Estimation of Height Growth Patterns and Site Index Curves of *Pinus kesiya* in Philippines\(^1\)

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I. Objectives of the study

Site index can be evaluated using two methods which are the mathematical models and graphical method. However, the graphical method is less preferred due to the involvement of the element of subjectivity and also the difficulty in conducting statistical tests on the goodness of fit of the curve (Akindele 1991, Onyekwelu and Fuwape 1998, Onyekwelu 2005). Mathematical methods use different techniques to fit the site index curves and it could be classified as special cases of three general equation development methods which are the guide curve, difference equation and parameter prediction methods (Clutter *et al.* 1983). Among these, the guide curve is considered to be the most popular in recent times especially on even-aged single species in the different forest stands (Nanang and Nunifum 1999). In addition, this technique is very suitable for stands with temporary sampling plots (Akindele 1991).

Thus, the objectives of this study were to investigate the height growth pattern and to develop anamorphic site index curves for the pure stands of *Pinus kesiya* in the Philippines using the Chapman-Richards growth function (Richards 1959, Chapman 1961).

II. Materials and Methods

The study sites were located in the pine forest of the Northern region in Philippines. Forests in these areas are classified as tropical lower montane rainforest (Fernando *et al.* 2008). The temperature in these provinces ranges from 6°C to 26°C. The coldest months are from December to February. It has Type I climate, having two pronounced seasons. Rainy days are usually from May to October with August being the wettest month with an average rainfall of 1,000 mm and dry during the rest of the year.

A total of 60 temporary plots with a size of 20 m x 20 m were established in the pure stands of *Pinus kesiya*. The total height of the dominant and co-dominant trees inside the plots were measured. The average total height was 18.05 m with a range of 6 - 31.4 m whereas the average age was 33 years with a range of 10-83 years.

The basic growth function used in this study was the Chapman-Richards function (Richards 1959, Chapman 1961). The form of this function is

\[
H = b_1 \left(1 - \exp\left(-b_2 A\right)\right)^{b_3} \quad (1)
\]

where:
- \(H\) = total height of the tree,
- \(A\) = stand age,
- \(b_1\) = the asymptote,
- \(b_2\) = the rate parameter, and
- \(b_3\) = the shape parameter.

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In order to evaluate the model, evaluation criteria were used and these were the coefficient of determination \( R^2 \), root mean square error (RMSE), mean difference (MD), absolute mean difference (AMD) and mean percent bias (MPB).

### III. Results and Discussion

#### 1. Model fitting

Results indicated that none of the asymptotic 95% confidence intervals contained zero for each parameter estimates therefore it was concluded that the equation parameters are significant. The \( R^2 \) was 0.9684 or it was estimated that the model explained about 96.84% of the variation in the average value of height. In addition, Peng et al. (2001) stated that a larger \( R^2 \) or a value near to one is better and this means that the result of the created model is well fitted. The MD was -0.004 m while AMD was 2.566 m. Peng et al. (2001) explained that a negative value of MD indicates that the model developed gives over prediction while positive value will give under prediction. This also means that if the computed MD values are near to zero, the created model is better. On the other hand, lower AMD value means that the equation developed is more precise. Moreover, the computed RMSE was 3.331 while the MPB was 3.88%.

#### 2. Site index curves

The guide curve method described by Clutter et al. (1983) was used in this study for the development of anamorphic site index prediction equation to estimate site index (SI) for any given index age of *Pinus kesiya*. The equation for the guide curve is

\[
H = 24.3121(1 - \exp(-0.0419A))^{0.8823} \quad (2)
\]

For instance, using the index or base age \( A_0 \) of 25 for *Pinus kesiya*, as suggested by Fonweban et al. (1995), the calculated total height is 16.606 m. Goelz and Burk (1992) stated that index age is commonly selected less than the rotation age. To get the curves for the other site index values, the procedures described by Clutter et al. (1983) was also used. In this method, the rate parameter \( b_2 \) and the shape parameter \( b_3 \) of the equation (2) were constant while the asymptote parameter \( b_1 \) was varied in order to determine the needed \( H \) value if the \( A \) is equivalent to \( A_0 \). The equation created to estimate site index for any given age was:

\[
SI = H \left[ \frac{1 - \exp(-0.0419A_0)}{1 - \exp(-0.0419A)} \right]^{0.8823} \quad (3)
\]

Equation (3) can be arranged algebraically to estimate the \( H \) at a given site index and this was:

\[
H = SI \left[ \frac{1 - \exp(-0.0419A)}{1 - \exp(-0.0419A_0)} \right]^{0.8823} \quad (4)
\]