# BIOMASS ESTIMATION BY COUPLING LIDAR DATA WITH FOREST GROWTH MODEL IN CONIFER PLANTATION

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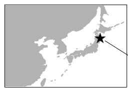
**ABSTRACT** Recent studies have shown the potential of remote sensing data at optical wavelengths to provide spatially referenced input data for process-based ecosystem models. Airborne Light Detection and Ranging (LiDAR) data have potential to provide stand development information of forest and spatially referenced input data for the models. The aim of this study is coupling airborne LiDAR data with a process-based forest growth model. In this study, 3-PG (Physiological Principles to Predict Growth) which is one of the simplest forest growth models is used to estimate forest growth and productivity. The model requires few parameter values and only readily available input data. Species specific parameters for the model are specified by field measured data and literatures. Stand forest parameters such as tree height, population and biomass are estimated by LiDAR data and a tree size distribution function. The fit between simulated and the stand parameters derived by LiDAR data is improved by tuning parameter values. The coupling method is applied for a Japanese cedar (Sugi) plantation. The estimations are corresponded with field measured data and yield table. It is concluded that coupling LiDAR data with the process-based forest growth model can estimate the forest growth and productivity. This coupling method focused in this study can play an important role in improving the estimation accuracy above-ground biomass and forest productivity.

## 1. INTRODUCTION

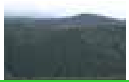
- There is increasing demand for precise estimates of forest biomass, potential productivity and forest growth.
- Recent studies have shown the potential of remote sensing data at optical wavelengths, such as leaf area index (LAI) and land cover, to provide spatially referenced input data for process-based ecosystem models.
- LiDAR data can estimate useful information for stand forest development, such as tree height, stem populations and biomass.
- Process-based forest growth model (3-PG) is developed by Landsberg and Waring (1997). Using LiDAR data, the 3-PG has great potential to estimate biomass and productivity precisely and spatially.

The objective of this study is coupling airborne LiDAR data with the process-based forest growth model.

**Fig. 1 Study area**



Shichinohe
Aomori
Northern part of Japan



40 plots

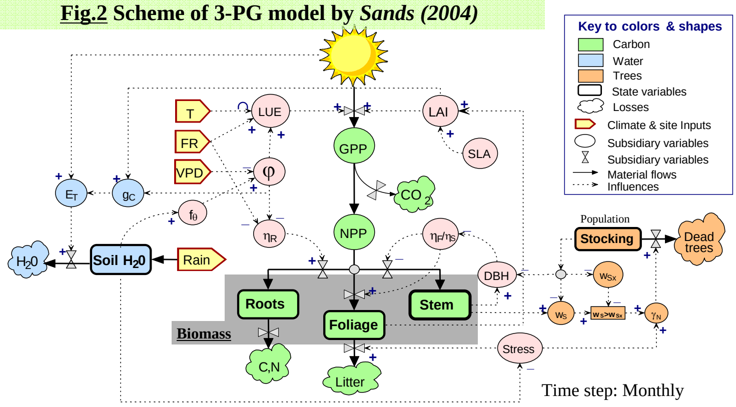
***Cryptomeria japonica* D. Don (Japanese cedar; Sugi)**

**Table. 1 The Specification of LiDAR Obs.**

| | |
|---|---|
| Sensor | ALS50 |
| Flight altitude | 1829 m (Ave) |
| Observed date | 11, 12 Aug 2004 |
| Scan angle | ±20 degree |
| Pulse rate | 46 kHz |
| Footprint size | 0.47m |

## 2. FOREST GROWTH MODEL "3-PG"

**Fig.2 Scheme of 3-PG model by *Sands (2004)***




Time step: Monthly

- The 3-PG model is tree growth model based on **<u>P</u>hysiological <u>P</u>rinciples that <u>P</u>redict <u>G</u>rowth** (Landsberg and Waring, 1997).
- The model uses light use efficiency (LUE). The theoretical maximum canopy quantum efficiency is reduced by physiological function and site environment.

## 3. STEM BIOMASS & POPULATION by LiDAR

- Tree crown detection method developed by Taguchi et al, (in review) is used.
- Tree height is converted to stem biomass, using DBH-tree height relation and allometric equation of DBH and stem biomass.
- In canopy-closed plot, stem biomass and population are underestimated, because it is difficult to detect suppressed trees.
- Tree size distribution function (MNY method) developed by Hozumi (1971) is applied in canopy closed plot.

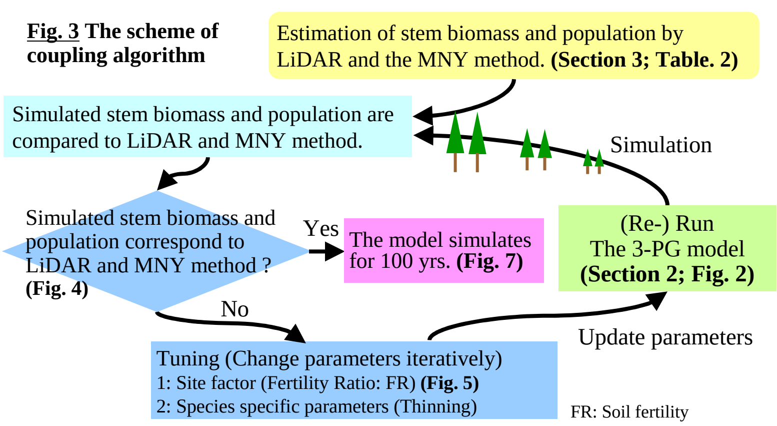
**Table. 2 The comparison between (1) field measured with (2) LiDAR data and (3) LiDAR data and the MNY method.**

| Plot | Plant Year | (1) Field measured Mean H (m) | (1) Population (stem/ha) | (1) Stem Biomass (t/ha) | (2) LiDAR Mean H (m) | (2) Population (stem/ha) | (2) Stem Biomass (t/ha) | (3) LiDAR + MNY Population (stem/ha) | (3) Stem Biomass (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1956 | 22.33 | 1088 | 239.1 | 22.7 | 897 | 192.7 | 1229 | 232.1 |
| 6* | 1961 | 25.72 | 530 | 187.7 | 24.88 | 528 | 175.3 | ----- | ----- |
| 12 | 1961 | 21.02 | 1146 | 206.2 | 19.97 | 963 | 131.1 | 1190 | 162 |
| 39 | 1987 | 6.84 | 1965 | 30.4 | 6.45 | 1162 | 13.6 | 3943 | 28.8 |

* Plot 6 is not applied by the MNY method, because it was not canopy-closed plot.

## 4. COUPLING ALGORITHM

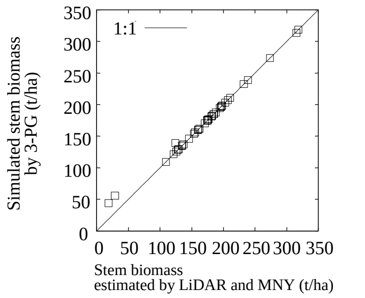
**Fig. 3 The scheme of coupling algorithm**




FR: Soil fertility

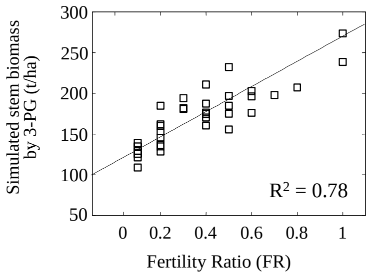
## 5. RESULTS

**Fig. 4 Stem biomass by observation vs. Simulated stem biomass**



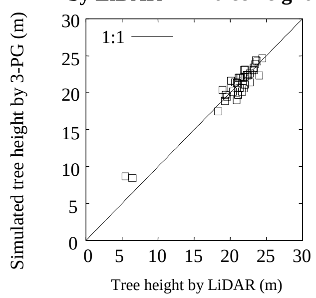

Parameters are tuned in each plot appropriately.

**Fig. 5 The relation between simulated stem biomass and fertility ratio at 43 years plots**



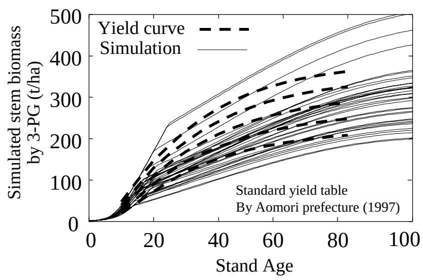

The FR values constrain the converting factor.

**Fig. 6 Tree height by LiDAR vs. Simulated tree height**




The model reconstructs each forest stand.

**Fig. 7 The estimation of stem biomass for 100 years**




Compared to yield table, the model estimates time series stem biomass appropriately.

## 6. CONCLUSION

- In this study, LiDAR data is coupled with process-based forest growth model "3-PG" for a Japanese cedar plantation.
- The tuning scheme works well. Compared to yield table values, the model estimates time series stem biomass appropriately.
- <u>Tree height data derived by remote sensing would play an important role in improving estimating time-series forest biomass and productivity using process-based forest growth model.</u>

< Future tasks >

- Scaling up to extensive area. Estimating site environmental factors (solar radiation and soil water) using DEM for the scaling up.

• Landsberg, J.J. and Waring, R.H. 1997. A generalized model of forest productivity using simplified concept of radiation-use efficiency, carbon balance and partitioning. *For. Ecol. Manage.* 95:209-228.
• Hozumi, K. 1971. Studies on the frequency distribution of the weight of individual trees in a forest stand III. A beta-type distribution. *Jap. J. Ecol.* 21:152-167.
• Taguchi, H., Endo, T. and Yasuoka, Y. in review. A development of a method for model-based individual conifer tree crown detection using LiDAR point clouds. *J. Remote Sens. Soc. Jpn.*