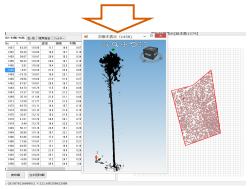
Analysis on economic balance of a clear cutting operation with terrestrial LiDAR at the Funyu experiment forest of Utsunomiya University, Japan

Kazuhiro Arugar[1], *C. Liu*[1], *R. Uemura*[1] *and A. Kato*[2]
[1]Department of Forest Science, Utsunomiya University, Utsunomiya, Tochigi, Japan
[2] Department of Environmental Science and Landscape Architecture, Chiba University, Matsudo, Chiba, Japan

Introduction

LiDAR technology is commonly used as basic information of terrain and vegetation. Airborne LiDAR could measure crown surfaces and calculate tree height and the number of trees. Then, stem volumes and stand volumes were estimated using crown volumes, tree height, the number of trees and so on. However, airborne LiDAR could not measure stem shape and stem volumes, directly. On the other hand, terrestrial LiDAR has been used to measure detailed description of stem shape such as taper, sweep and lean.

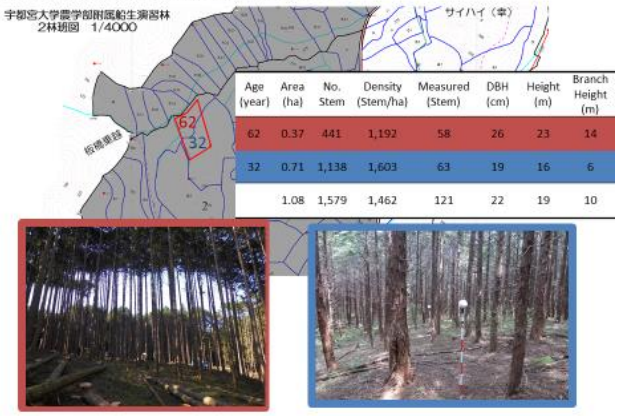




The present study applied terrestrial LiDAR with an optimal bucking algorithm to the Funyu experimental forest, Utsunomiya University, Japan.

Study site

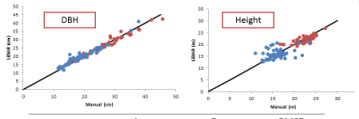
Japanese cypress and cedar



Age (year)	Area (ha)	No. Stem	Density (Stem/ha)	Measured (Stem)	DBH (cm)	Height (m)	Branch Height (m)
62	0.37	441	1,192	58	26	23	14
32	0.71	1,138	1,603	63	19	16	6
	1.08	1,579	1,462	121	22	19	10

Comparison between manual and LiDAR measurements

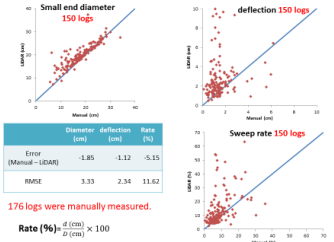
DBH and Height



	Average		Error		RMSE	
Age (year)	Density (stems/ha)	DBH (cm)	Height (m)	DBH (cm)	Height (m)	DBH (cm)	Height (m)
62	1,192	26.08	22.69	0.47	0.68	1.35	1.41
32	1,603	18.79	16.08	-0.34	0.41	1.33	2.29
	1,462	22.28	19.25	0.05	0.54	1.34	1.92

DBH were normally rounded to 2 cm; therefore, RMSE of DBH were within allowable ranges.
RMSE of height on the 32-year-old forest was higher than the 62-year-old forest because of higher stand density and disrupting a laser scanning.

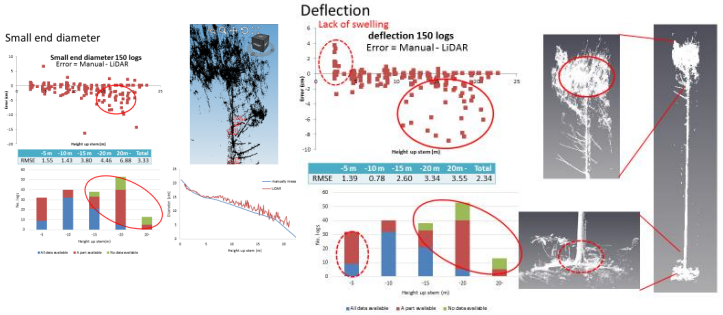
Small end diameter, defletion, an sweep rate



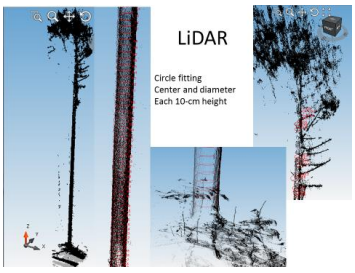
	Diameter (cm)	deflection (cm)	Rate (%)
Error (Manual – LiDAR)	-1.85	-1.12	-5.15
RMSE	3.33	2.34	11.62

176 logs were manually measured.

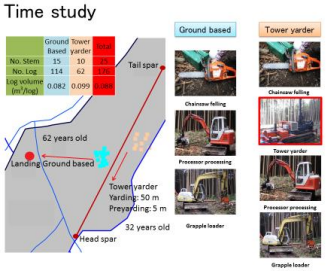
Rate (%)$=\frac{d\,(\mathrm{cm})}{D\,(\mathrm{cm})}\times 100$



Method



Time study



Manual measurements

Cost estimation
Productivity
Labor cost: USD26.09/h
Machinery cost
Chainsaw: USD4.02/h
Processor: USD40.54/h
Grapple loader: USD23.59/h
Tower yarder: USD27.59/h

- Chainsaw felling V_{tr}: stem volume (m³/stem)

$$C_c=\frac{1.05}{V_{tr}}+1.78\ (\mathrm{USD/m^3})$$

- Processor processing V_{lo}: log volume (m³/log), n: No. log

$$C_p=\frac{(2.42V_{lo}+0.23)n+1.56}{Vl_{tot}n}\ (\mathrm{USD/m^3})$$

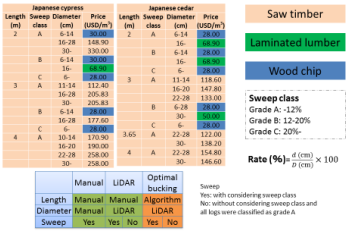
- Grapple Loader V_{lo}: log volume (m³/log), n: No. log

$$C_g=\frac{1.50}{Vl_{tot}n}+2.46\ (\mathrm{USD/m^3})$$

- Tower yarder x yarding distance (m), μ: prevarding disntace (m)

$$C_t=0.05x+0.16y+4.42\ (\mathrm{USD/m^3})$$

Revenue



	Manual	LiDAR	Optimal bucking
Length	Manual	Manual	Algorithm
Diameter	Manual	LiDAR	LiDAR
Sweep	Yes	Yes	No	Yes	No

Saw timber
Laminated lumber
Wood chip

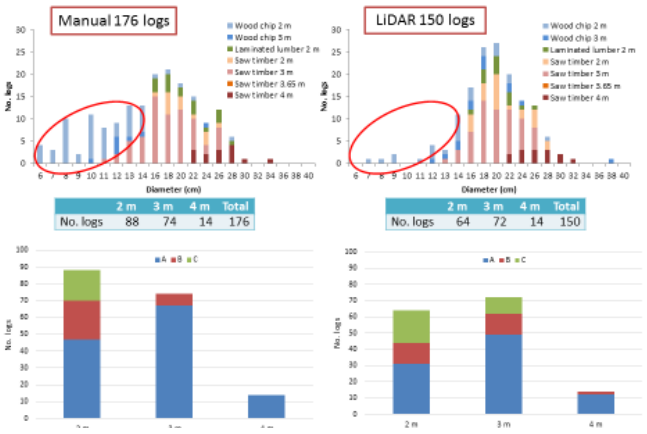
Sweep class
Grade A: -12%
Grade B: 12-20%
Grade C: 20%-

Rate (%)$=\frac{d\,(\mathrm{cm})}{D\,(\mathrm{cm})}\times 100$

Sweep
Yes: with considering sweep class
No: without considering sweep class and all logs were classified as grade A

Result

Diameter, length and sweep class distribution



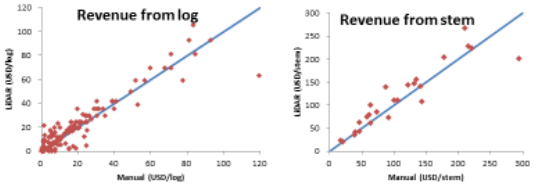
	2 m	3 m	4 m	Total
No. logs	88	74	14	176

	2 m	3 m	4 m	Total
No. logs	64	72	14	150

Economic balance

	Manual	LiDAR		Optimal bucking	
Length	Manual	Manual		Algorithm	
Diameter	Manual	LiDAR		LiDAR	
Sweep	Yes	Yes	No	Yes	No
No. logs	176	150	150	125	127

Cost Including Indirect cost
Transportation cost: USD13.00/m³
In the log auction market,
handling fee: 8% of revenues
piling fee: USD7.00/m³.



Corresponding author: Kazuhiro Aruga
Department of Forest Science
Faculty of Agriculture
Utsunomiya University
E-mail: aruga@cc.utsunomiya-u.ac.jp