Examining the optimal bucking method of clear cutting operations in Nasu Forest Owners' Co-operative, Tochigi prefecture, Japan

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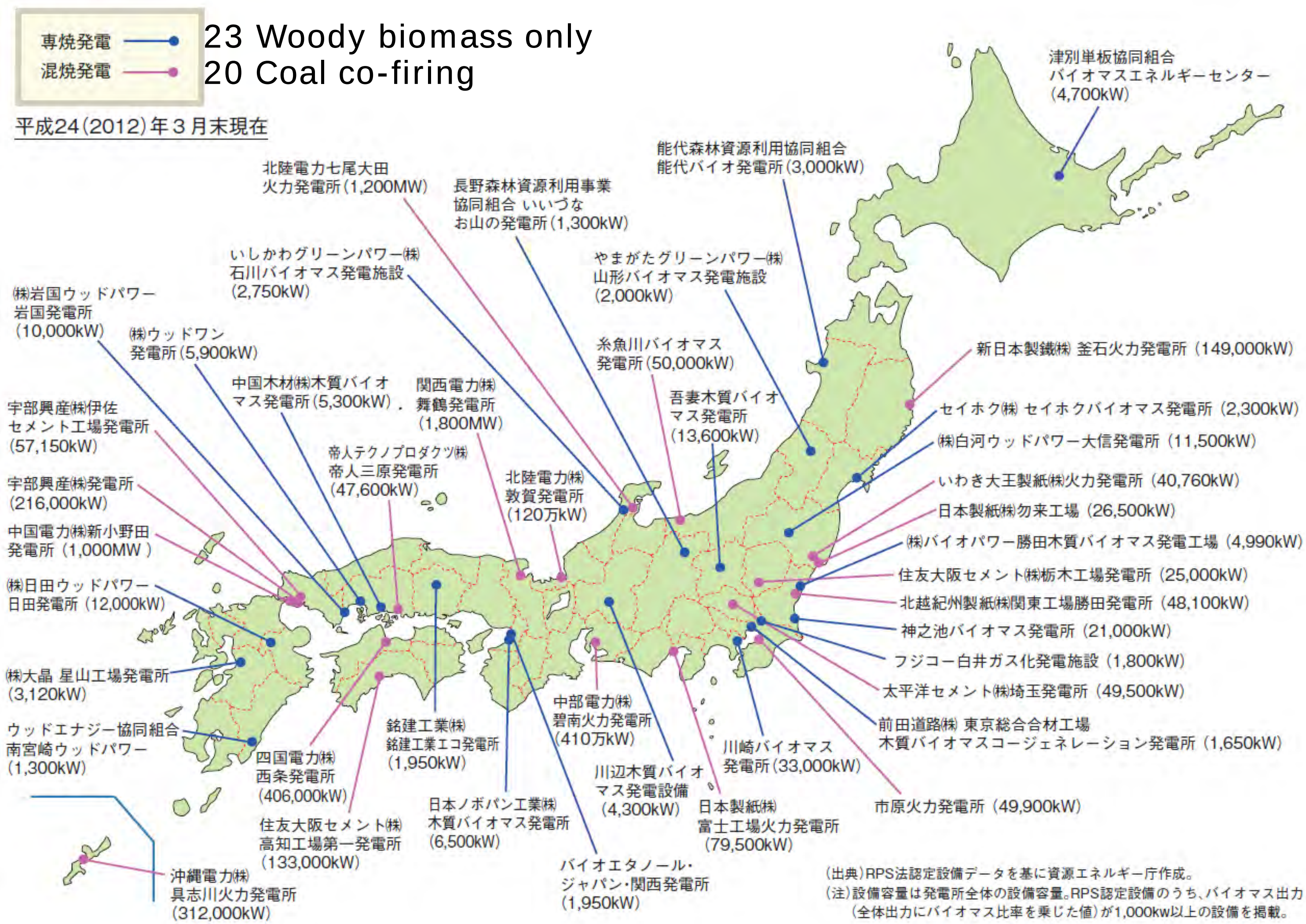
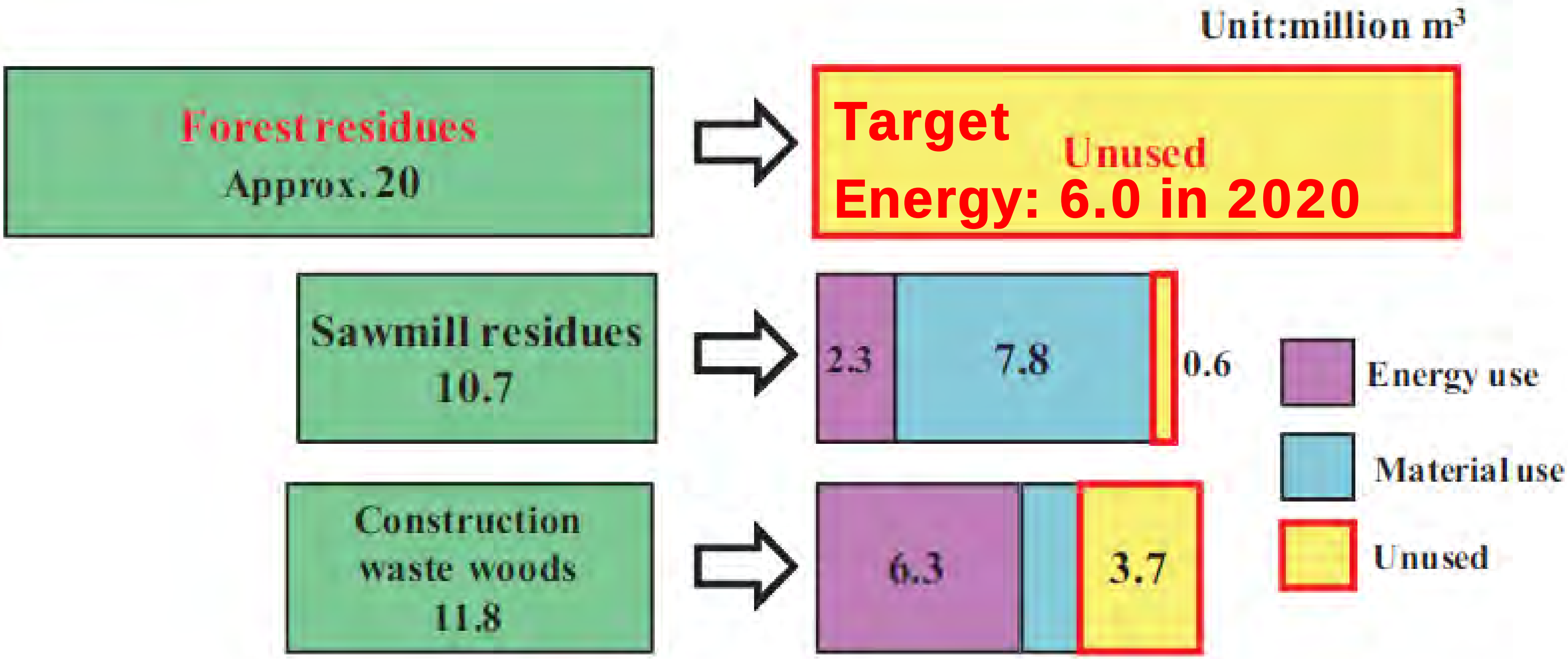
43 woody biomass power generation plants in Japan



Sources and Utilization of Woody Biomass (Japan Forestry Agency 2009)



- These resources are mainly supplied by sawmill residues and construction waste woods.
- Large amount of woody biomass, in particular forest residues, still remains unused due to high harvesting costs.

Feed-in tariffs (FIT) in Japan

- Feed-in tariffs (FIT) were introduced in Japan from July 1, 2012.
- In FIT, power generation with unused materials such as thinned woods and logging residues was gave incentives.
- Buying prices: 32 cents/kWh for unused woods
  - 24 cents/kWh for general woods: sawmill residues
  - 13 cents/kWh for recycled woods: construction waste
  - Power generation costs: about 8 cents/kWh for coal
- Over 50 plants with unused materials were planned or under construction, and will be operated this year.

Introduction

Logging residue

Saw log

Small diameter log

- The extraction of small diameter logs and logging residues could increase total revenues, but would also increase costs compared with saw logs, subsequently might decrease profitability.

Introduction

- Nakahata, C., Aruga, K. & Saito, M. (2014): Examining the optimal bucking method to maximize profits in commercial thinning operations in Nasunogahara area, Tochigi Prefecture, Japan. *Cro J For Eng* **35**(1), 45-61.
- In this study, clear cutting operations were investigated and the relationships between log sizes and operational costs were analyzed.
- Then, the equations to estimate operational costs according to log sizes and the optimal bucking methods to maximize profits were developed.
- Finally, the optimal bucking methods were applied to two operational sites in numerical experiment.

Contents

- Study sites
- Development of the equations to estimate operational costs according to log sizes
- Development of the optimal bucking method to maximize profits
- Examination of the optimum extraction rate of extracting thinned woods

Nasu in Tochigi Prefecture, Japan

Study sites

- Site A: 0.77 ha
- Age: 58 years old
- DBH: 30 cm
- Height: 23 m
- Volume: 0.89 m^3/stem
- Slope: 28 degrees

- Site B: 1.45 ha
- Age: 50 years old
- DBH: 28 cm
- Height: 22 m
- Volume: 0.71 m^3/stem
- Slope: 6 degrees

Forestry operation system

Chainsaw felling

↓

Grapple-loader bunching

↓

Processor processing

↓

Forwarder forwarding

↓

Truck transportation

- Strip road for operation
- Road width: 3.5 m
- Road density: 300 m/ha
- Road cost: USD5.00/m

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The existing equations to estimate operational costs

- Chainsaw felling OE_F

Site A: $0.45/V_n + 0.51$ (USD/m³)

Site B: 0.58 (USD/m³)

V_n: Stem volume (m³/stem)

- Grapple-loader bunching OE_S

Site A: 6.40 (USD/m³)

Site B: 4.23 (USD/m³)

- Productivities of chainsaw felling and grapple-loader bunching were not affected by log sizes because these operations were conducted with whole trees. The existing equations to estimate operational costs were used.

The existing equations to estimate operational costs

- Processing OE_P

Site A: $2.32/V_l + 2.50$ (USD/m³)

Site B: $1.12/V_l + 2.05$ (USD/m³)

V_l: Extracted volume per stem (m³/stem)

- Forwarding OE_E

Site A: $0.00448L + 4.79$ (USD/m³)

Site B: $0.00482L + 5.07$ (USD/m³)

L: Forwarding distance (m)

- The existing equations consisted of extracted volumes for processing and forwarding distances for forwarding.

The existing equations to estimate operational costs

- Processing OE_P

Site A: $2.32/V_l + 2.50$ (USD/m³)

Site B: $1.12/V_l + 2.05$ (USD/m³)

- Forwarding OE_E

Site A: $0.00448L + 4.79$ (USD/m³)

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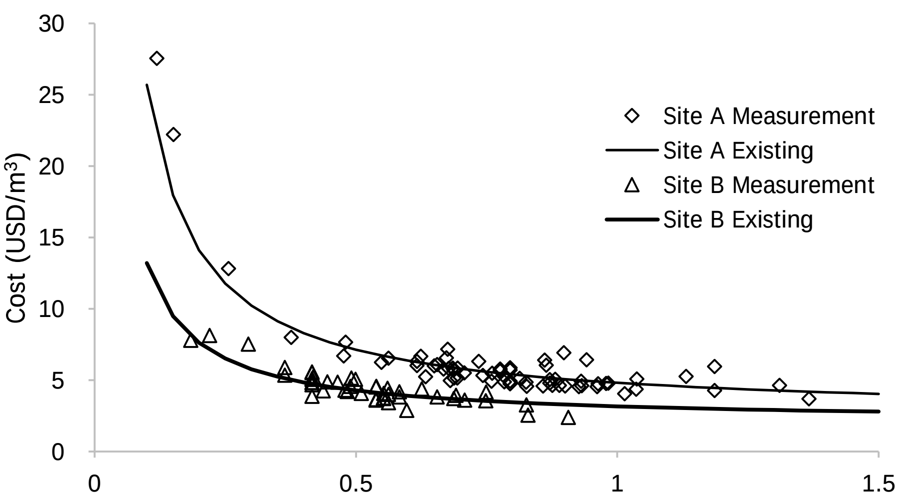
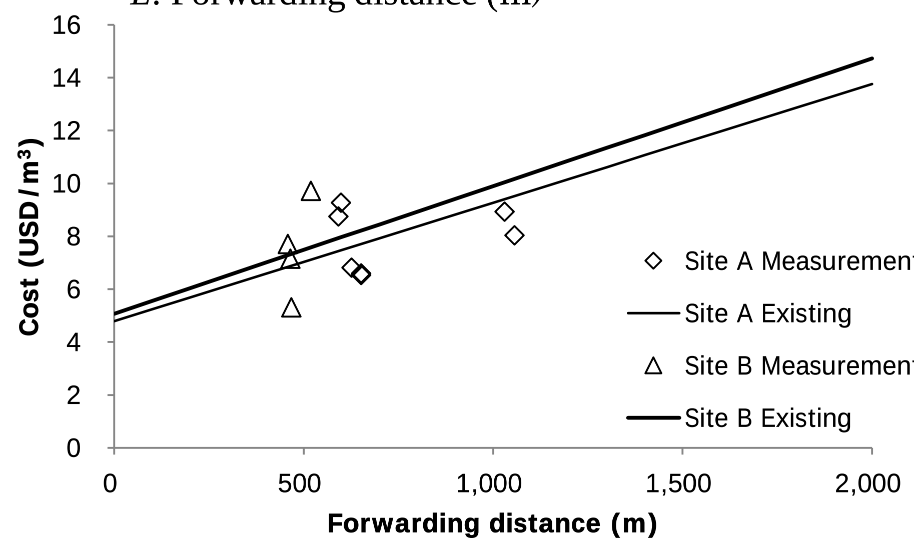
V_l: Extracted volume per stem (m³/stem)



L: Forwarding distance (m)



- The existing equations did not consider log sizes. Measured values were different even with same extracted volumes and forwarding distances.

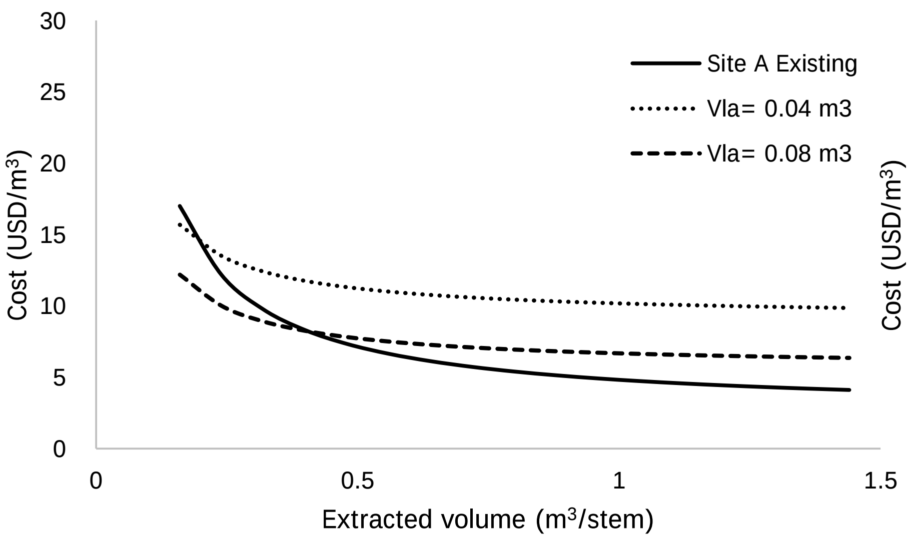
Development of the equations to estimate operational costs according to log sizes

- Processing OE_P

Site A: $\frac{(2.13Vla+0.28)n+1.05}{Vla \times n}$ (USD/m³)

Site B: $\frac{(0.65Vla+0.19)n+0.60}{Vla \times n}$ (USD/m³)

Vla: Log volume (m³/log), n: No. of log (log/stem)

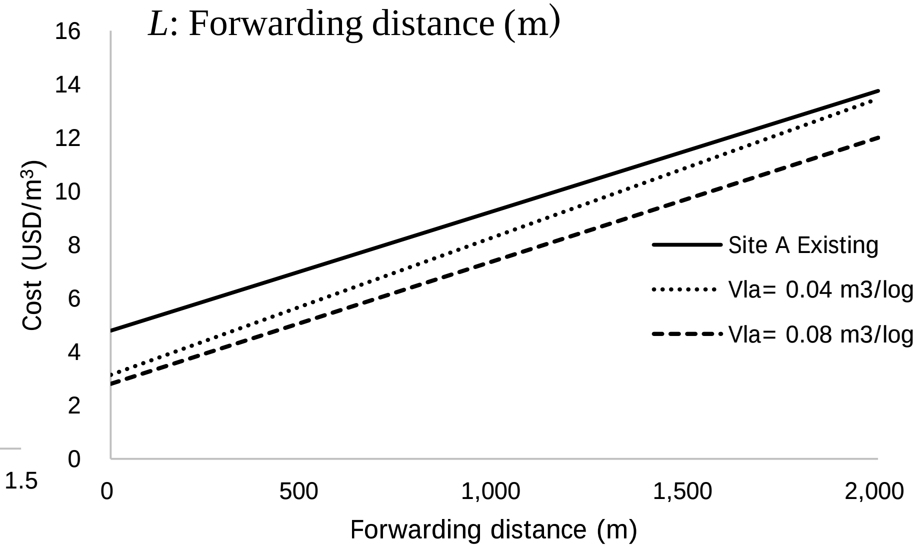


- Forwarding OE_E

Site A: $\frac{0.0118L+0.0541n+6.50}{6.93Vla+2.01}$ (USD/m³)

Site B: $\frac{0.0127L+0.0541n+6.50}{6.93Vla+2.01}$ (USD/m³)

Vla: Log volume (m³/log), n: No. of log (log/stem), L: Forwarding distance (m)



- This study developed the equations consider log sizes. Costs were reduced according to the increased average log volume.

Development of the optimal bucking method to maximize profits

- Determination of the taper-curve formula
- Estimation of extracted volumes
- Estimation of revenues
- Estimation of expenses
- Estimation of economic balances
- Determination of the optimal bucking method and extraction rate to maximize profits.

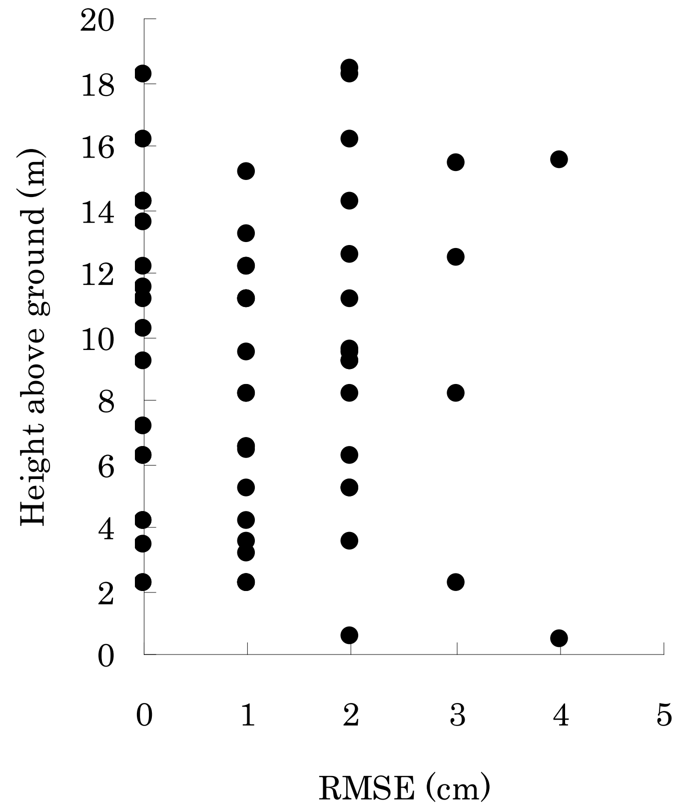
Determination of the taper-curve formula

Stem diameter *d* (cm) at the height above ground *h* (m) was estimated in the following taper-curve formula

$$d = \frac{\{a(1-1.2/H)-0.9a+1.8\}(1-h/H)}{\{a(1-h/H)-0.9a+1.8\}(1-1.2/H)}D$$

$$a = \frac{(18-21.6/H)-12.6\sqrt{7/10f}}{(2-2.4/H)+(0.7-8.4/H)\sqrt{7/10f}}$$

$$f = 4Vn/(HD^2\pi/10{,}000)$$



- Average RMSE was 1.1 cm. Log diameters were usually rounded by 2 cm. Therefore, RMSE was within allowable ranges.

Estimation of extracted volumes and revenues

- Extracted volumes and revenues were estimated with possible combinations of log length bucked from a wood using log prices
- Saw logs between USD75.00/m^3 and USD130.00/m^3
  - 3.00-m long exceeding 10-cm diameter
  - 3.65-m long exceeding 26-cm diameter
  - 4.00 m long exceeding 10-cm diameter
- Lamina logs with USD50.00/m^3
  - 2.00-m long exceeding 16-cm diameter.
- Chip logs with USD30.00/m^3
  - 2.00-m long exceeding 6-cm diameter

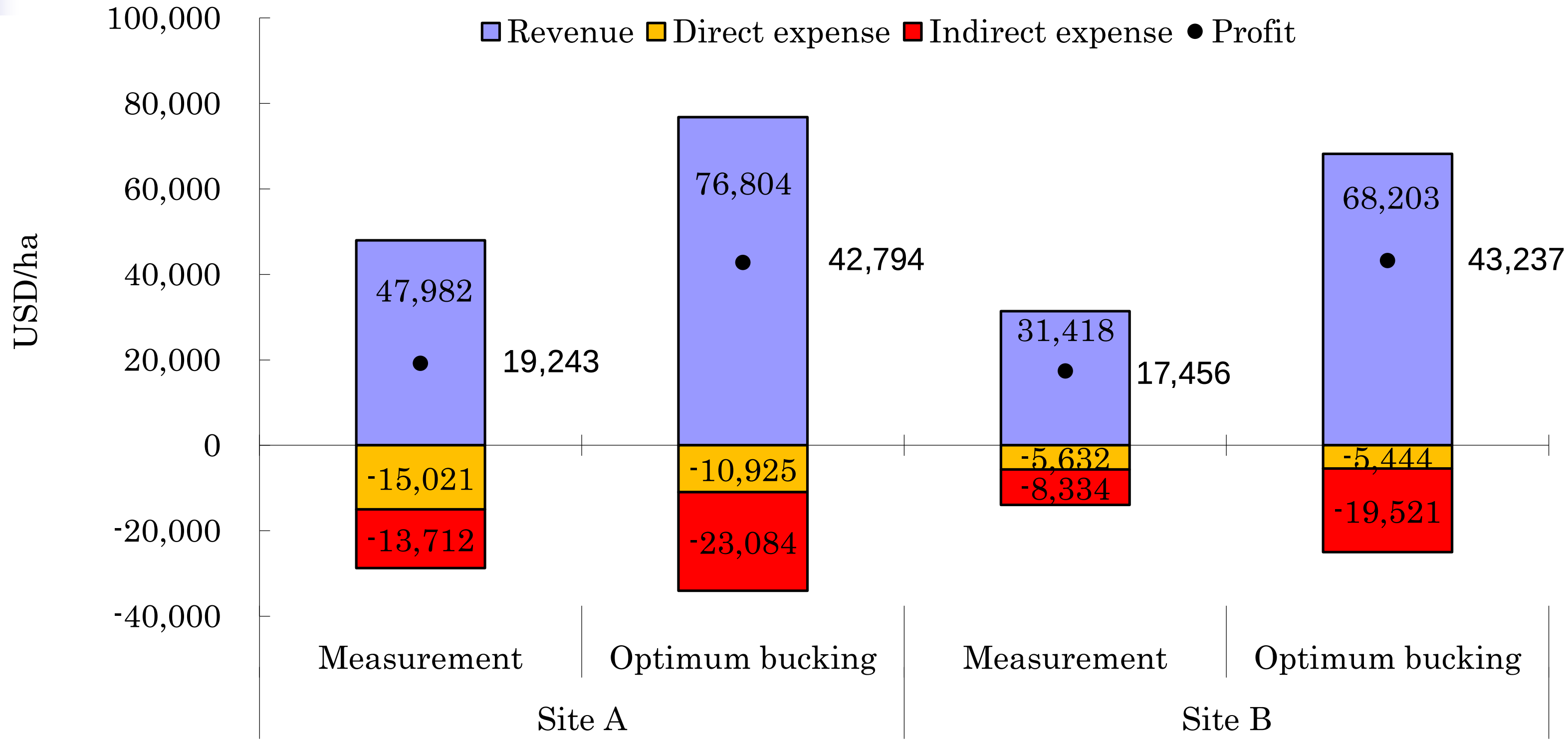
Estimation of expenses

- Direct operation expenses: chainsaw, grapple-loader, processor, forwarder
- Strip road expenses: USD5.00/m
- Truck transportation expenses: USD13.00/m^3 for saw logs, USD0/m^3 for lamina and chip logs because of landing sale
- Machine transportation expenses: USD50.00/machine
- Insurance costs: 20% of direct expenses
- Handling fees of forest owners' cooperative: 5% of revenues
- Handling fees of the log market: 5% of revenues in the log market
- Piling fees in the log market: USD7.00/m^3

Estimation of economic balances

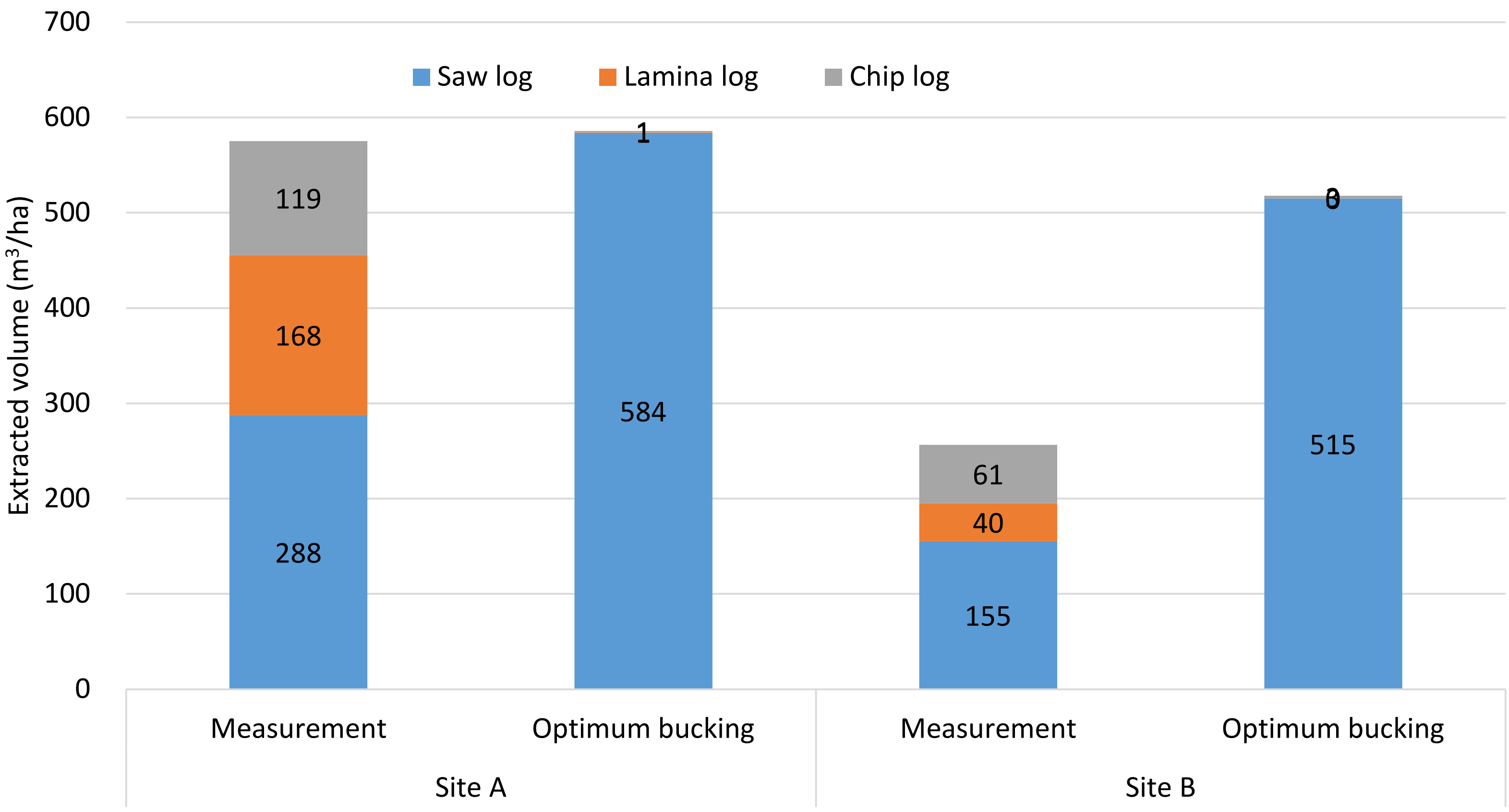
- Economic balances were estimated with revenues and costs of possible combinations of log length bucked from a wood.
- The optimal bucking method and the optimal extraction rate were determined as the bucking method and the extraction rate with maximum profits.

Economic balances



- Revenues were increased according to the increased saw log volumes with relatively higher log prices.
- Direct expenses were decreased according to the increased average log volumes using the equation developed in this study.

Extracted volume



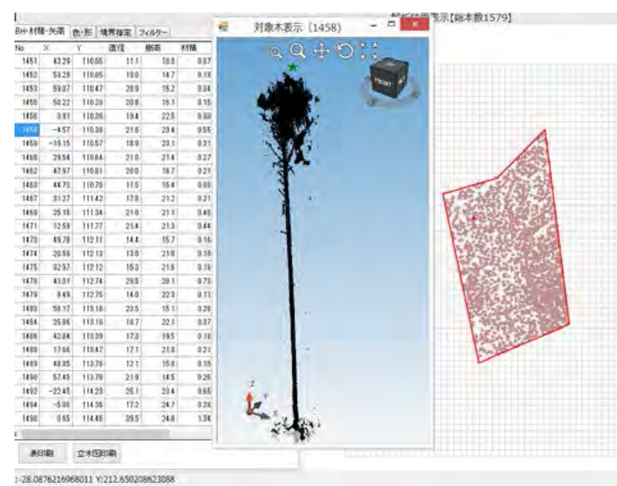
- The optimum bucking successfully optimized extracted volumes to increase saw logs with relatively higher log prices.

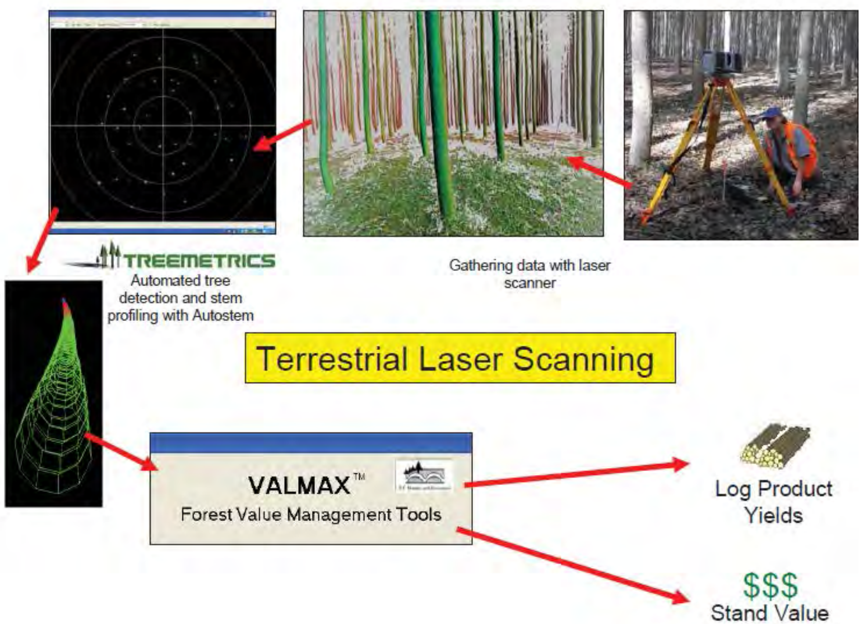
Future study

- Stem diameter at the height above the ground was estimated with the taper curve formula.
- Detailed description of stem shape such as sweep and lean were not considered.
- Terrestrial LiDAR has been used to measure detailed description of stem shape.
- The future study will apply terrestrial LiDAR to optimal bucking algorithm to consider detailed description of stem shape such as sweep and lean.

Terrestrial LiDAR

- Murphy, GE, Acuna, MA, and Dumbrell, I. (2010): Canadian Journal of Forest Research. 40:2223-2233

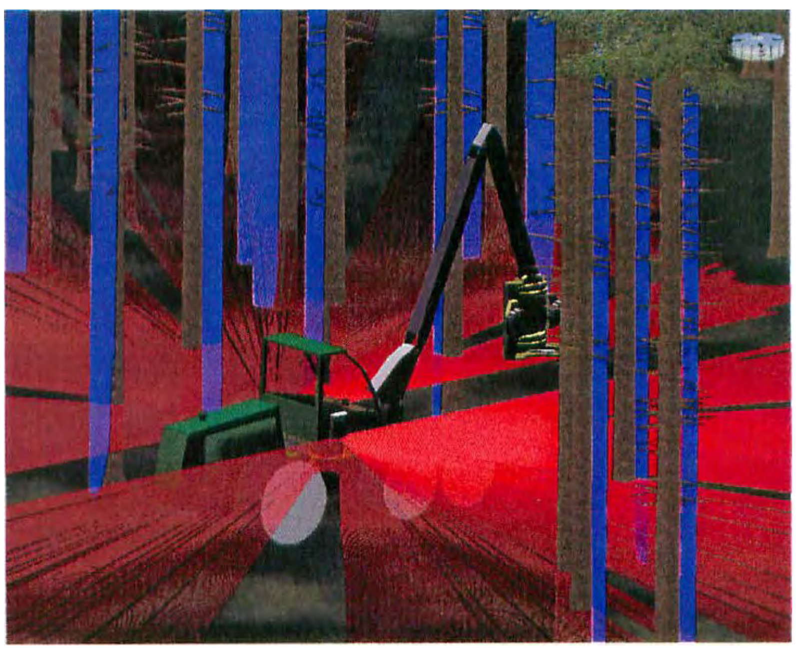


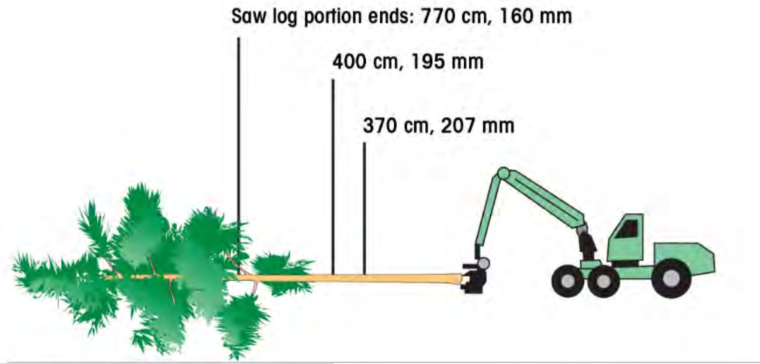


Treemetrics, Ireland

Future study

- Rossmann, J., Schluse, M.,Schlette, C., Buecken, A., Krahwinkler, P., and Emde, M. (2010): Journal of Forest Planning. 16:263-271





Demand matrix, T

D, mm \ L, cm	330	410	490	530
300	20	10	50	20
320	20	10	40	30
340	30	30	30	10
360	20	30	40	10

Output matrix, O

D, mm \ L, cm	330	410	490	530
300	12	5	55	20
320	9	1	48	45
340	22	30	24	23
360	19	7	29	3

Price matrix, P

D, mm \ L, cm	330	410	490	530
300	400	400	400	400
320	400	400	400	400
340	400	400	400	400
360	400	400	400	400

Deviation matrix, D

D, mm \ L, cm	330	410	490	530
300	-8	-5	5	0
320	-11	-9	8	15
340	-8	0	-6	13
360	-1	-23	-11	-7

New price matrix, P′

D, mm \ L, cm	330	410	490	530
300	420	410	380	380
320	420	420	380	380
340	420	380	410	380
360	410	420	420	410

- Uusitalo, J. (2010): Introduction to forest operations and technology