

# Forest Carbon Budgeting Using Airborne Laser Altimetry



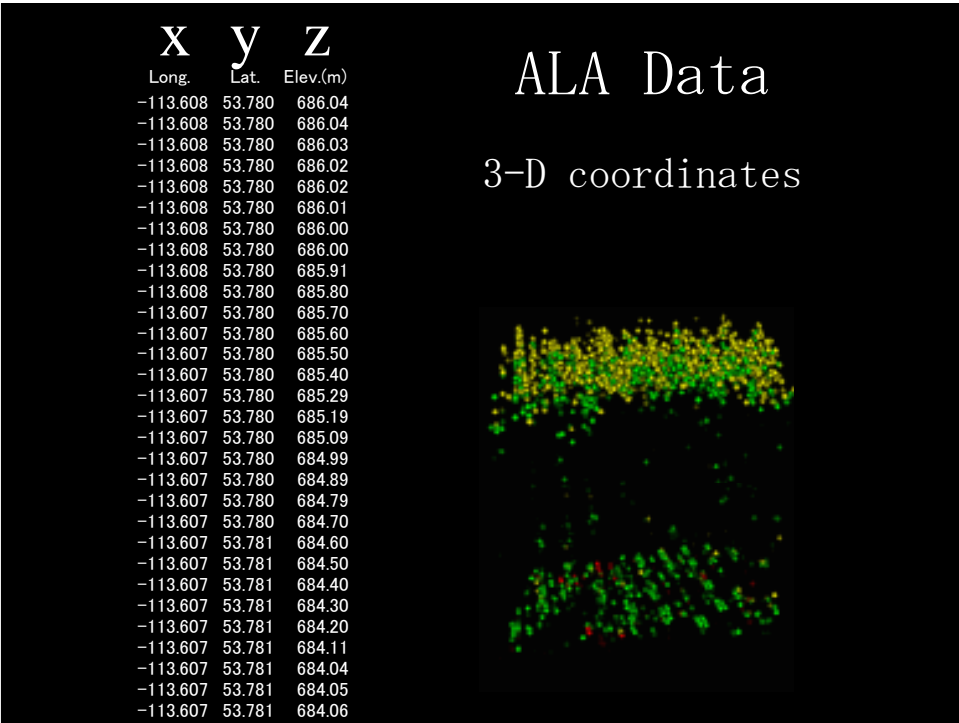
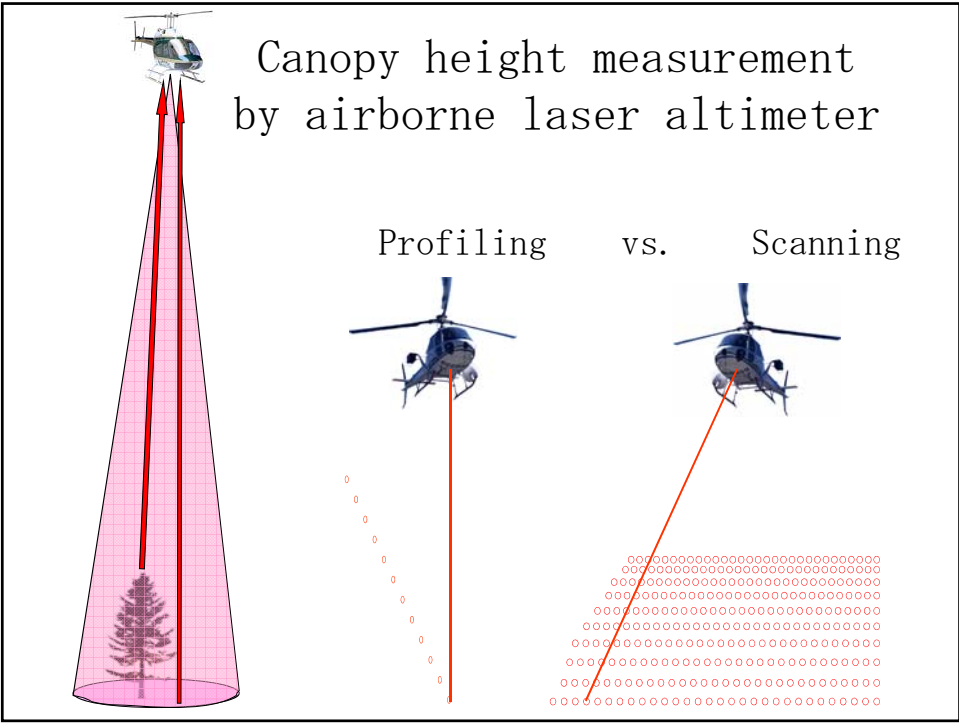
Research (PALS, NASA)

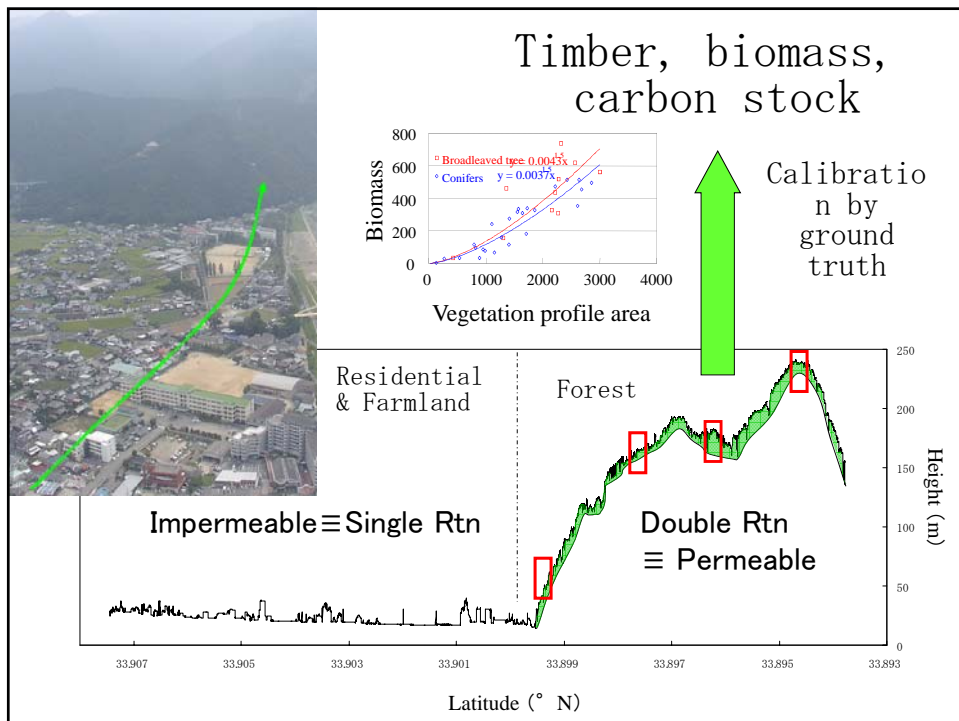
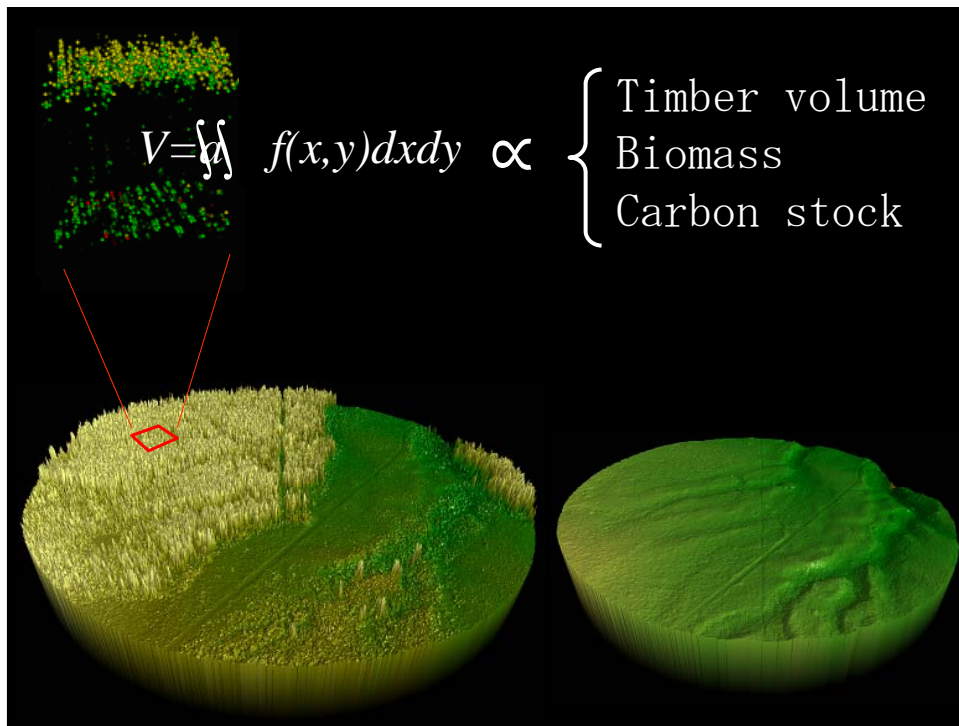


Commercial (ALTM 2050 )



Airborne Laser Altimeter





## Ground Truth Biomass

- Sample Tree Measurement

$$\begin{array}{l} \text{Allometric} \\ \text{Biomass} \\ \text{Equations} \end{array} \left\{ \begin{array}{ll} \text{Stem} & W_{\text{St}} = f(\text{dbh}) \\ \text{Branch} & W_{\text{Br}} = f(\text{dbh}) \\ \text{Leaf} & W_{\text{Lf}} = f(\text{dbh}) \\ \text{Root} & W_{\text{Rt}} = f(\text{dbh}) \end{array} \right.$$

- Plot Survey

dbh Census

$$\text{Plot biomass} = \sum \text{tree biomass} = \sum f(\text{dbh})$$







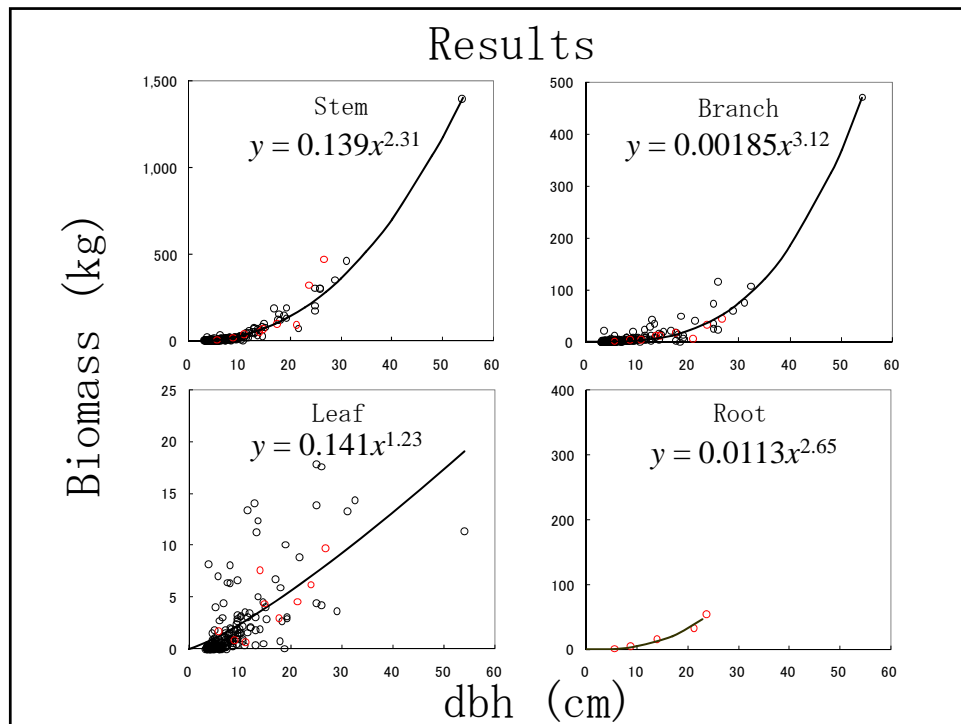




Leaf & branch biomass



Root biomass



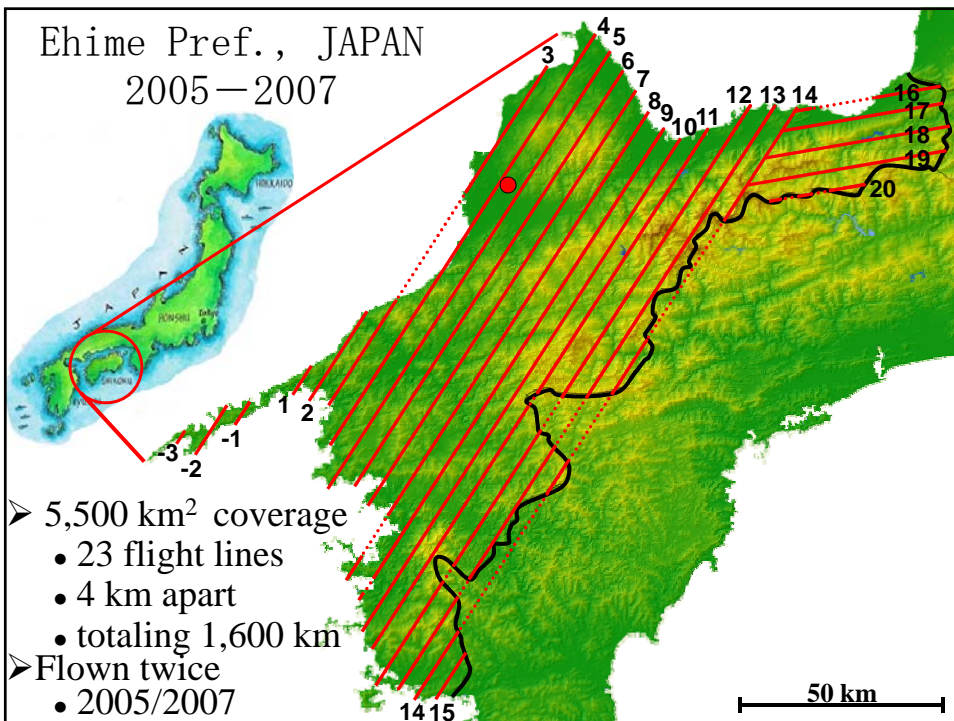


# Forest Carbon Budgeting for Ehime Prefecture, Japan



Stock change method  
by  
airborne laser altimetry

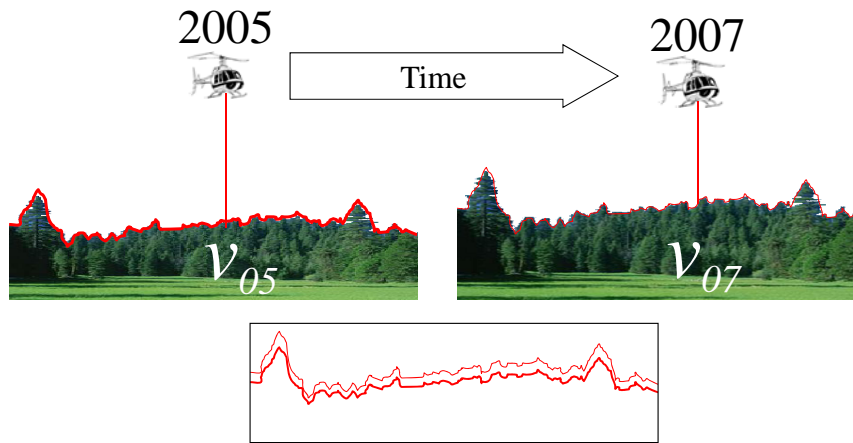
Ehime Pref., JAPAN  
2005—2007



- 5,500 km<sup>2</sup> coverage
  - 23 flight lines
  - 4 km apart
  - totaling 1,600 km
- Flown twice
  - 2005/2007



## Multi-temporal Laser Altimetry for Carbon Budgeting

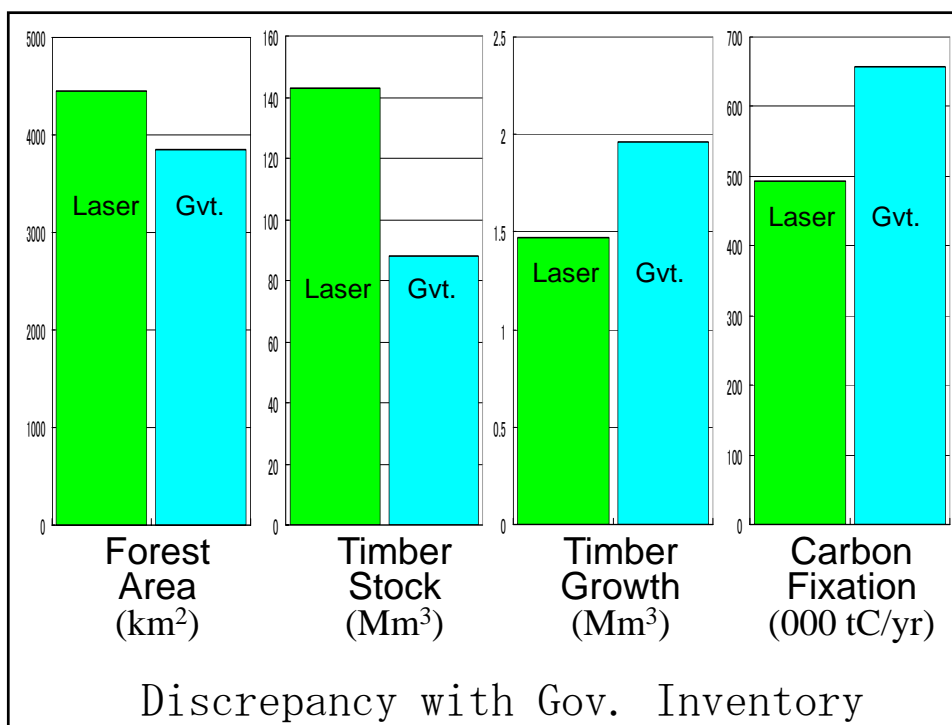


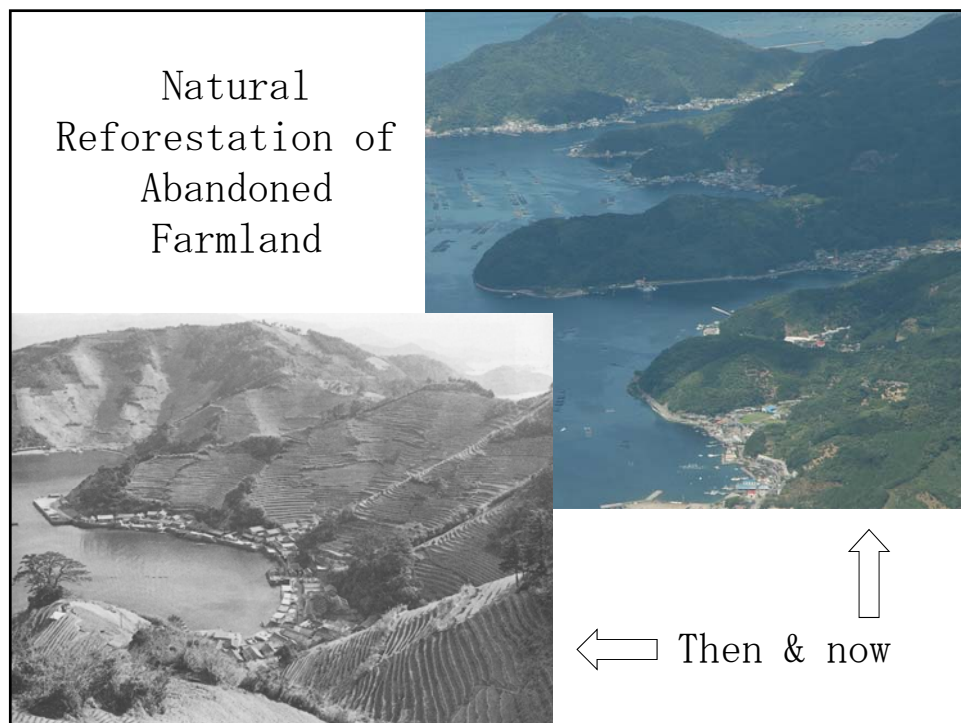
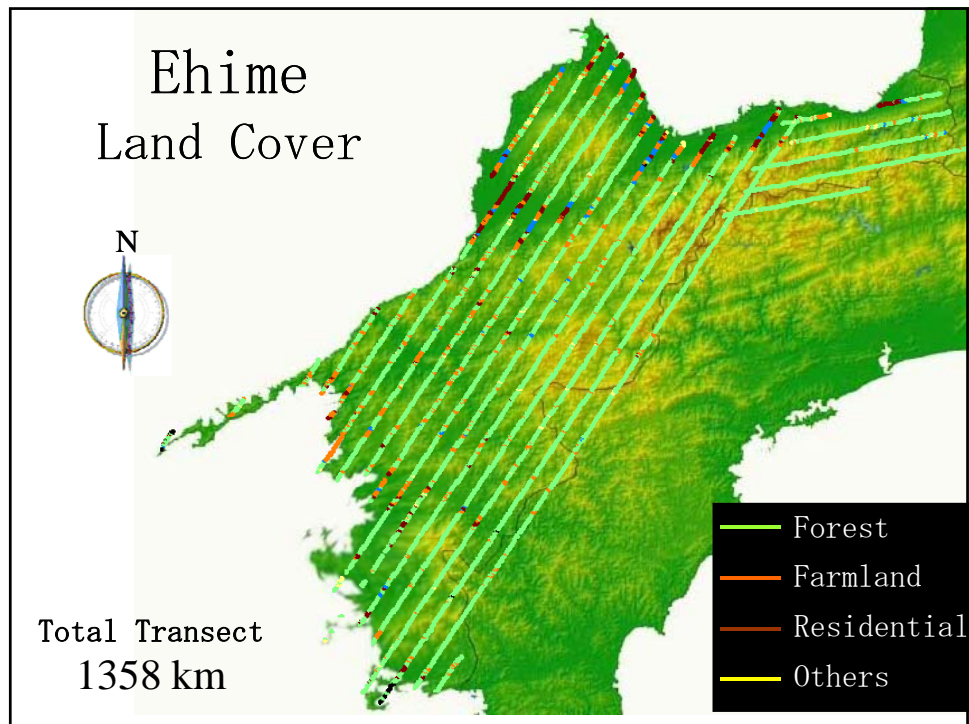
## Ehime Timber Stock, Growth & C Budget

|                                |                           |                         | Airborne<br>Laser |              |
|--------------------------------|---------------------------|-------------------------|-------------------|--------------|
|                                |                           |                         | Sept.<br>2005     | Aug.<br>2007 |
| Forest area (km <sup>2</sup> ) |                           |                         | 4,457             |              |
| Tim-<br>ber                    | Total (Mm <sup>3</sup> )  |                         | 142.8             | 145.7        |
|                                | Mean (m <sup>3</sup> /ha) |                         | 320.3             | 326.9        |
|                                | Growth                    | (Mm <sup>3</sup> /yr)   | 1.47              |              |
|                                |                           | (m <sup>3</sup> /ha•yr) | 3.3               |              |
| C Sequestration (t/yr)         |                           |                         | 492,000           |              |

## Discrepancy with Gov. Inventory

|                                |                           |                         | Airborne<br>Laser |              | Gvt.<br>Inventory |              |
|--------------------------------|---------------------------|-------------------------|-------------------|--------------|-------------------|--------------|
|                                |                           |                         | Sept.<br>2005     | Aug.<br>2007 | Dec.<br>2005      | Dec.<br>2007 |
| Forest area (km <sup>2</sup> ) |                           |                         | 4,457             |              | 3,846             |              |
| Tim-<br>ber                    | Total (Mm <sup>3</sup> )  |                         | 142.8             | 145.7        | 88.0              | 91.9         |
|                                | Mean (m <sup>3</sup> /ha) |                         | 320.3             | 326.9        | 228.8             | 239.0        |
|                                | Growth                    | (Mm <sup>3</sup> /yr)   | 1.47              |              | 1.96              |              |
|                                |                           | (m <sup>3</sup> /ha•yr) | 3.3               |              | 5.1               |              |
| C Sequestration (t/yr)         |                           |                         | 492,000           |              | 657,000           |              |







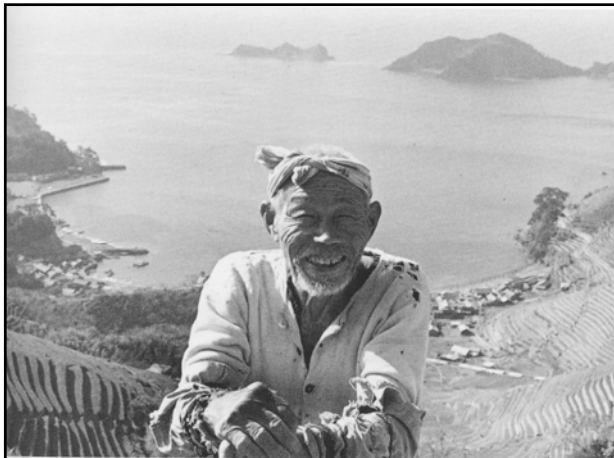


Then (50 years ago)



Now

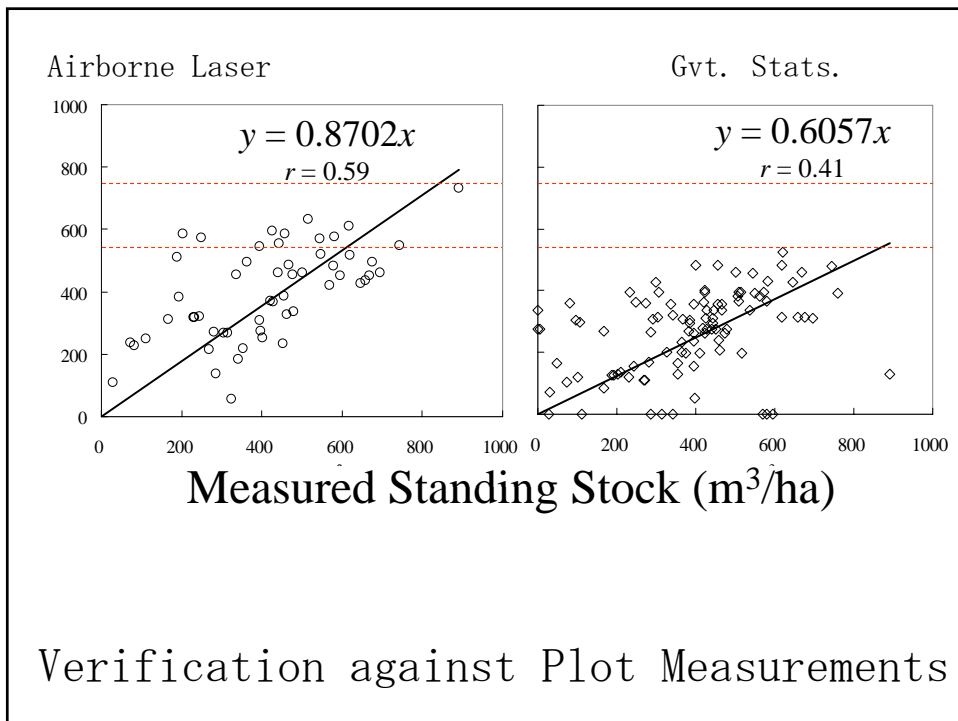
Plantation



**1950s** (Harada 1995)

**2008**





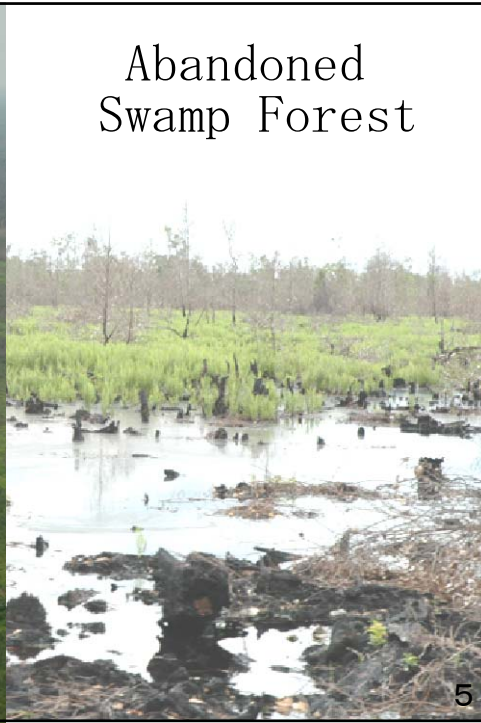
# Full Carbon Accounting of Kalimantan Peat Swamp Forest using Airborne Laser Altimetry

The map illustrates the geographical context of the study area. Kalimantan is located on the island of Borneo, which is shared with Malaysia and Brunei. The map shows the surrounding seas (Indian Ocean, Pacific Ocean, Andaman Sea, Celebes Sea, Arafura Sea, Timor Sea) and neighboring countries (Malaysia, Brunei, Papua New Guinea, Timor-Leste). Major Indonesian islands and cities are labeled, with a red square specifically marking the location of Kalimantan. A legend in the bottom left corner provides details on land height (ranging from 500m to 4000m+), population (ranging from over 50,000 to over 5,000,000), and a scale bar (0 to 1000 miles).





## Abandoned Swamp Forest



5

## Drainage

- ⇒ lowers water table
- ⇒ dries peat
- ⇒ { aerobic decomposition  
fire



## Consequences of Drainage





Aerobic Decomposition



Increased Fire Occurrence





Burn



Peat subsidence varies from one place





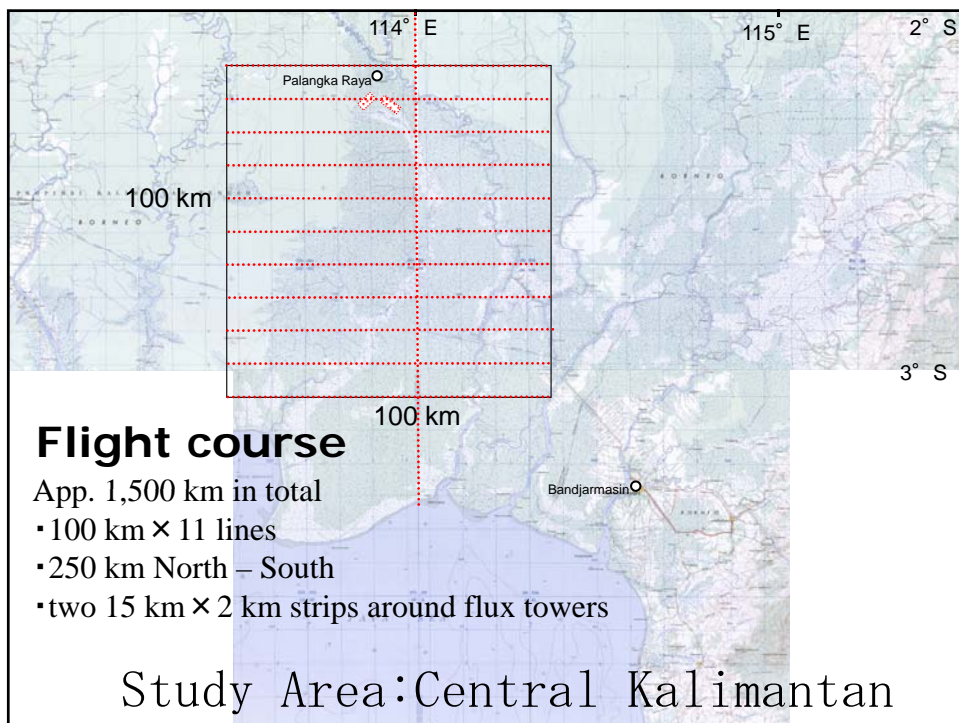
to another



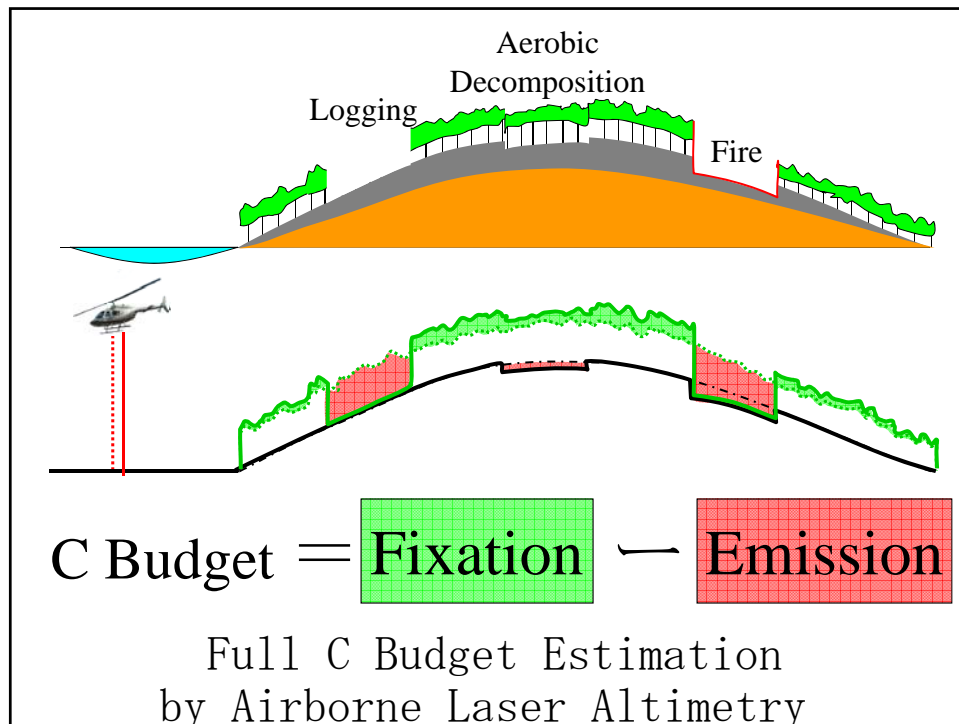
and yet to another



Peat fire burns underground too







**NEWS FEATURE ROAD TO COPENHAGEN**

**Counting carbon in the Amazon**

If the next climate treaty tackles deforestation, tropical nations will need to monitor the biomass of their forests. One ecologist has worked out a way to do that from the sky, finds **Jeff Tollefson**.

**G**reg Asner peers out an open window, taking stock of the tangle as the single-engine prop plane chugs over a pair of scarlet macaws gliding among the treetops 120 meters below. The Peruvian Amazon stretches in all directions, painted in countless shades of green, accented here and there by patches of purple, pink and yellow. Occasionally, naked white trunks rise amid the leaves, a reminder that even the rainforest has deciduous tendencies.

Forty-five minutes into the flight, Asner spots his quarry: narrow red trails, barely visible, then a fallen tree in the middle of an otherwise intact canopy. The cause isn't immediately clear to the untrained eye, but Asner knows all too well. "When trees die in the tropics, they don't just fall over," he says as the plane passes over more dense forest. "Then a small clearing that contains stacked logs and a butt-log, it's a legal concession, authorized by the Peruvian

government to extract just three species of hardwood trees. As the plane veers away from the clearing, Asner gives his verdict: "The biomass levels are going to be a lot lower here," he says. "But it really is low-impact logging compared with the mambo of Brazil."

As a tropical ecologist with the Carnegie Institution for Science's global ecology department in Stanford, California, Asner has developed a keen ability to interpret the rainforest from great heights. Frequently operating with oxygen masks at high altitude, he now uses a powerful laser system to map trees and calculate the biomass of the forest. Satellites extend his view across the tropics, and he has developed automated software that can track annual changes in forest cover and calculate the biomass of the vegetation. The system can even spot small logging operations like the one he just passed, which he reports on in maps, satellite images.

The fully integrated system is designed to measure the

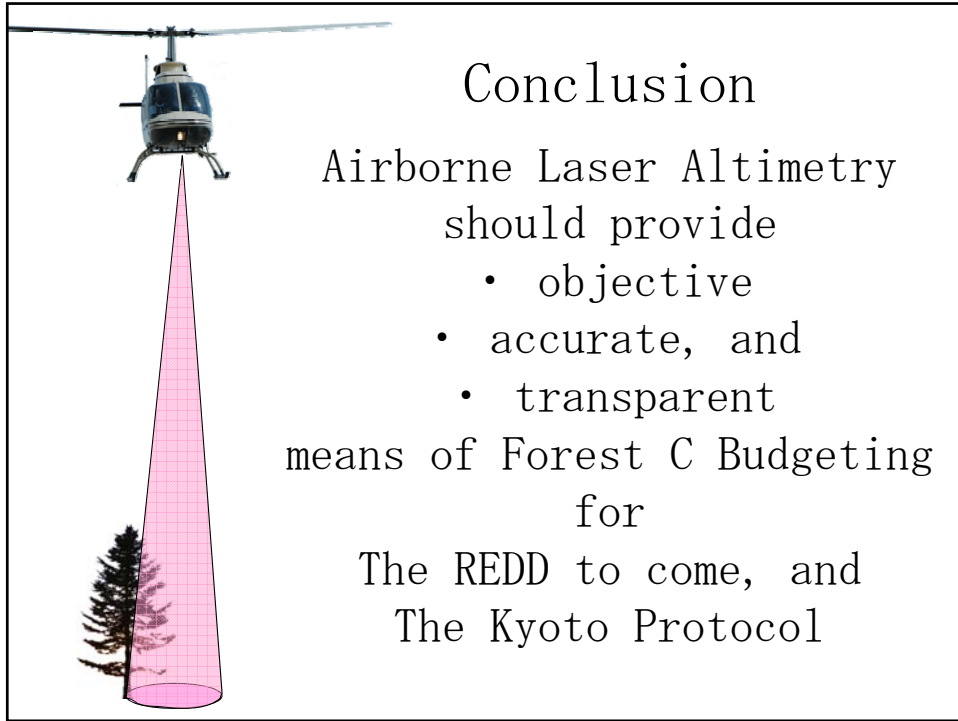
A similar effort  
in the Amazon

Nature 461: 1048-1052, 2009

Above-ground  
Carbon Budgeting  
with  
Airborne Laser

Global Ecology Department  
Carnegie Inst. for Science  
Stanford, USA





## Conclusion

Airborne Laser Altimetry  
should provide

- objective
- accurate, and
- transparent

means of Forest C Budgeting  
for

The REDD to come, and  
The Kyoto Protocol