Assessing LIDAR Technology for Monitoring and Reporting of GHG emissions from Forest degradation

by Teobaldelli M.

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LIDAR is an active remote sensing technique using laser light.
5.7.2 Verification Approaches

“The criteria for selecting verification approaches include: scale of interest, costs, desired level of accuracy and precision, complexity of design and implementation of the verification approaches, and the required level of expertise needed to verify”

APPROACH 4: REMOTE SENSING (RS)

- To verify land-cover/land-use attribution, detection of land-cover change and estimations of land areas under conversion and abandonment.
- To estimate changes in aboveground biomass
- Not applicable to the verification of belowground biomass, litter, dead wood or soil organic matter.
- Different scales ranging from plot to continental level.
- The cost will depend upon the scope and scale of the programme and the availability of material
- The accuracy of remote sensing will depend upon the scale at which it is used and the source of the images.
- Generally, it can be quite accurate, but ground truthing is needed to improve result accuracy.

LIDAR is an active remote sensing technique using laser light.

**Time of flight:**
laser scanners emit a pulse of laser light that is reflected off of the object to be scanned. The resulting reflection is detected with a sensor and the time that elapses between emission and detection yields the distance to the object since the speed of the laser light is precisely known.

**Phase measurements:**
- scanners work by comparing the phase shift in the reflected laser light to a standard phase, which is also captured for comparison. This is similar to time of flight detection except that the phase of the reflected laser light further refines the distance detection.
**LIDAR** is an active remote sensing technique using laser light.

<table>
<thead>
<tr>
<th>Measurement technology</th>
<th>Range [m]</th>
<th>Accuracy [mm]</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of flight</td>
<td>&lt; 100</td>
<td>&lt; 10</td>
<td>Callidus, Leica, Mensi, Optech, Riegl</td>
</tr>
<tr>
<td></td>
<td>&lt; 1000</td>
<td>&lt; 20</td>
<td>Optech, Riegl</td>
</tr>
<tr>
<td>Phase measurement</td>
<td>&lt; 100</td>
<td>&lt; 10</td>
<td>IQSun, Leica, VisImage, Zoller+Fröhlich</td>
</tr>
<tr>
<td>Optical triangulation</td>
<td>&lt; 5</td>
<td>&lt; 1</td>
<td>Mensi, Minolta</td>
</tr>
</tbody>
</table>

*Source: Fröhlich & Mettenleiter (2004)*
Commercial application of laser scanning in forestry with experience from Norway

Costs: Example project in municipality of Nordre Land

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost, € per hectare</th>
<th>Percentages of total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laser scanning</td>
<td>Photo-interpretation</td>
</tr>
<tr>
<td>Aerial photos, scanning</td>
<td>1.45</td>
<td>1.45</td>
</tr>
<tr>
<td>Adjustments for digital photogrammetry</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>DPW and field maps</td>
<td>2.41</td>
<td>3.61</td>
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<tr>
<td>Laser scanning</td>
<td>3.01</td>
<td></td>
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<tr>
<td>Laserdata processing</td>
<td>1.81</td>
<td></td>
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<tr>
<td>Sample plots</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td><strong>Sum 1, remote sensing</strong></td>
<td><strong>10.2</strong></td>
<td><strong>5.7</strong></td>
</tr>
<tr>
<td>Fieldworks</td>
<td>3.01</td>
<td>7.23</td>
</tr>
<tr>
<td>Productions of FMP and maps</td>
<td>3.01</td>
<td>3.01</td>
</tr>
<tr>
<td>Other costs</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>Sum 2, total cost</strong></td>
<td><strong>16.9</strong></td>
<td><strong>16.5</strong></td>
</tr>
</tbody>
</table>

Source: ScandLaser 2003, Umeå, 02.09.03
Tord Aasland
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Number of commercial systems in operation world-wide (Flood 2001)

Year:
- 1995: 3
- 1996: 9
- 1997: 11
- 1998: 20
- 1999: 38
- 2000: 53

N. of systems
Approach 4b: RS to verify changes in living biomass

Other approaches for area and biomass verification using imagery data may include:
- Airborne photography (for the vertical canopy structure of forest, labour-intensive);
- Laser profiler (LIDAR canopy height and structure, accuracy still to be examined, experimental, expensive);
- Comparison with maps/data produced by independent agencies using RS.

Use of RS to Derive Vegetation Parameters

“Above ground biomass can be estimated efficiently also by LIDAR airborne sensing that measure the canopy surface and ground elevation height at the same time, by emitting laser pulses with wavelengths that reflect over the canopy surface but pass through trees and reflect off the ground as well. However, because of the small diameter beams of laser, mapping large areas requires extensive flying missions (Dubayah and Drake, 2000).

The Laser Vegetation Imaging Sensor (LVIS) by airborne or satellite instruments such as Vegetation Canopy LIDAR with large footprints will possibly solve such problems (Blair et al., 1999; Means et al, 1999; Dubayah and Drake, 2000). One can also estimate vegetation structure from optical satellite data using the Bi-Directional Reflectance property based on the Sun-Target-Sensor Geometry”

Forest Aboveground Biomass Estimation

Permanent Plot data:
Direct or Indirect (e.g. terrestrial laser scanning) measurements (DBH, Height, Basal area, Stocking by Age)

Aerial LIDAR data:
(tree Height, Crown Cover)

Statistical Analysis

Biomass of the single tree

Volume/total → C → Biomass/total

Volume/stem → E+C → Biomass/stem

Volume/merchantable → C → Biomass/merchantable

(Biomass/merch) → E+C → (Somogyi et al. 2004)

BFs
Aerial LIDAR (i.e. Laser Altimetry)
LIDAR measurements of Forest Land:

- Record of the first, last, multiple or fully digitize return signal
- Footprint size (Large and Small footprint LIDAR)
- Sampling rate/scanning pattern.

- Laser sensor
- GPS receiver
- Inertial Navigation System
- Inertial Measurement Unit
- Data Acquisition System
LIDAR Mapping in the Republic of Congo
by John Tolman*

*Currently Managing Director of Sensor Design Group, LLC, Houston, Texas.
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**Why:** to realize a Digital Elevation Model (DEM) and Digital Terrain Model (DTM) and two meters contour map

**When:** 2003

**Where:** 532 Km² forest area near Gamboma
The Congo jungle typically has three layers of canopies created by low-lying bush near the ground, medium-sized trees above the bushes, and large trees towering above everything else.
Data acquisition:

• **Ground Survey** (4 weeks): GPS base station sites + other 15 Ground Control Points, located in open spaces or in villages in the periphery of the project area (made by SwissPhoto)

• **Aerial Survey** (1 week): TerraPoint Advanced Laser Terrain Mapping System (ALTMS) with up to seven returns per laser pulse; flight altitude =1000 m above the ground; 20,000 laser pulses s⁻¹; ground swath = 650 meters

Data processing: 2 months

Results: Extraction of DEM and DTM and mapping of three canopy layers of forest

**Vertical Accuracy:** from 0.3 (open area) to 1 m (forest)

**Horizontal Accuracy:** 1 meter
By Peter Stephens  
Ministry for the Environment (New Zealand)

Colour Infrared Imagery
- Quantization 12 Bit.
- GSD of 0.18m generalised to 0.20m.
- Wavelengths, Green, Red, Near Infrared.

Airborne Laser Scanner
- Optech ALTM 3100.
- Up to 4 returns captured.
- Laser footprint size of 0.25m (narrow).
- Flying Altitude 1100m.
- Swath width of ~ 200m.
- 70,000 points per second.

- Permanent sample sites (4 plots, each 0.04 ha) on 4 km grid system – 400 plots for Kyoto Forests
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**LiDAR Pulses (Returns)**

- 1st return
- 2nd return
- 3rd return
- 4th return

**Repeat Measurements of Plots**

Range of tree crown displacements was 0.023 m to 0.138 m

**LiDAR 30th Height Percentile against Top Height**

Work-in-progress: RMSEs between predicted and field of 1.4 m (9%) [3-8%]

**LiDAR-derived Basal Area against Field Measured Basal Area**

Work-in-progress: RMSEs 4.9 m²/ha (25%) [7-14%]
Terrestrial laser scanner and Forest Inventory

by

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² European Commission, DG-JRC, Institute for the Protection and Security of the Citizen, Nuclear Safeguards Unit
**Diameter Measuring Instruments**

- Diameter tape
- Tree Calipers.
- Dendrometers.
- Optical Fork (Relaskop, Telerelaskop).
- Optical Calipers (Wheeler penta-prism caliper).
- Short-Base Rangefinder Dendrometer

**Height Measuring Instruments.**

- Telescoping Measuring Rod.
- Haga Altimeter.
- Blume-Leiss Altimeter.
- Clinometer.
- Abney Level.
- Spiegel-Relaskop.

**Laser Measuring Devices**

*IMAGER 5003 + JRC 3D Reconstructor*
Analysis of allometric relationships

**Populus I-214**

Direct vs Indirect Measurements of Stem and Branches Sections (*Populus I-214*)

\[ y = 1.0029x - 0.009 \]

\[ R^2 = 0.9304 \]

Sources: Teobaldelli et al. 2008, submitted to Plant Functional Biology Journal
Conclusions
- Survey could be performed during day & night on small or large forest area;

- Analysis of “bare” ground elevation model in forested areas is less expensive, more fast and accurate than traditional form of data collection;

- Analysis of vertical and horizontal structure of forests, at tree or stand level;

- **Aerial LIDAR**: combined with reliable allometric equations, it permits to make an accurate estimation of aboveground biomass;

- **Terrestrial LIDAR**: could be used to analyze tree architecture and compute new allometric equations.
Conclusions

- Is quite expensive if compared with other traditional RS techniques (LANDSAT, SPOT, SAR, etc.)

- Raw LIDAR data need, generally, to be processed by proprietary softwares;

- Returning signal could be affected by the presence of clouds, aerosols or particular reflecting materials;

- Software development is still in progress, especially for those projects in which the analysis is carried out on large area, in order to guarantee: (1) better automation of the analysis processes (2) better segmentation of raw data, (3) data size reduction, (4) better classification and organization of data (DBS) and (5) a better accuracy assessment of data.
Conclusions

• New methodologies for analyzing forest biomass and stand structure on large area as well new perspective or field of application of those techniques should be investigated

• For examples, on large-area forest inventory, LIDAR’s costs could be reduced by sampling permanent or non permanent sample plots on a strip-base (Holopainem & Talvitie, 2004)

• The integration of LIDAR with traditional RS methodologies and other source of informations (ground based biomass surveys, growth models, BFs, BECFs) should be more exploited, especially in remote forested areas.

• In this way we could enhance policy decisions and may serve certain purposes in global-level politics, such as international agreements over actions concerning biodiversity, deforestation and degradation or global warming.
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Thank you!
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Thank you!

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