Stem Taper Models for Volume and Biomass Estimation of Japanese Cedar in Jeju Island, Korea: A Tool for Climate Change Mitigation

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Content

I. Introduction and Objectives
II. Methodology
III. Results and Discussion
IV. Application
V. Conclusion
VI. References
Introduction

Biomass and carbon stock estimations in forests have become a major research interest because of the **CRUCIAL ROLE OF FORESTS** in global climate change.

United Nations Framework Convention on Climate Change

different countries are required to accurately assess the carbon stocks available in their forests.
**Introduction**

**Stem taper equation** - one of the most useful tools to accurately predict the:

- Stem diameter at any given height \((d)\),
- Volume and
- Biomass and \(\text{CO}_2\) of a tree
Objectives

Develop stem taper models for Japanese cedar in Korea

Evaluate the performance of these stem taper models in predicting $d$ and total stem volume.
Content

I. Introduction
II. Objective
III. Methodology
IV. Results and Discussion
V. Application
VI. Conclusion
VII. References
Study sites: Jeju Island, South Korea

Location:
33° 11' to 33° 33' N
126° 08' to 126° 58' E

Total land area:
184,400 ha

Forest:
88,874 ha
ha (48%)
A total of 120 trees were harvested for the measurement of DBH ($D$ in cm), Total height ($H$, in m), diameter ($d$ in cm) and height of $d$ from the ground ($h$ in m).

Most of the stem taper models use $H$, $D$, and $h$ as predictor variables.

$H$ and $d$ from 2.2 m up to the top of the tree with 1 m interval were measured after felling.
### Materials and Methods

#### Stem Taper Modeling

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
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<th>Minimum</th>
<th>Maximum</th>
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</table>
Six commonly used stem taper equations:

a. variable exponent or form taper models

Kozak88 equation (Kozak 1988)

\[ d = a_1 D^{a_2} a_3^D X^{b_1 Z^2 + b_2 \ln(Z + 0.001) + b_3 Z^{1/2} + b_4 \epsilon Z + b_5 (D/H)} \]

Kozak01 equation (Kozak 2004)

\[ d = a_1 D^{a_2} X^{b_1 + b_2 (1/e^{D/H}) + b_3 D^X + b_4 X^{D/H}} \]

Kozak02 equation (Kozak 2004)

\[ d = a_1 D^{a_2} H^{a_3} X^{b_1 Z^4 + b_2 (1/e^{D/H}) + b_3 X^{0.100} + b_4 (1/D) + b_5 H^0 + b_6 X} \]
Materials and Methods

Six commonly used stem taper equations:

a. variable exponent or form taper models

Lee03 equation (Lee et al. 2003)

\[ \hat{d} = a_1 D^{a_2} \left( 1 - Z \right)^{b_1 Z^2 + b_2 Z + b_3} \]

Modified Lee 2003 equation (Berhe and Arnoldsson 2008)

\[ \hat{d} = a_1 D^{a_2} \left( 1 - \sqrt{Z} \right)^{b_1 Z^2 + b_2 Z + b_3} \]

b. segmented polynomial taper model

MB76 equation (Max and Burkhart 1976)

\[ \frac{d^2}{D^2} = b_1 (Z - 1) + b_2 (Z^2 - 1) + b_3 (a_1 - Z)^2 I_1 + b_4 (a_2 - Z)^2 I_2 \]
Model parameters were estimated using the Statistical Analysis System Non-linear (SAS NLIN) procedure (SAS Institute Inc. 2004).

Kozak (2004) recommended: standard error of estimate (SEE), mean bias, mean absolute bias (MAB) and coefficient of determination ($R^2$).

To determine the best model, rank analysis was employed.
Content

I. Introduction
II. Objective
III. Methodology
IV. Results and Discussion
V. Application
VI. Conclusion
VII. References
Results and Discussion

Estimated parameters of the six candidate stem taper models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kozak88</th>
<th>Kozak01</th>
<th>Kozak02</th>
<th>MB76</th>
<th>Lee03</th>
<th>Mod Lee03</th>
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## Results and Discussion

Evaluation statistics of the different fitted stem taper models

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Performance of the taper models to accurately predict total stem volume was also assessed using lack of fit statistics.

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<td>2</td>
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</table>
Several studies proved that Kozak88 stem taper model can provide accurate estimate of $d$ for various species in different countries.

- Huang et al. (2000) - *Picea glauca* in Alberta, Canada
- Klos et al. (2007) - for the five major commercial trees (*Populus balsamifera*, *Populus tremuloides*, *Picea glauca*, *Picea mariana* and *Pinus banksiana*) in Manitoba, Canada.
- In Sweden, Hjelm (2013) - *Populus maximowiczii* x *P. trichocarpa*
- In Ethiopia, Berhe and Arnoldsson (2008) - for *Cupressus lusitanica*
- Son et al. (2009) - for *Acacia mangium* and *Eucalyptus pellita* in Kalimantan, Indonesia
Results and Discussion

The stem taper models can be applied in the estimation of stem form of Japanese cedar.
Kozak88 model VS volume model developed for Japanese cedar by Lee et al. (2001) VS computer program called Forest Resources Evaluation and Prediction Program (FREPP) in predicting volume of Japanese cedar
Content

I. Introduction
II. Objective
III. Methodology
IV. Results and Discussion
V. Application
VI. Conclusion
VII. References
What is the Volume, Biomass, and Carbon sequestered of a Japanese cedar with a DBH of 32 cm and total height of 20 m?

You cannot cut this tree!
Volume, Biomass, Carbon prediction of Japanese cedar

The $d$ in the different $h$ should be predicted first using the best model (Kozak88)

Using the Smalian formula, the volume of the different log section can be determined and summed up for the total stem volume estimation.

Smalian’s Formula:

$$\text{Volume} = 0.00007854 \times \left[\frac{(d_1^2 + d_2^2)}{2}\right] \times L$$
The \( d \) starting from the stump height (0.20 from the ground) to the \( H \) with intervals of 0.50 m, can be predicted as follows:

\[
d_1 = 0.7683 \times 32^{1.2363} \times 0.9922^{32} \times 1.01^{[2.1374 \times 0.04^2] + [-0.9214 \ln(0.04 + 0.001)] + [2.9157 \times 0.04^{1/2}] + [-1.6652 \exp^{0.04}] + [0.0949(32/20)]}
\]

\( d_1 = 44.10 \text{ cm} \)

The \( d \) of the next height position \( (h_2 = 0.70 \text{ m}) \) can also be predicted as follows:

\[
d_2 = 0.7683 \times 32^{1.2363} \times 0.9922^{32} \times 0.91^{[2.1374 \times 0.04^2] + [-0.9214 \ln(0.04 + 0.001)] + [2.9157 \times 0.04^{1/2}] + [-1.6652 \exp^{0.04}] + [0.0949(32/20)]}
\]

\( d_2 = 35.67 \text{ cm} \)
This process will be done at every 0.5 m height position until the 19.70 m.

After the estimation of \( d \), the volume for each log section can now be determined as shown below:

\[
\text{Volume}_1 = 0.00007854 \times \left[ \frac{(44.10^2 + 35.67^2)}{2} \right] \times 0.5
\]

\[
\text{Volume}_1 = 0.0632 \text{ m}^3
\]

By summing up the volumes from the different sections, the total stem volume of this tree is 0.7272 m\(^3\)
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</table>
Wood density of Japanese cedar is 0.37 g cm$^{-3}$ (Jung et al. 2014)

Stem Biomass of this tree: 269.06 kg

Carbon (Stem) sequestered (47% of Biomass is Carbon as suggested by IPCC): 126.46 kg

CO$_2$ sequestered: 464.11 kg
The Kozak88 model provided the best performance in accurately predicting $d$ of Japanese cedar in the southern part of Korea.

The Kozak88 model also showed its superiority in total volume estimation as compared to the other stem taper models.

This model was also superior as compared to the FREPP computer program and volume model developed by Lee et al. (2001) in accurately estimating the total stem volume of Japanese cedar.
Stem Taper Modeling

References


Korea Forest Service. 2012. Statistical yearbook of forestry p488


• Yoon WJ, Kim SS, Oh TH, Lee NH, Hyun CG. 2009. Cryptomeria japonica Essential Oil Inhibits the Growth of Drug-Resistant Skin Pathogens and LPS-Induced Nitric Oxide and Pro-Inflammatory Cytokine Production. Pol J Microbiol 58(1):61-68
Thank You very much!