Using Lidar Remote Sensing to Detect Forest Change

Dr. Amanda Whitehurst
6/17/2015
Lidar

• Light Detection and Ranging
  • Laser altimeter

• Active remote sensing
  • Spaceborne
  • Airborne
  • Ground-based
<table>
<thead>
<tr>
<th>Lidar Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Biomass</td>
</tr>
<tr>
<td>• Species habitat</td>
</tr>
<tr>
<td>• Forest ecosystem dynamics</td>
</tr>
<tr>
<td>• Canopy height</td>
</tr>
<tr>
<td>• Canopy cover and/or closure</td>
</tr>
<tr>
<td>• Vegetation density</td>
</tr>
<tr>
<td>• Quartile metrics</td>
</tr>
<tr>
<td>• Height where X% of return occurs</td>
</tr>
<tr>
<td>• 25%, 50%, 75%</td>
</tr>
<tr>
<td>• Often used for biomass estimation and species habitat</td>
</tr>
</tbody>
</table>
Hubbard Brook Experimental Forest, New Hampshire, USA

- Logging in early 19th century
- Based on field data, considered to not be accumulating biomass
- But there has been recent disturbance in the area
- How has that impacted the forest: structure, habitat, growth?
# Change in Hubbard Brook

<table>
<thead>
<tr>
<th>HBEF Change</th>
<th>Canopy Height (m)</th>
<th>Canopy Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2.23</td>
<td>6.28</td>
</tr>
<tr>
<td>Std Dev</td>
<td>1.94</td>
<td>7.99</td>
</tr>
</tbody>
</table>

Legend:
- Rivers
- HBEF Boundary
- Canopy Height Change meters:
  - -1.4 - 0
  - 0 - 2
  - 2 - 5
  - 5 - 10
  - 10 - 15
  - 15 - 21
  - No significant change
Ice Storm Impact

- Damage from ice storm in 1998
- Exact extent unknown
- Upper elevations
- Can use growth to determine extent of damage?

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>N</th>
<th>Average</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 624</td>
<td>30</td>
<td>1.61</td>
<td>0.007</td>
</tr>
<tr>
<td>&gt; 624</td>
<td>17</td>
<td>3.26</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (m)</th>
<th>N</th>
<th>Average Change</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>10135</td>
<td>2.18 m</td>
<td>2.49e-07</td>
</tr>
<tr>
<td>&gt; 600</td>
<td>5555</td>
<td>2.34 m</td>
<td></td>
</tr>
</tbody>
</table>
Implications

• Questions raised about judging Hubbard Brook as a whole
  • Biomass accumulation
  • Aggregating species count data across the entire forest and over multiple years

• Areas damaged by storm are still recovering
Caveats

- Need lidar at two time points
- Need extensive lidar coverage
- Expensive
- Need to have instruments that produce compatible data
Use of Lidar for estimating Reference Emission Level in Nepal

S.K. Gautam
DFRS, Nepal
Nepal’s LAMP project area covers 12 districts in the Terai Arc Landscape

- Total area is 2.3 million ha (about 15% of the country);
- About 52% of the area (1.18 million ha) is under different types of forest cover.
- The area is linked with eleven trans-boundary protected areas across Nepal and India and is home to flagship species like tigers, rhinos, Asiatic wild elephants, and many other endangered species.
Introduction: LAMP

- Samples (5%) of LiDAR data to calibrate **satellite models**

- Reference field sample plots to calibrate/validate **LiDAR models**

- Landsat satellite imagery for **wall-to-wall biomass** map.
Method: LAMP Workflow

Calibrating AGB estimator

**Lidar data** (5% coverage)

A Sparse-Bayesian method used to regress measured data from field plots with LiDAR variables

Calibrate lidar-to-AGB model with Measured AGB

**Measured AGB** (measured from plots)

1000 forest class-specific “surrogate plots” (simulated field plots) are randomly generated within the lidar area.

Estimated AGB For Surrogate plots

Validation: independent field plots

**Vegetation plots** (within lidar coverage)

Mapping Biomass

**Satellite data** (100% coverage)

Calculate mean AGB from surrogate plots to each forest type and condition

Classify satellite imagery to main forest types and conditions

Apply forest class-specific mean AGB values to classified satellite imagery of the entire area

**Mapped AGB** For entire area

field validation

Validation: -Surrogate plots -Field plots -Independent field validation
Research and Development: Difference in AGB between 1999-2011
## Results: Historical CO2 emissions

### CO₂ Emissions (tCO₂e)

<table>
<thead>
<tr>
<th>Period</th>
<th>Above-ground</th>
<th>Below-ground</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999-2002</td>
<td>13,136,430</td>
<td>2,627,286</td>
<td>15,763,716</td>
</tr>
<tr>
<td>2002-2006</td>
<td>1,736,537</td>
<td>347,307</td>
<td>2,083,845</td>
</tr>
<tr>
<td>2006-2009</td>
<td>9,644,698</td>
<td>1,928,940</td>
<td>11,573,637</td>
</tr>
<tr>
<td>2009-2011</td>
<td>19,020,661</td>
<td>3,804,132</td>
<td>22,824,793</td>
</tr>
<tr>
<td>Total 12-yr</td>
<td>43,538,325</td>
<td>8,707,665</td>
<td>52,245,991</td>
</tr>
<tr>
<td>Average annual</td>
<td>3,628,193</td>
<td>725,639</td>
<td>4,353,833</td>
</tr>
</tbody>
</table>

Average annual net CO₂ emissions (tCO₂e) in TAL between 1999 and 2011.
Costs and Future Monitoring

- The cost of this project is USD 0.28/ha
- Our experience shows that 1-2% LiDAR coverage is sufficient for this integrated approach
- LiDAR is needed only once
- Subsequent monitoring is based on new satellite images to which the LAMP models are applied
Lidar in Developing Global Maps

Landsat Vegetation Continuous Fields
Global, 30-m percent tree cover (Landsat VCF)

Sexton et al 2013
Landsat vs. LiDAR & MODIS

- Lidar is reference
  - High resolution
  - High accuracy
  ...but rare

- Landsat & MODIS are consistent

- Landsat > MODIS
  - Resolution of small patches
  - Accuracy over agriculture
Oil palm & tropical deforestation in Costa Rica
Thanks!