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Development of height curves for Japanese larch in relation to GIS-derived site index

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Abstract The objectives of this study were: (1) to relate the height growth pattern to the GIS-derived site index, (2) to construct various types of polymorphic height curves, and (3) to select the most accurate height curve for Japanese larch (*Larix kaempferi*). A total of 14 dominant trees were felled for stem analysis. Richards’ function was first fitted to the height/age dataset recorded from stem analyses of 14 trees, and its parameters (i.e., \(A\), \(k\), and \(m\)) were then estimated for each sample tree. The relationship between parameter \(A\) and the GIS-derived site index was significant, while that of parameters \(k\) and \(m\) were not significant. The 12 height curve equation forms developed from the Richards’ function were then fitted to the dataset consisting of 563 observations of height, age, and GIS-derived site index derived from 14 trees. All height curves were unbiased and provided an equally good fit. The shape of the height curves differed among sites of different site indices. These results indicated that Richards’ function was sufficiently flexible to represent the polymorphic height growth pattern of Japanese larch. Finally, the best-fit height curve was selected so that accurate height growth predictions would be possible at any given age and site.

Key words Height growth · Site index · Richards function · *Larix kaempferi*

Introduction

Height curves that represent height growth trajectories (patterns) with an age axis have been used to estimate the site index and predict height at any desired age. The measured height and age of site trees are used as coordinates to determine the site index from a set of height curves. Conversely, for a stand with a known site index, height curves provide a simple and efficient method to predict tree height at any given tree age (Clutter et al. 1983; Nigh and Sit, 1996; Chen et al. 1998). Thus, an accurate height curve is essential not only for determining the site index but also for predicting height growth.

The form of the height curve has evolved over several decades from anamorphic through polymorphic to site-specific curves (Wang et al. 1994). Early height curves were typically anamorphic, as derived by the guide curve method (Clutter et al. 1983). The site index could accurately describe the differences between various height curves if height curves were anamorphic. However, previous studies for several species have indicated that the height curve shape varies with the site quality (e.g., Carmean 1956, 1972; Beck 1971; Burkhart and Tennent 1977). The height growth patterns for different sites are often better described with a polymorphic growth curve, which allows for the height curves for different sites to have different shapes (McDill and Amateis 1992).

Although anamorphic height curves are still used, the most recently developed height curves are polymorphic (Goelz and Burk 1992). One way to allow polymorphism is to categorize the collected height/age data into classes and then estimate the parameters of the height curve equations for each class. For example, Carmean (1972) sorted his data into site index classes and fitted individual equations to each class. Béland and Bergeron (1996) developed height curves for each productivity class, which was a combination of surface deposit and moisture regime classes. Clutter et al. (1983) presented two other procedures to provide polymorphic height curves; one was the difference equation method and the other was the parameter prediction method. A difference form of the height/age equation is used in the difference equation method to express height at re-measurement as a function of the re-measurement age, the initial measurement age, and the height at initial measurement (e.g., Cieszewski and Bella 1989; Goelz and Burk
The objectives of this study were: (1) to relate the height growth pattern to the GIS-derived site index, (2) to construct various types of polymorphic height curves, and (3) to select the most accurate height curve for Japanese larch using stem analysis data. Additional objectives are to confirm the precision of the constructed height curves and to determine whether polymorphic height growth patterns occur.

Materials

The data used to develop height curves are derived from three sources (Clutter et al. 1983): (1) measurements of stand height and age on temporary plots, (2) measurements of height and age over time with documented trees or permanent plots, and (3) reconstructed height/age development patterns for individual trees using stem analysis techniques. Stem analysis is currently a widely used method of data collection (Johansson 1999). According to Monserud (1984), stem analysis provides information on a real growth series, allowing for the estimation of polymorphic height growth patterns. Therefore, we used stem analysis data to construct the height curves in this study.

A total of 14 stands in a plantation of Japanese larch (*Larix kaempferi*), where the stand age exceeded 38 years (base age of the site index), were selected for this study within the experimental forest of Kyushu University in Hokkaido. In each stand, a plot was laid out in an area of 20 × 20 m, representing relatively uniform terrain, soil, and stand characteristics. A site index was estimated in each plot using the GIS-derived site index model, and the dominant or codominant trees were felled for stem analysis. The general characteristics of the sample trees are summarized in Table 1. The total heights of the felled trees were measured in the field. Stem discs were cut at ground height, 0.3, 0.8, and 1.3 m above the ground, and then at 1 m intervals from 1.3 m to the top of each tree. The rings on each disk were counted in four directions with the aid of a microscope. We reconstructed the annual height/age development patterns for each sample tree using the support software for stem analysis developed by Imamura et al. (2001). An example of actual height growth patterns is shown in Fig. 1. The dataset consisted of 563 observations of height, age, and site index derived from 14 trees.

Method

A number of growth equations formed using different numbers of parameters are available to express the height growth over stand age (Zeide 1993). In addition to showing logical behavior and being biologically sound, desirable attributes for growth equations are often suggested, such as (1) passing a zero point, (2) tending to increase with age, (3) approaching an asymptote that is parallel to the age axis, and (4) allowing an inflection point to occur (Goelz and Burk 1992; Eriksson et al. 1997). The basic height curve equation form used in the present study was Richards’ three-parameter model (Richards 1959), which describes a sigmoid growth curve that passes through the origin and approaches some maximum height as age approaches...