loss, 2000 to 2009
ETM+ forest cover loss, 1999 to 2009
ETM+ forest cover loss, 1999 to 2009
Validation data of forest cover loss 2000-2005

- Expert interpreted sample blocks (n = 64)
- Sample based estimate: 2.95% +/- 0.41
Comparison of model (map) results with expert-interpreted sample blocks

Model based on differencing the time 1 / time 2 characterizations

percent deforestation (2000-2005) per sample block

expert vs. model (n=64)

\[ y = 0.6716x + 1.3105 \]

\[ R^2 = 0.7424 \]
Comparison of model (map) results with expert- interpreted sample blocks II

Model based on full time series analysis per pixel

percent deforestation (2000-2005) per sample block
expert vs. model (n=64)

\[ y = 0.9593x + 0.3252 \]

\[ R^2 = 0.9169 \]
Forest cover loss and land use

Percent of mapped deforestation per land use zone

- 69% in zones designated for forest land use
- 52% in zones designated for production or limited production and 17% occurred in conversion zones
- 24% in zones not designated for forest land use
- 2.35% in conservation zones and 5.12% in protected zones

=> 2,132 km² of illegal cutting

Total mapped forest cover loss 2000-05:
2.86% or 28,546 km²
Landsat boreal forest cover monitoring
Lambert Azimuthal Equal Area projection centered at the North Pole

Tiling system

h01v01

300,000 m
5000 pixels at 60m spatial resolution

h24v28
Tiling system

Test areas

1. Quebec, Canada
   28 tiles

2. European part of Russia
   52 tiles
Image selection

All selected WRS2 path/row (3154)
Landsat image selection criteria

- Date
  - Circa 2000 composite

Available Landsat images for year 2000
(within growing season, with cloud cover below 50%)

<table>
<thead>
<tr>
<th>Images per path/row</th>
<th>Percent of all path/row</th>
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Image selection

Landsat image selection criteria

- **Dates**
  - Within growing season

Growing season start

Growing season end
Image selection

Landsat image selection criteria

- **Dates**
  - Within growing season

- **Cloud cover**
  - Less then 50% ACCA cloud cover
  - OR, less then 50% cloud cover for any of the scene quarter

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<th>Image inputs</th>
<th>European Russia</th>
<th>Quebec, Canada</th>
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<td>1999-2002</td>
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<td>2003-2007</td>
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</table>
Landsat-based training

Classified Landsat scenes

Forest cover

0% 100%

Coniferous forest mask

Coniferous forests
Source imagery
Quebec (P17R27)

1999/08/27
2000/06/26
2000/07/12
2000/08/13
2001/06/13
2001/07/31
Quality assessment flags

Cloud likelihood
- 50-90%
- >90%

Shadow likelihood
- 50-90%
- >90%

Water likelihood
- >50%

Dates:
- 1999/08/27
- 2000/06/26
- 2000/07/12
- 2000/08/13
- 2001/06/13
- 2001/07/31
Composite image for circa year 2000
Quebec, Canada

Classification results
- Forest 2000
- Forest loss 2000-05
- Non-forest 2000

Quebec, Canada

composite image for circa year 2000

composite image for circa year 2005
Quebec, Canada: Classification examples

Classification results:
- Forest 2000
- Forest loss 2000-05
- Non-forest 2000
European Russia: Classification examples

Classification results
- Forest 2000
- Forest loss 2000-05
- Non-forest 2000
Selected 42 administrative regions

European Russia

St. Petersburg
Moscow
European Russia

Forest cover (% of regions’ area)

- <10%
- 10-25%
- 25-50%
- >50%

Total forest cover:
- Landsat derived: 150,228 thousand ha
- Russian Forest Service: 148,852 thousand ha
**European Russia**

**Gross forest cover loss (% of total)**

- **<0.5%**
- **0.5-2%**
- **2-5%**
- **5-10%**
- **10-15%**

Total gross forest cover loss:

- 2,210 thousand ha
- 1.5% of year 2000 forest cover
European Russia

Forest cover loss
2000-2005 as percent of forest cover for year 2000

- <0.5%
- 0.5-1%
- 1-1.5%
- 1.5-2.5%
- >2.5%

Regions with the highest forest cover loss:

- Vladimir (3.7%)
- St. Petersburg (3.5%)
- Moscow (3.1%)
The bark beetle outbreak 1999-2000 followed by increased “sanitary” logging
European Russia

Extensive forest and peat bog fires (fall 2002)

MODIS image 07/30/2002
www.ssec.wisc.edu
European Russia

Moscow suburbs expansion (partly illegal construction on forest lands)
European Russia

Yaroshenko et al. (2008)
European Russia’s Forests (poster map and GIS dataset).
*Moscow, Greenpeace.*
**European Russia**

**Annual gross forest cover loss, thousand ha**

- **1990-2000:** 530 ha*1000
- **2000-2005:** 406 ha*1000

**Annual timber harvesting**

\[ m^3 \times 1,000,000 \]**
Landsat dry tropical forest cover monitoring example
Dry tropical biome – Tanzania test case

% of maximum annual NDVI from MODIS

MODIS 16-day composite periods
Factors affecting Landsat processing for forest monitoring

- Acquisition strategy
- Observation frequency (scene overlap/SLC-off)
- Observation quality (clouds/haze/shadow)
- Phenology
Conclusions

- Our methods for generic and automated forest change monitoring for large areas are quickly maturing.
- A goal is to provide consistent results over large areas that retain local relevance.
- We rely on 1) systematic global acquisitions and the provision of data at 2) no cost and with 3) easy access.
- Current work is aimed at creating a standard approach applicable at the global scale.
- Approach validated using existing reference datasets.
- Monitoring results are and will be available:
  - carpe.umd.edu
  - globalmonitoring.sdstate.edu/projects/boreal
  - Indonesia and Quebec to come...