Evaluation of Some Stem Taper Models for *Camellia japonica* in Mount Halla, Korea

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**Abstract:** This study was conducted to evaluate the performance of the four stem taper models on *Camellia japonica* in Jeju Island, Korea using fit statistics and lack-of-fit statistics. The five statistical criteria that were used in this study were standard error of estimate (SEE), mean bias (\( \bar{E} \)), absolute mean difference (AMD), coefficient of determination \( (R^2) \), and root mean square error (RMSE). Results showed that the Kozak model 02 stem taper had the best performance in all fit statistics (SEE: 3.4708, \( \bar{E} \): 0.0040 cm, AMD: 0.9060 cm, \( R^2 \): 0.9870, and RMSE: 1.2545). On the other hand, Max and Burkhart stem taper model had the poorest performance in each statistical criterion (SEE: 4.2121, \( \bar{E} \): 0.2520 cm, AMD: 1.1300 cm, \( R^2 \): 0.9805, and RMSE: 1.5317). For the lack-of-fit statistics, the Kozak model 02 also provided the best performance having the best AMD in most of the relative height classes for diameter outside bark prediction and in most of the DBH classes for total volume prediction while Max and Burkhart had the poorest performance. These stem taper equations could help forest managers to better estimate the diameter outside bark at any given height, merchantable stem volumes and total stem volumes of the standing trees of *Camellia japonica* in the forests of Jeju Island, Korea.

**Keywords:** Mount Halla; Stem volume; Diameter outside bark; Kozak model; Model evaluation

**Introduction**

Accurate methods for estimating total and merchantable volumes are important for efficient forest inventory which is essential for sustainable forest management (Fonweban 1999; Hofstads 2005; Akindele and LeMay 2006; Haywood 2009; Guendehou et al. 2012). Models that can estimate stem volume at any height are important in forest growth and yield modeling (Klos et al. 2007) and are considered as prerequisite for a successful forest planning and management (Kublin et al. 2008). Several authors (Figueiredo-Filho et al. 1996; Jiang et al. 2005; Ozelik et al. 2011; Subedi et al. 2011; Li et al. 2012) stated that stem taper equation is one of the most accurate methods that can predict the stem diameter at any given height and volume of standing trees. Most of the stem taper models use total height, DBH, and height above the ground as predictor variables (Berhe and Arnoldsson 2008) because these are usually measured during forest inventories (Brook et al. 1997).
According to Berhe and Arnoldsson (2008) and Li et al. (2012), the most commonly used stem taper equations could be divided into two major categories. First is the segmented polynomial taper model such as Max and Burkhart (1976) stem taper model, which according to Kozak (1988) uses different sub-functions for various parts of the stem. The second one is the continuous variable exponent or form taper models such as Kozak taper models (Kozak 1988; 2004), wherein it is assumed that the form of the tree changes continuously along the stem (Yang et al. 2009; Li and Weiskittel 2010; Heidarsson and Pukkala 2011; Li et al. 2012). Kozak (2004) explained that stem taper equations are better compared to the conventional volume equations because the former can estimate the stem diameter at any height along the stem, merchantable height to any top diameter and from any stump height, and volume of a stem log at any length and at any height from ground in addition to merchantable stem volume and total stem volume. Moreover, different researches had proven the accuracy and efficiency of stem taper models for the different species in many countries (Figueiredo-Filho et al. 1996; Brooks 2001; Brooks et al. 2002; Lee et al. 2003; Kozak 2004; Jiang et al. 2005; Rojo et al. 2005; Coble and Hilpp 2006; Corral-Rivas et al. 2007; Klos et al. 2007; Berhe and Arnoldsson 2008; Brooks et al. 2008; Son et al. 2009; Li and Weiskittel 2010; Heidarsson and Pukkala 2011; Li et al. 2012). In Korea, the Kozak (1988), Max and Burkhart (1976), and Lee et al. (1999) stem taper equations are the most commonly used taper models that were fitted to the different species. In most studies in this country, the Kozak (1988) model has provided better performance as compared to the two stem taper equations specifically for six major tree species (Pinus densiflora, Pinus rigida, Pinus koraiensis, Larix kaempferi, Quercus accutissima and Quercus mongolica) (Son et al. 2002), and Quercus acuta in Jeju Island (Chung et al. 2010).

The Republic of Korea has a total of 5164 ha of experimental forests being managed by the Korea Forest Research Institute (KFRI) and approximately 3053 ha can be found in Jeju Island, the southernmost part of this country (KFRI 2014). The three experimental forests in this island namely, Gotjawal (300 ha), Hannam (1203 ha) and Seogwipo (1550 ha) are classified as subtropical forests (KFRI 2014). One of the most dominant tree species in these forests is the Camellia japonica. However, growth and yield model such as stem taper equation has not been developed for Camellia japonica. Developing stem taper models for this species could help forest managers to easily determine the stem diameter at any given height and subsequently, the volume of the standing trees of Camellia japonica. Thus, the objective of this study was to develop stem taper models for Camellia japonica in Jeju Island, Korea and to evaluate the performance of these stem taper models.

1 Materials and Methods

1.1 Study site

Jeju Island is located in the southernmost part of South Korea between 126°08’43” to 126°58’20” E and 33°11’27” to 33°33’50” N (Lee et al. 2009) which according to the Korea Forest Service (2012), has total land area of 184,840 ha and 88,874 ha forest cover. Specifically, the study sites were located in the three experimental forests of Jeju Island (Figure 1). The elevation of Hannam experimental forest ranges from 300-750 m above sea level (a.s.l.) and it was 500-900 m a.s.l. in Seogwipo experimental forests (KFRI 2014). On the other hand, Gotjawal forests are considered one of the most important forests in this island due to its unique ecosystem such as the Dongbaekdongsan wetland, which has been designated as a National Wetland Protected Area by the Ministry of Environment of the Republic of Korea and a Ramsar site (Ramsar Convention on Wetlands 2014). These forests are located in Mount Halla which is the highest mountain in the Republic of Korea. The Mean Annual Temperature (MAT) of this island is 15.40°C. In addition, the minimum MAT is 3.20°C and the maximum MAT is 29.80°C. The Mean Annual Precipitation is 1560.80 mm (Korea Meteorological Administration 2014).

1.2 Stem taper models

A total of 200 Camellia japonica trees were measured for DBH (cm) and total height (m) using