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

by Teobaldelli M.

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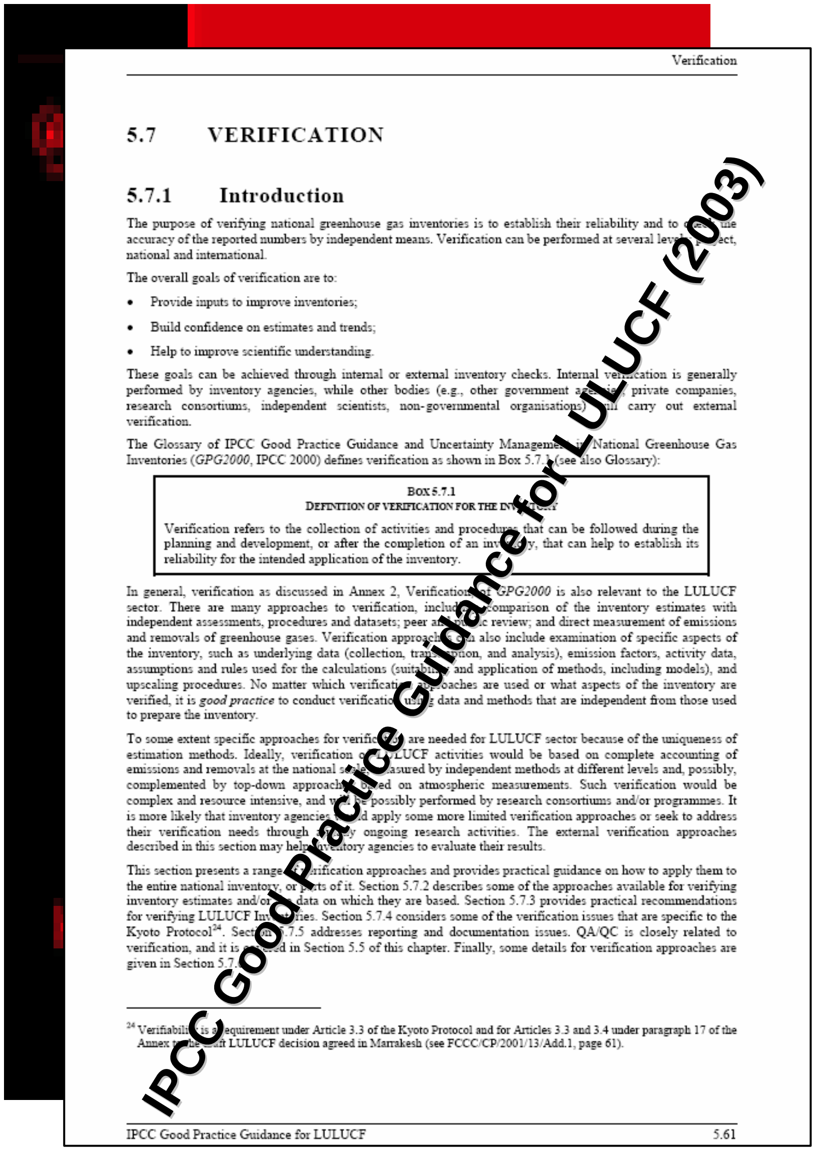
Climate Change Unit,

Workshop on "Monitoring and Reporting of GHG emissions from Forest degradation"
Paris, 10th -11th March 2008

Light Detection And Ranging

LIDAR Is an active remote sensing technique using laser light.



5.7 VERIFICATION

5.7.1 Introduction

The purpose of verifying national greenhouse gas inventories is to establish their reliability and to check the accuracy of the reported numbers by independent means. Verification can be performed at several levels: project, national and international.

The overall goals of verification are to:

- Provide inputs to improve inventories;
- Build confidence on estimates and trends;
- Help to improve scientific understanding.

These goals can be achieved through internal or external inventory checks. Internal verification is generally performed by inventory agencies, while other bodies (e.g., other government agencies, private companies, research consortiums, independent scientists, non-governmental organisations) will carry out external verification.

The Glossary of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*, IPCC 2000) defines verification as shown in Box 5.7.1 (see also Glossary):

> BOX 5.7.1
> DEFINITION OF VERIFICATION FOR THE INVENTORY
>
> Verification refers to the collection of activities and procedures that can be followed during the planning and development, or after the completion of an inventory, that can help to establish its reliability for the intended application of the inventory.

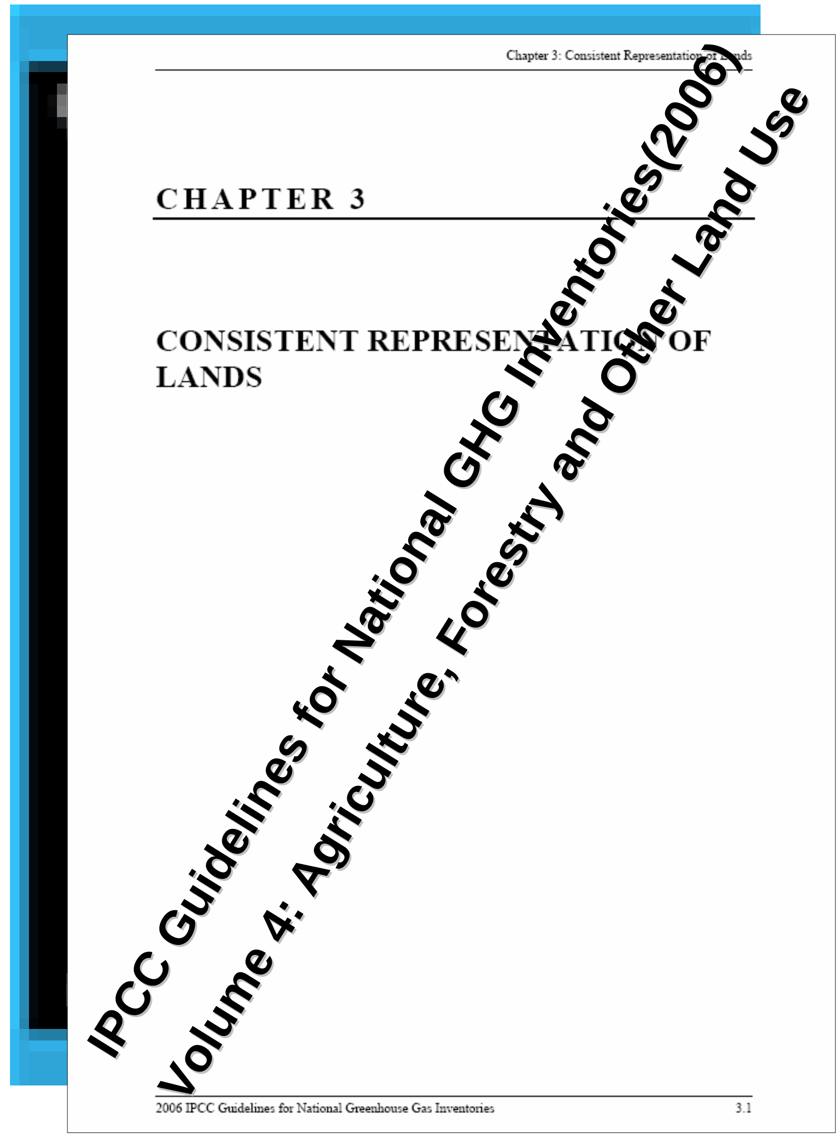
In general, verification as discussed in Annex 2, Verification of *GPG2000* is also relevant to the LULUCF sector. There are many approaches to verification, including comparison of the inventory estimates with independent assessments, procedures and datasets; peer and public review; and direct measurement of emissions and removals of greenhouse gases. Verification approaches can also include examination of specific aspects of the inventory, such as underlying data (collection, transmission, and analysis), emission factors, activity data, assumptions and rules used for the calculations (suitability and application of methods, including models), and upscaling procedures. No matter which verification approaches are used or what aspects of the inventory are verified, it is *good practice* to conduct verification using data and methods that are independent from those used to prepare the inventory.

To some extent specific approaches for verification are needed for LULUCF sector because of the uniqueness of estimation methods. Ideally, verification of LULUCF activities would be based on complete accounting of emissions and removals at the national scale measured by independent methods at different levels and, possibly, complemented by top-down approaches based on atmospheric measurements. Such verification would be complex and resource intensive, and would be possibly performed by research consortiums and/or programmes. It is more likely that inventory agencies would apply some more limited verification approaches or seek to address their verification needs through their ongoing research activities. The external verification approaches described in this section may help inventory agencies to evaluate their results.

This section presents a range of verification approaches and provides practical guidance on how to apply them to the entire national inventory, or parts of it. Section 5.7.2 describes some of the approaches available for verifying inventory estimates and/or the data on which they are based. Section 5.7.3 provides practical recommendations for verifying LULUCF Inventories. Section 5.7.4 considers some of the verification issues that are specific to the Kyoto Protocol[24]. Section 5.7.5 addresses reporting and documentation issues. QA/QC is closely related to verification, and it is addressed in Section 5.5 of this chapter. Finally, some details for verification approaches are given in Section 5.7.6.

[24] Verifiability is a requirement under Article 3.3 of the Kyoto Protocol and for Articles 3.3 and 3.4 under paragraph 17 of the Annex to the draft LULUCF decision agreed in Marrakesh (see FCCC/CP/2001/13/Add.1, page 61).

IPCC Good Practice Guidance for LULUCF (2003)



CHAPTER 3

CONSISTENT REPRESENTATION OF LANDS

IPCC Guidelines for National GHG Inventories(2006)
Volume 4: Agriculture, Forestry and Other Land Use

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.**

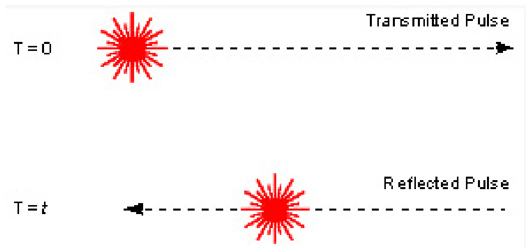
Source: IPCC Good Practice Guidance for LULUCF (2003)

IPCC WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

LIDAR Is an active remote sensing technique using laser light.

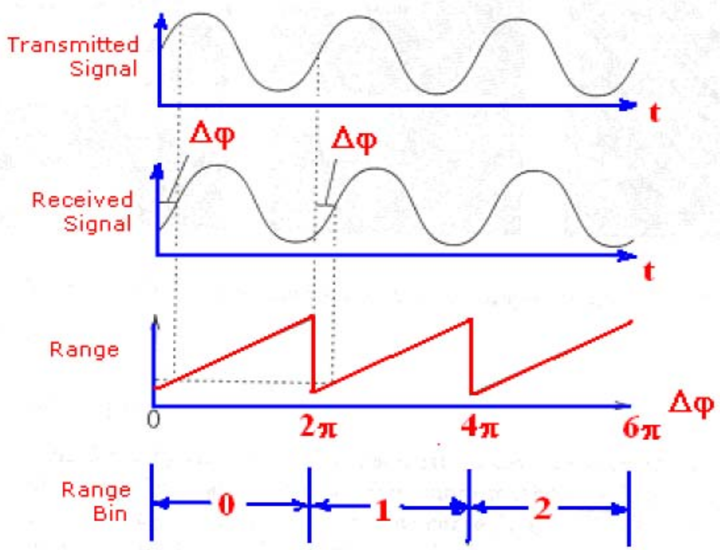
Time of flight:

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:

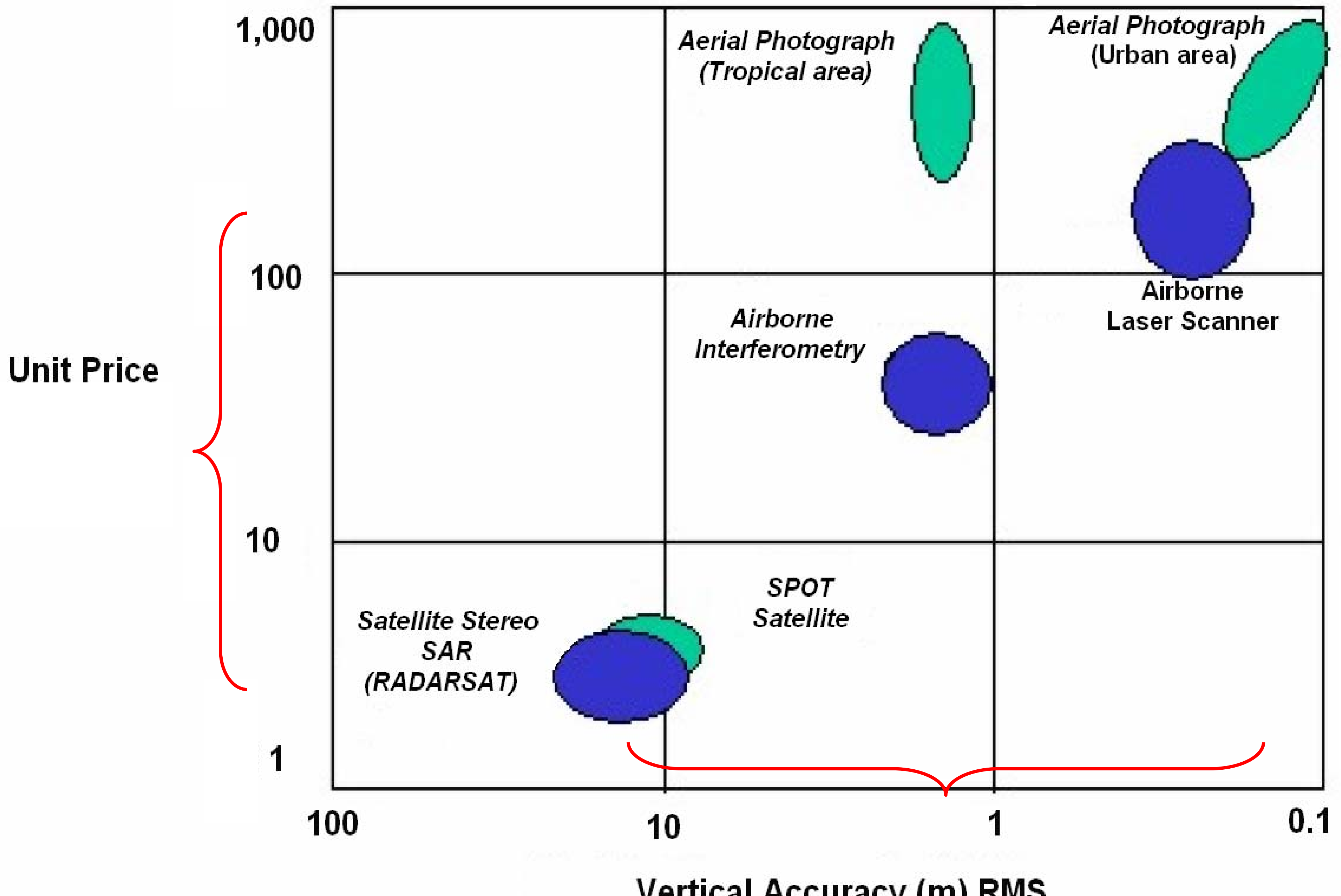
•scanners work by comparing the phase shift in the reflected laser light to a standard phase, which is also captured for comparison. This is similar to time of flight detection except that the phase of the reflected laser light further refines the distance detection.



LIDAR Is an active remote sensing technique using laser light.

Measurement technology	Range [m]	Accuracy [mm]	Manufacturers
Time of flight	< 100	< 10	Callidus, Leica, Mensi, Optech , Riegl
	< 1000	< 20	Optech, Riegl
Phase measurement	< 100	< 10	IQSun, Leica, VisImage, Zoller+Fröhlich
Optical triangulation	< 5	< 1	Mensi, Minolta

Source: Fröhlich & Mettenleiter (2004)



Source: F. Zucca. Lab. GIS & RS. dip. Scienze della Terra – Università degli Studi – Pavia
URL: http://www.disat.unimib.it/vast/lezioni/file%20pdf/presentazione_LIDAR_colori.pdf

Commercial application of laser scanning in forestry with experience from Norway

Costs: Example project in municipality of Nordre Land

Activity	Cost, € per hectare: Laser scanning	Cost, € per hectare: Photo-interpretation	Percentages of total cost	
Aerial photos, scanning	1,45	1,45		
Adjustments for digital photogrammetry	0,60	0,60		
DPW and field maps	2,41	3,61		
Laser scanning	3,01			
Laserdata processing	1,81			
Sample plots	0,84			
GPS	0,12			
Sum 1, remote sensing	**10,2**	**5,7**	**61 %**	**34 %**
Fieldworks	3,01	7,23	18 %	44 %
Productions of FMP and maps	3,01	3,01	18 %	18 %
Other costs	0,60	0,60	4 %	4 %
Sum 2, total cost	**16,9**	**16,5**	**100 %**	**100 %**

Prevista

Source: ScandLaser 2003, Umeå, 02.09.03

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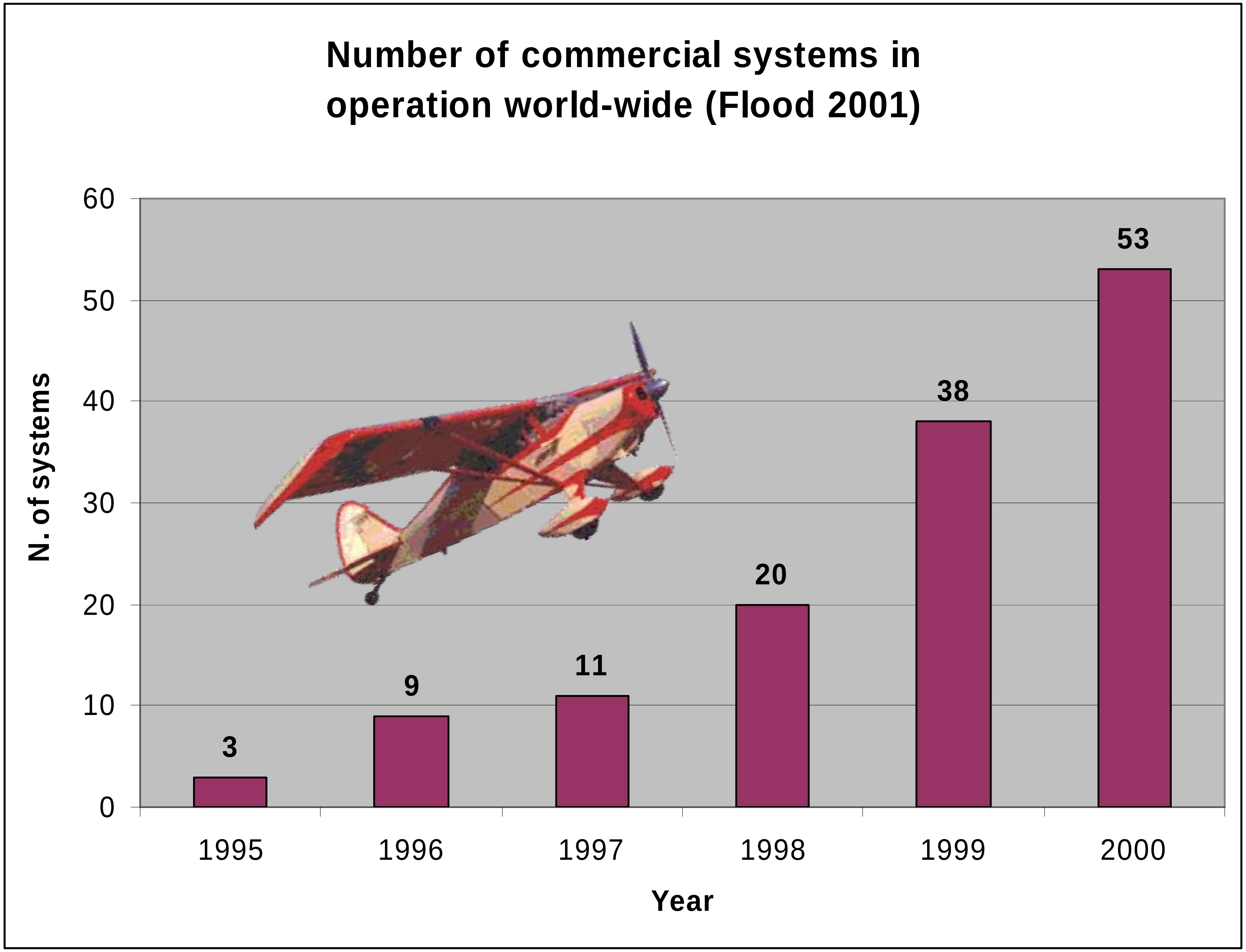
Number of commercial systems in operation world-wide (Flood 2001)
60
50
40
30
20
10
0
N. of systems
3
9
11
20
38
53
1995
1996
1997
1998
1999
2000
Year

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"

Source: IPCC Good Practice Guidance for LULUCF (2003)

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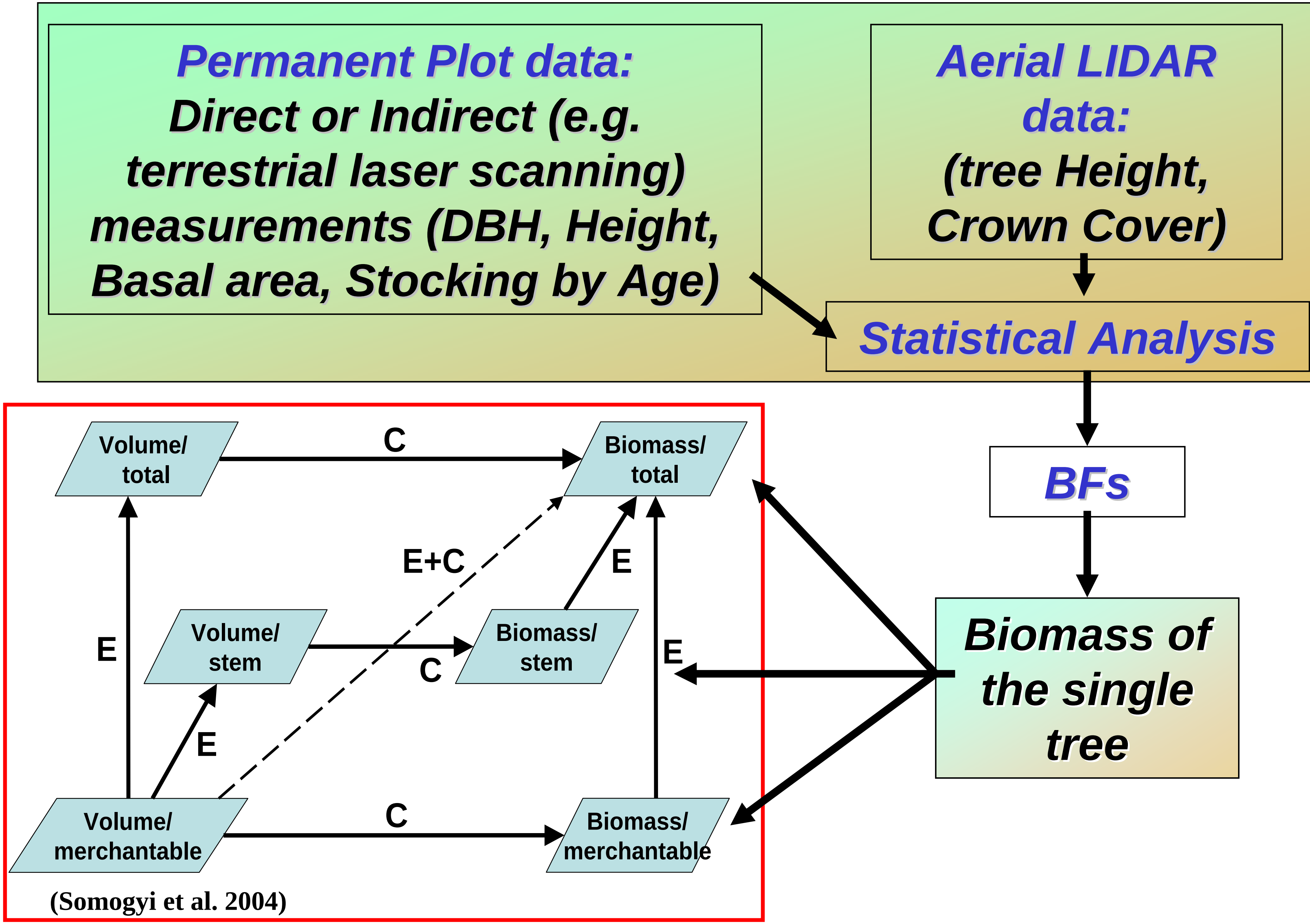
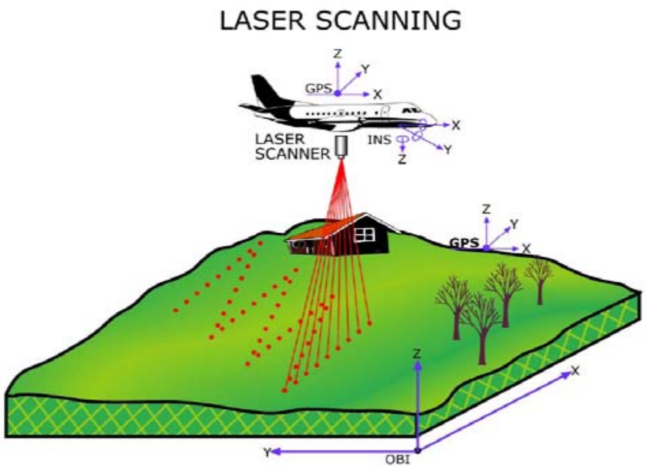
Forest Aboveground Biomass Estimation



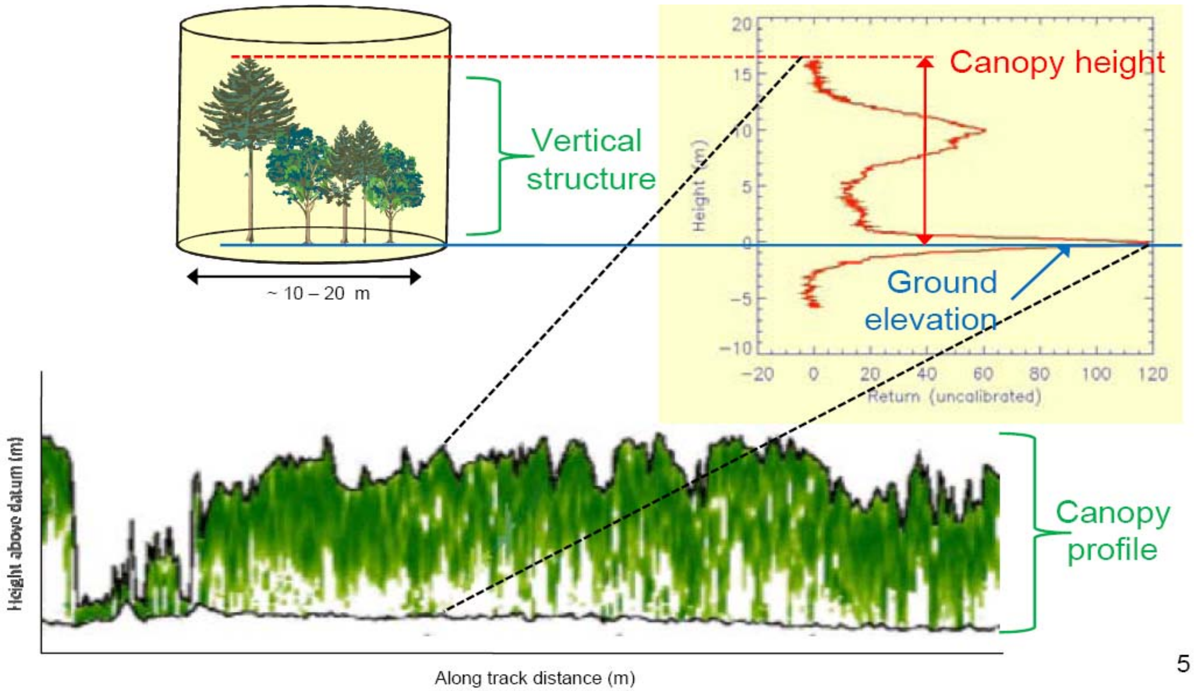
Aerial LIDAR
(i.e. Laser Altimetry)

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.

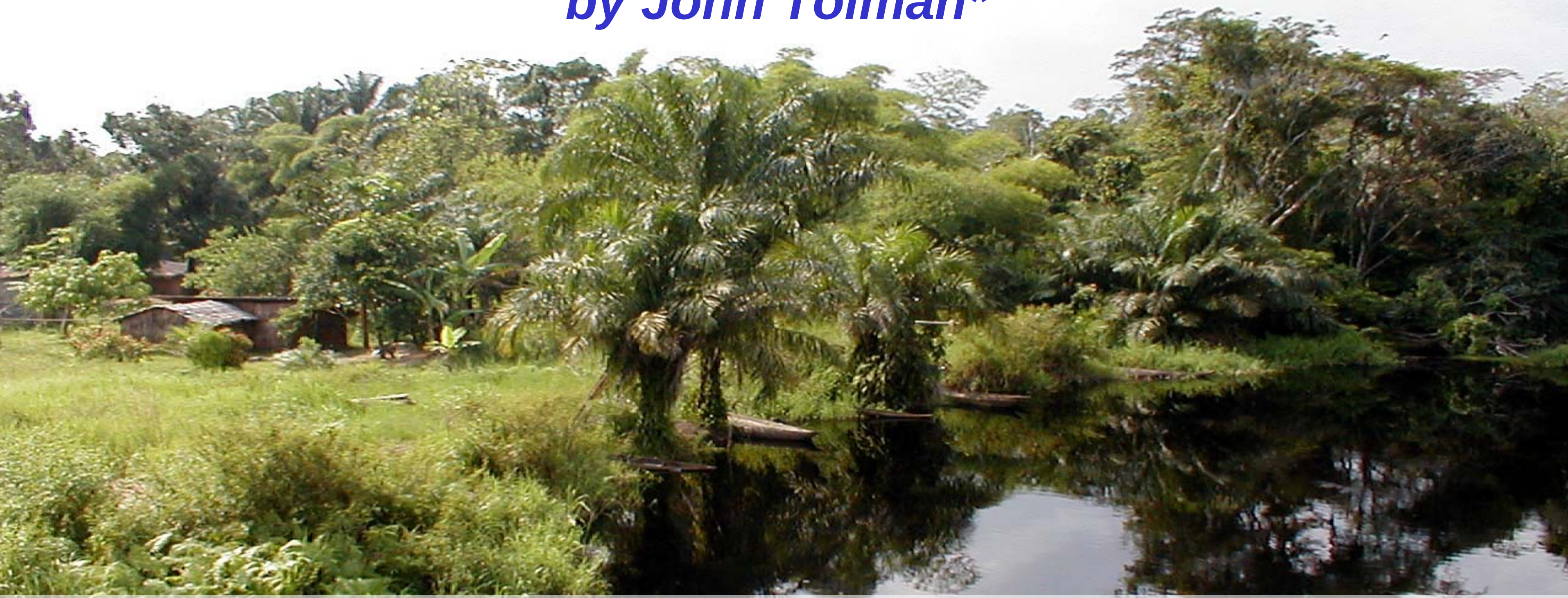


- Laser sensor
- GPS receiver
- Inertial Navigation System
- Inertial Measurement Unit
- Data Acquisition System



LIDAR Mapping in the Republic of Congo

*by John Tolman**



**Currently Managing Director of Sensor Design Group, LLC, Houston, Texas.*

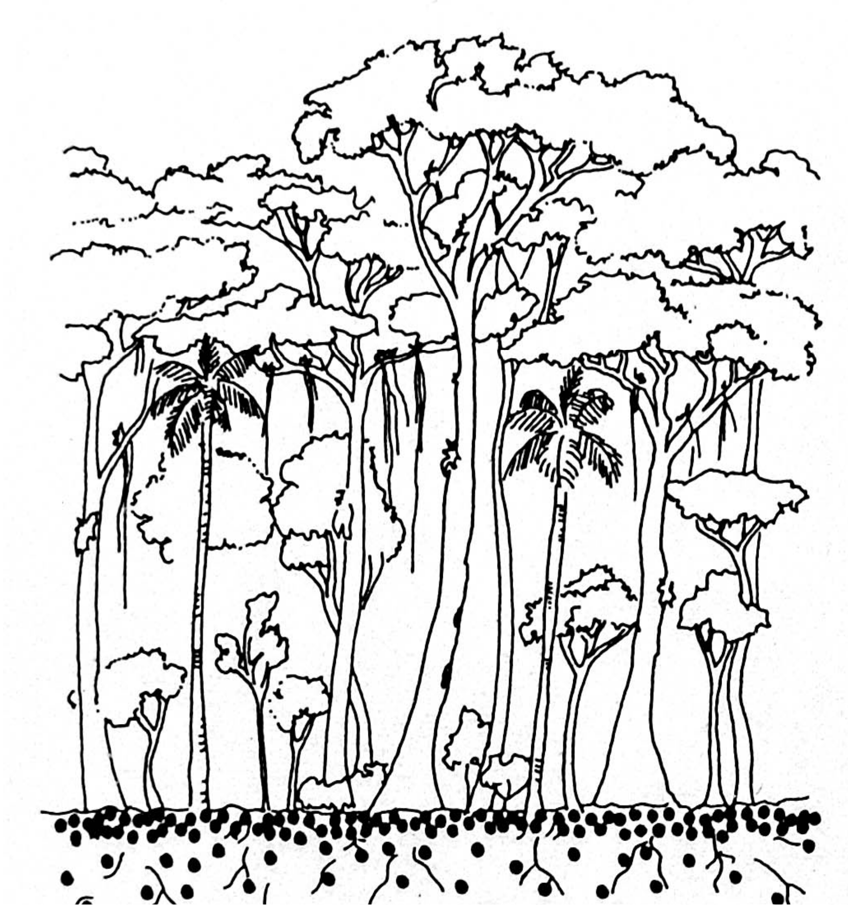
E-mail: john.tolman@sensordesigngroup.com

Why: ***to realize a Digital Elevation Model (DEM) and Digital Terrain Model (DTM) and two meters contour map***

When: ***2003***

Where: ***532 Km^2 forest area near Gamboma***

LIDAR Mapping in the Republic of Congo



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

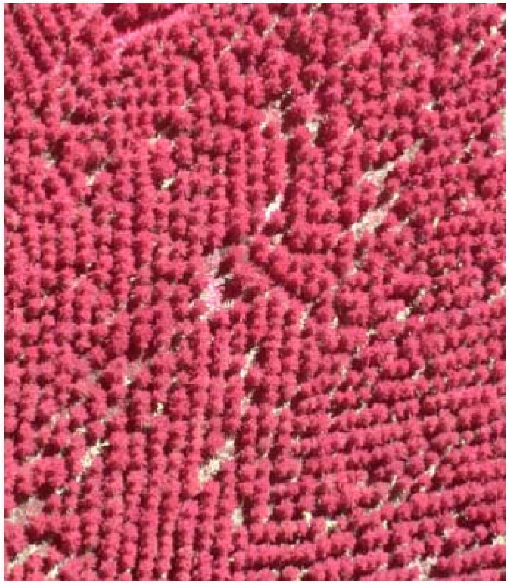
Ministry for the Environment (New Zealand)

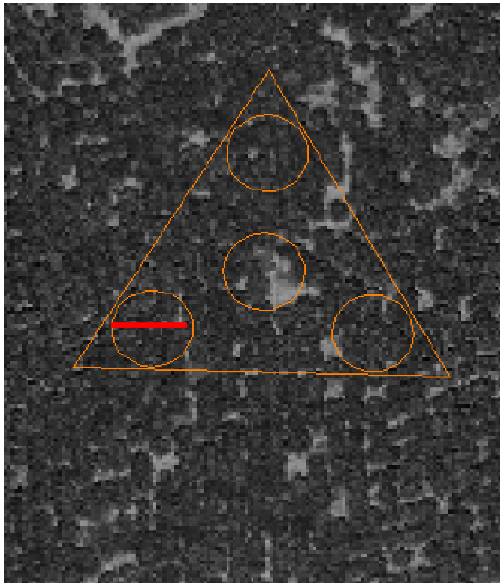
Colour Infrared Imagery

- 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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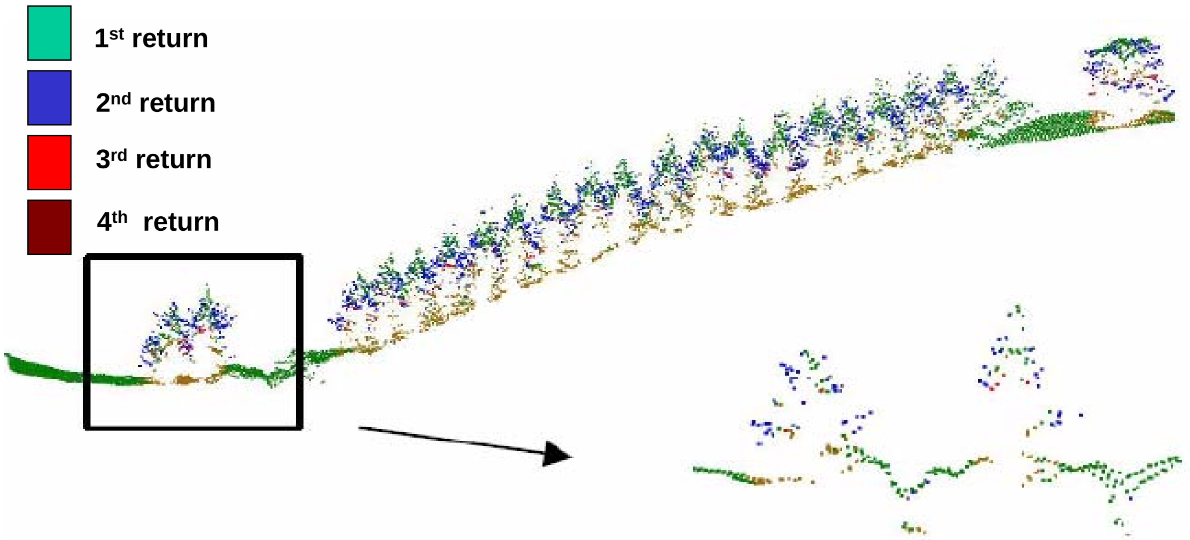
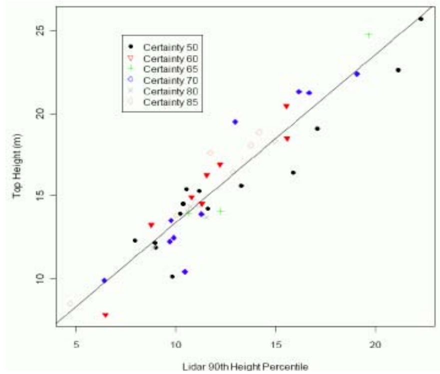
LiDAR Pulses (Returns)

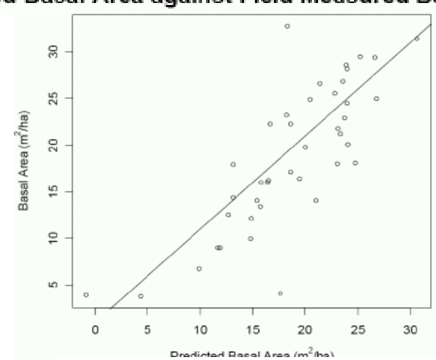


LiDAR 90th Height Percentile against Top Height

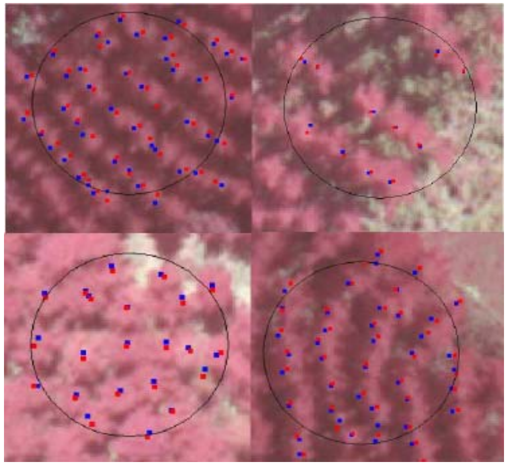


Work-in-progress: RMSEs between predicted and field of 1.4m (9%) [3-8%]

LiDAR-derived Basal Area against Field Measured Basal Area



Work-in-progress: RMSEs $4.9m^2/ha$ (25%) [7-14%]



Repeat Measurements of Plots

Range of tree crown displacements was 0.023m to 0.138 m

Terrestrial laser scanner and Forest Inventory

by
Teobaldelli M.[1] , Puig D.[2]

[1.] European Commission, DG-JRC, Institute for Environment and Sustainability, Climate Change Unit
[2]European Commission, DG-JRC, Institute for the Protection and Security of the Citizen, Nuclear Safeguards Unit

Diameter Measuring Instruments

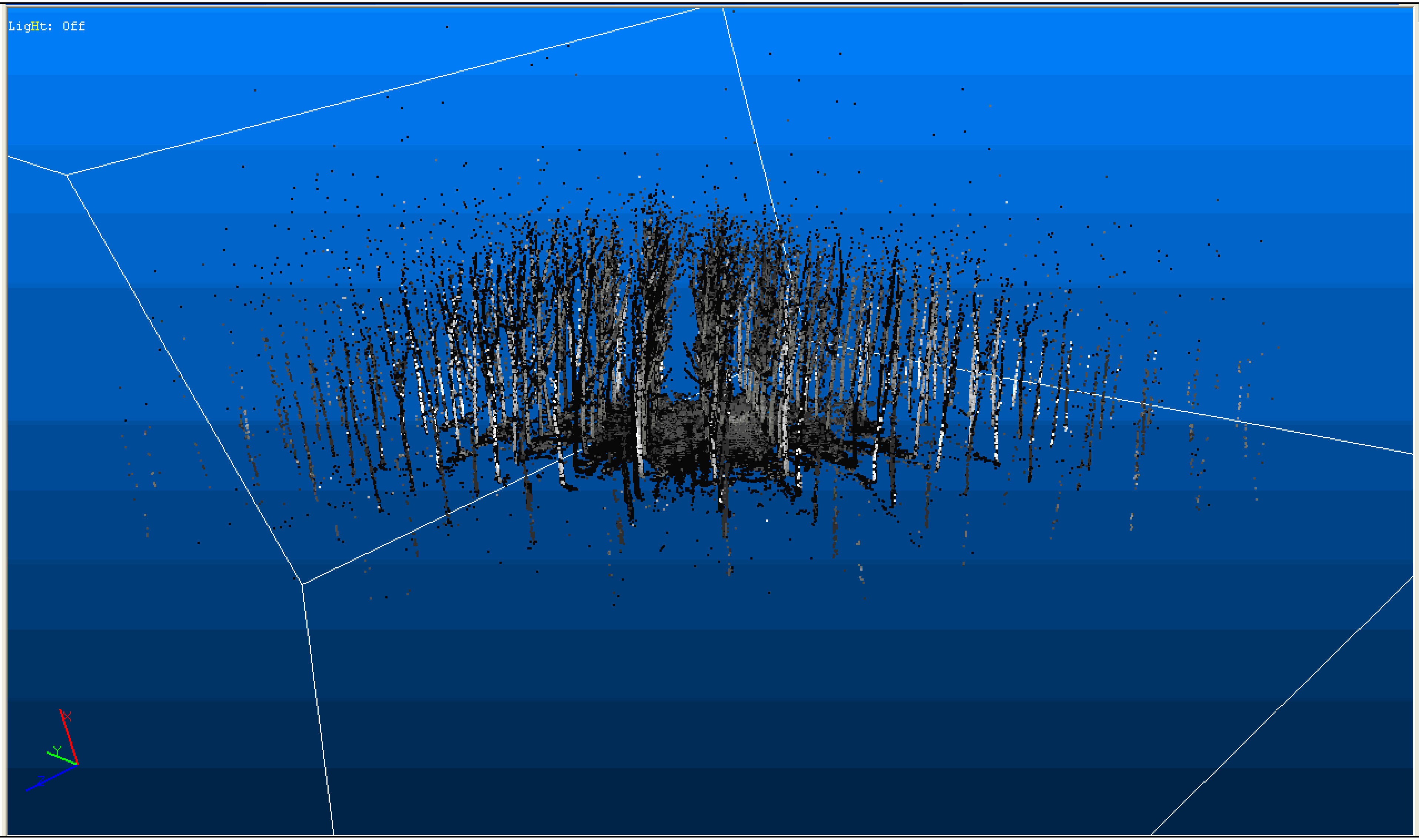
- Diameter tape
- Tree Calipers.
- Dendrometers.
- Optical Fork (Relaskop, Telerelaskop).
- Optical Calipers (Wheeler penta-prism caliper).
- Short-Base Rangefinder Dendrometer

Height Measuring Instruments.

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

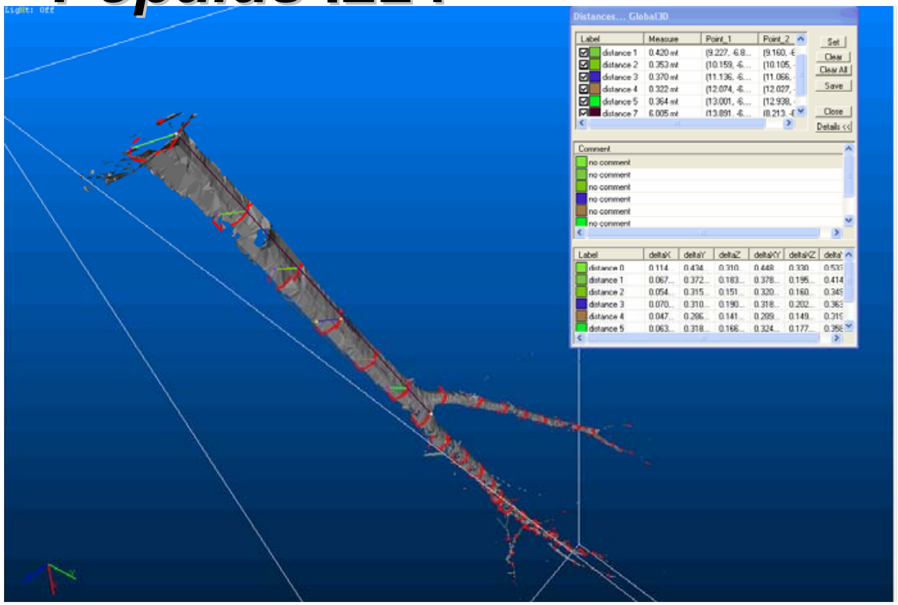
Laser Measuring Devices

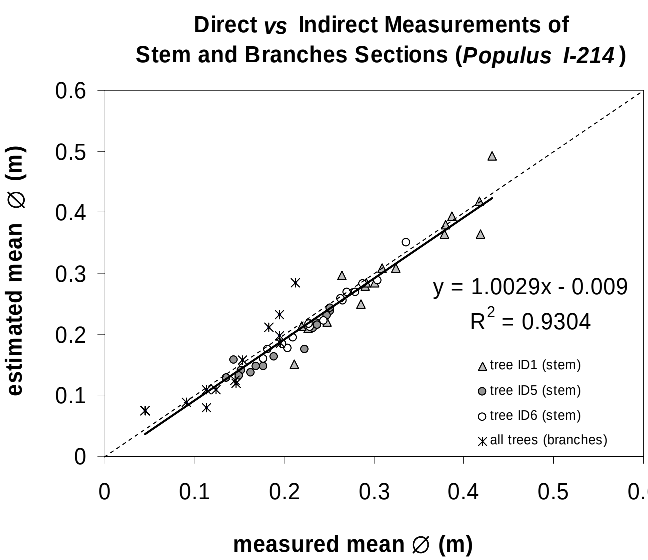
IMAGER 5003 + JRC 3D Reconstructor


Light: Off
X
Y

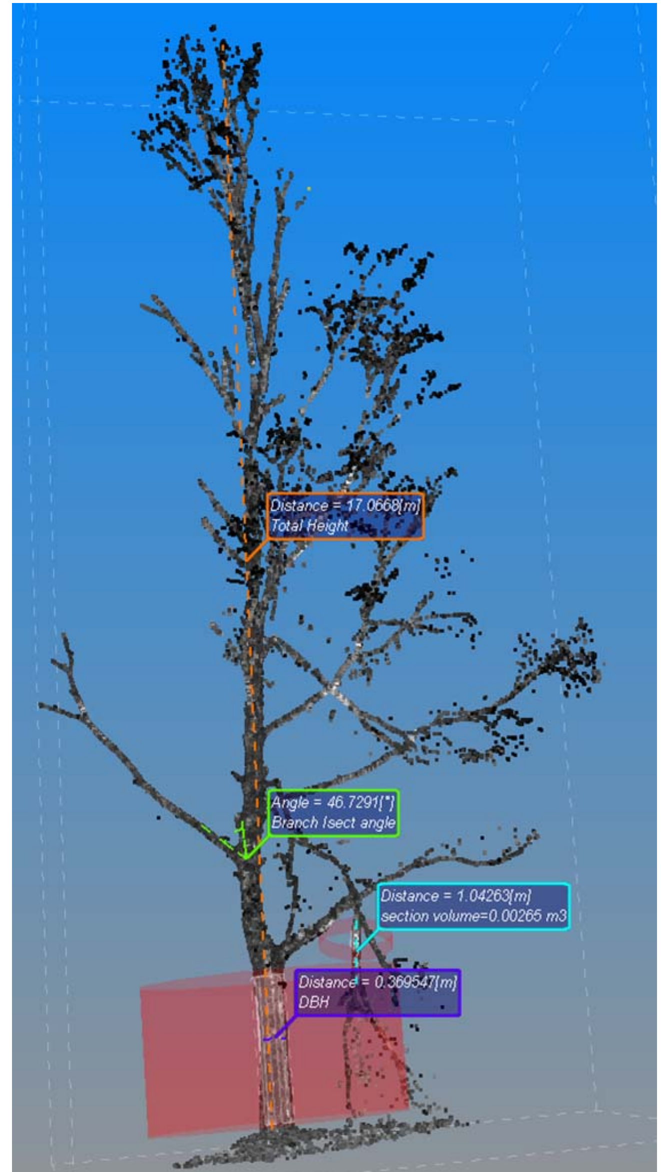
Analysis of allometric relationships

Populus I214





Betula alba



Sources: Teobaldelli et al. 2008, submitted to Plant Functional Biology Journal

Conclusions

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;*

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

- *<u>Terrestrial LIDAR</u>: 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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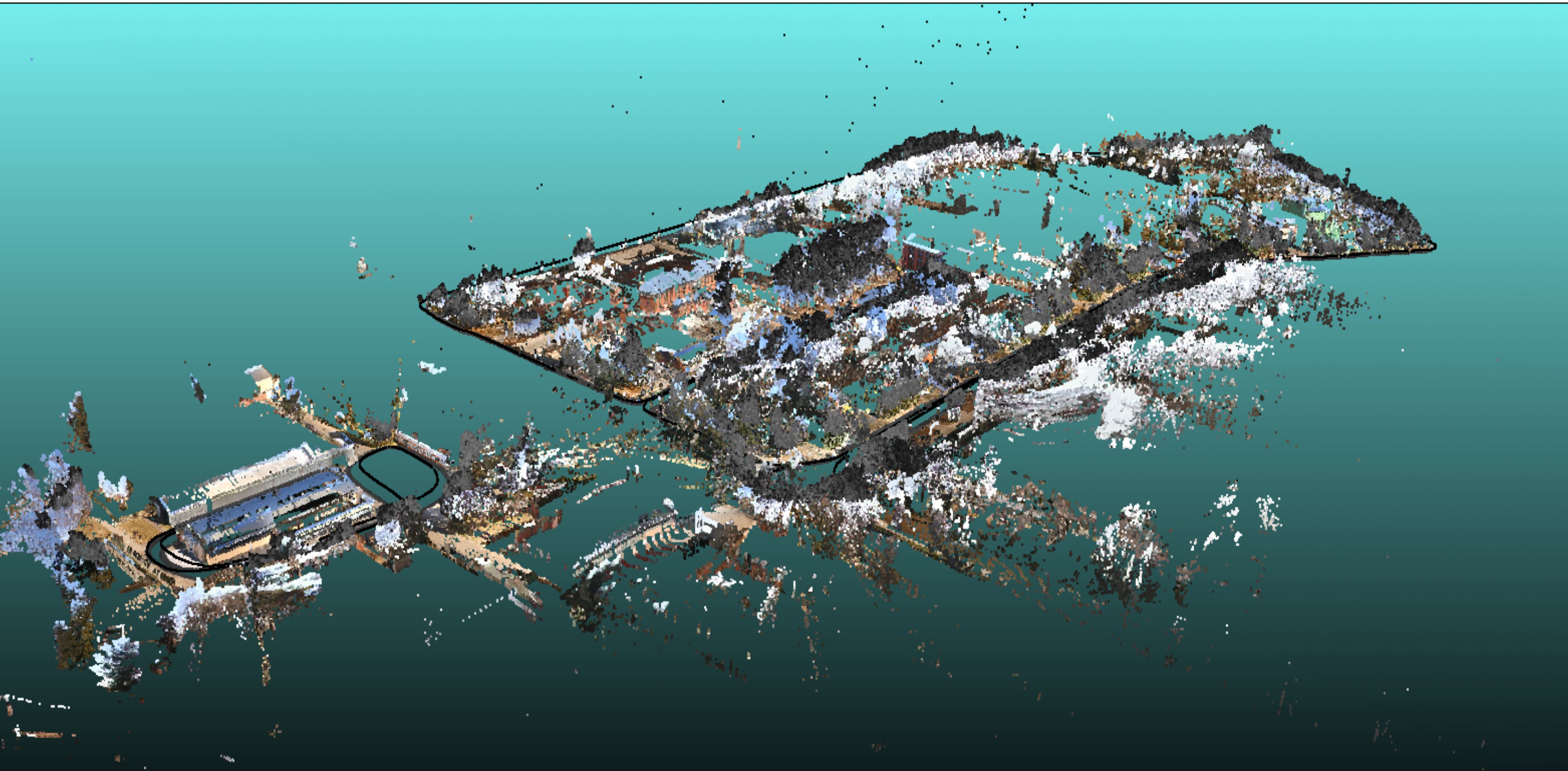
Thank you!



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Thank you!

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