Study of the Site Class Index Chart of Larch Plantation Based on the Mitscherlich Model1

Youquan Jiao*, Ji Feng
Department of Water Conservancy and Construction Engineering, Beijing Vocational College of Agriculture, Beijing, 102442, P.R.China
*Corresponding author’s e-mail: 70710@bvca.edu.cn

Abstract. In this paper, 196 plots and 460 larches were selected as the material, and analyzed the oriented exponential order site class index curve model of larches located at Wangyedian in Chifeng City, Inner Mongolia. The forestal statistical analysis software (SPSS 18.0) was used to data fitting and analytic comparison of larch plantation data. The results showed that: the oriented Mitscherlich curvilinear function was the more appropriate model of oriented larch plantation site class index curve after comprehensive considering of fitting accuracy, curve trend, distribution trend of sampling points and residual distribution. Based on regressive Mitscherlich model, the paper selected 30 a larches planted and operating level confirmed the exponential distance is 2m with 12 exponential orders, and then drew the site class curve cluster. Furthermore, the 12 exponential orders site class index table of larches located in Wangyedian, Chifeng City, Inner Mongolia was worked out.

1. Introduction
Site quality evaluation is the basic work for high and stable yields of plantation, which is necessary when investigating forest resources, determining forest thinning, predicting felling amount, building forest harvest model, drawing up harvest table and organizing the type of forest management. Germany evaluated woodland site quality at firstly in the 19th century. In the early 20th century, the relationship between average forest stand height and average tree age was used to divide the site class; and America introduced status index to indicate the advantages and disadvantages of the site quality in the 1920s. It was not until 1950s that China brought in site class level table by Forestry Investigation Department and drew site class level table of chief tree species in major forest areas, which was widely used in the forest management work. Previous researches revealed that the mean height growth curve (that is oriented curve) in site class table would become one of difficulties and hot research points in the future.

Oriented curve is the representative curve of tree growth equation, and the classical theoretical researches including Logistic、Mitscherlich、Gompertz (1825)、Korf(1939) and Richards (1959) equations etc. Furthermore, there were some empirical equations accepted in previous studies, such as Schumacher (1939)、Розенфельд(1878)、Hossfeld (1822)、Levakovic (1935)、modified Weibull(Yang et al., 1978)、Yoshida (1928)、Sloboda (1971) and other empirical equations, including power、logarithm and hyperbolic-type function.

Some domestic scholars drew up the larch plantation index table (Wang Jingyuan, Zhang Wanrong, Forestry Science and Technology, 1991)、Japan larch plantation site class index table in Funiu Mountain
in western Henan (Xiaorong Ping, Yin Hongzheng, Henan Science, 2004); Japan pulp larch multi-type site class index table (Zhao Wenhua, Wang Feng, Liaoning Forestry Science and Technology, 2002); Japan ENH larch multi-type site class index table (Ling Yuanyun, Hong Xinpu, Middle-of-south Forest Inventory and Planning, 1996); dahurian larch site class index table (Jiang Yibin, Bai Songlin, Inner Mongolia Forestry Science and Technology, 1993); Ali River artificial larch forest site class index table (Guo Jiaoqi, Gao Jun, Inner Mongolia Forestry Investigation and Design, 2003) and Butler River Xing'an larch forest site evaluation (Gao Mingfu, Zhang Binyu, Inner Mongolia Forestry Investigation and Design, 2006) etc.

All the site class index tables mentioned above used a single model or model comparison. Considering the differences between position, vegetation and climate would have an impact on oriented curves of various species, the paper used Mitscherlich theoretical model to optimize according to the pre-processing analogy, and then analyzed spatial-temporal variance of forest larch site class index in Wangyedian, Chifeng City, Inner Mongolia.

2. Materials and methods

2.1. Material origins

In this paper, by using 196 pieces of forest resource survey class in Chifeng, Inner Mongolia in 2012, we had a precise survey on 460 larches in plantation sample plot, and the tree age ranged between 12 a - 56 a. Based on the systematic analysis of average tree height growth of larch planted forest, the paper stated the technologies and methods of the site class index model and status index table formation, and then performed further analysis.

Based on the changing data of larch forest stand growth time and average forest stand height, the scatter diagram of tree age difference of 460 larches was acquired, which was shown in Fig.1. Seen from Fig.1, their relationship represented a non-linear relationship.

After a comprehensive statistic of tree age, average tree height and advantage tree height etc., we drew Fig.2, from which we found that larches with 30 a and 38 a were relatively more than others, and the intercept between average forest stand height and advantage tree height was the years of average intercept. Considering its strong representativeness, we selected 30a as a reference tree age.
2.2. Methods

Average tree height, High advantage Number of trees

Based on original survey results, the paper calculated the average tree age and average height of advantage trees, and then took average height of advantage trees as the standard, and eliminated the standard or advantage trees with abnormal data, which exceeded 3 times tree height standard deviation. After that, the data was rearranged and analyzed, average tree age, average advantage tree height and standard or amount tree numbers were calculated to fit site class index guiding curve (Table 1).

2.3. Site class index guiding curve model

The commonly used guiding curve functional equation (Equation 1, the Mitscherlich Model) was selected for fitting.

\[
H = \beta_0 (1 - e^{-\beta_1 \cdot t})
\]

where \(\beta_0\) represents maximum parameter of tree growth, \(H_{MAX}\), \(\beta_1\) represents referred parameter of growing rate.

2.4. Confirmation of standard tree age and class interval

Confirmation of standard tree age was based on site class distribution with stable tree height growth and most suitable to reflect forest stand growth. According to intersect between current annual increment and average increment, the standard tree age was 30 a. Through comprehensive analysis on growing rate, standard tree age, management level and average advantage tree height, the class interval was selected to be 2 m, which divided into 12 index levels, including I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII etc.

3. Results

3.1. Data processing and analysis

(1) Tree height standard deviation of different tree age grade

\[
S_i = \sqrt{\frac{\sum H_i^2 - (\sum H_i)^2 / n_i}{n_i - 1}}
\]
The tree height standard deviations (Si) of different standard plots were calculated (Table 1):

| Tree age | Survey data of tree age and height of standard plots / m | Standard plot | Si |
|----------|--------------------------------------------------------|---------------|----|
| 10       | 8.326 11.759 12.437 12.47 8.492 5                   |               |    |
| 12       | 7.183 8.085 7.000 7.143 7.118 5                       |               |    |
| 14       | 8.085 7.638 7.309 8.948 9.134 5                       |               |    |
| 16       | 9.585 9.084 8.656 8.819 9.585 5                       |               |    |
| 18       | 9.084 8.656 8.816 8.680 9.585 5                       |               |    |
| 20       | 9.714 8.292 9.412 8.948 8.928 5                       |               |    |
| 22       | 11.463 11.334 11.028 11.156 10.496 5                  |               |    |
| 24       | 10.065 10.052 10.500 11.104 11.010 5                  |               |    |
| 26       | 13.735 12.634 14.062 12.449 11.220 5                  |               |    |
| 28       | 16.995 13.211 15.734 12.945 15.087 5                  |               |    |
| 30       | 15.176 14.869 15.923 17.646 18.480 5                  |               |    |
| 32       | 17.609 16.942 16.613 17.428 16.657 5                  |               |    |
| 34       | 17.562 16.227 16.955 17.317 16.849 5                  |               |    |
| 36       | 16.605 16.493 14.154 14.638 14.136 5                  |               |    |
| 38       | 18.316 18.450 18.936 18.346 18.495 5                  |               |    |
| 40       | 20.233 19.587 20.233 20.261 20.401 5                  |               |    |
| 42       | 17.945 18.523 17.516 19.151 17.873 5                  |               |    |
| 44       | 16.439 15.054 15.096 14.780 16.327 5                  |               |    |
| 46       | 21.882 20.707 20.317 21.052 20.898 5                  |               |    |
| 48       | 25.001 24.289 24.808 24.556 24.720 5                  |               |    |
| 50       | 22.059 21.993 21.981 21.968 21.967 5                  |               |    |
| 52       | 21.865 22.604 21.088 20.904 22.033 5                  |               |    |
| 54       | 21.288 22.714 22.626 22.601 22.410 5                  |               |    |
| 56       | 22.714 24.817 24.556 23.660 24.360 5                  |               |    |

(2) Adjustment of Si

Fit tree height standard deviation equation in different tree ages. According to tree height standard deviation (SH) and average tree age (A), the paper used SH=a+blogA to fit tree height standard deviation equation. Take age grade in Equation 3 and calculate theoretical tree height standard (Si), and then put in Table 1.

\[ S_{Hi} = 1.705 - 0.671 \log A \]  \hspace{1cm} (3)

(3) Calculation of theoretical tree height standard deviation in different age grades

According to the relationship between tree height standard and age grade calculated by Equation 3, the paper selected regression equation \( H_s = c + dA \) and calculated to be \( H_s = 0.05587A - 0.029 \). Thus theoretical tree height standard deviations in different age grades were acquired.

3.2. Mitscherlich model site class index curve family

(1) Establishment of Mitscherlich model
Mitscherlich is a model used to describe the relationship between plant growth and growth control factors, and the theoretical Mitscherlich equation is:

\[ y = \sigma (1 - e^{-ax^1})(1 - e^{-ax^2}) \cdots \]

where \( y \) represents harvest yield; \( x_1, x_2 \ldots \) represent growth control factors; \( \sigma \) represents maximum parameter of plant growth. Among all the growth control factors, \( A \) is the most important. When considering the other factors have no obvious impact on controlling growth, Equation 5 is acquired:

\[ y = \sigma (1 - e^{-\alpha A})( \sigma, \ R>0 ) \]

where \( \sigma = y_{max} \) and \( r \) represents growth rate parameter.

Calculate first derivative of \( A \) in Equation 5 and then get Equation 6, from which we can see that growth rate \( \left( \frac{dy}{dt} \right) \) is in proportion with the difference between limit value \( \sigma (y_{max}) \) and plant size \( y \).

\[ \frac{dy}{dt} = r(y_{max} - y) \]

(2) Establishment of practical model

In this paper, by using 196 pieces of forest resource survey class in Chifeng, Inner Mongolia in 2012, we had a precise survey on 460 larches in plantation sample plot. According to statistical standard of forest measurement, the survey samples were not enough to fit guiding curve, due to their limited amount. The paper introduced dahurian larch guiding equation (Equation 2), and combined fitting results of Mitscherlich model and existing research results before obtaining guiding equation of advantage tree height:

\[ H = 30.8127(1 - e^{-0.026265A}) \]

where \( H \) represents average forest stand height; \( A \) represents forest stand age; \( \beta_0 \) and \( \beta_1 \) represent undetermined parameters.

The results showed that SSE=10.378 and \( R^2=0.9804 \), which represented good relatively. After analyzing the relationship between tree height standard deviation and tree age, we divided 8-56 a with the age grade of 2 a. Then calculated in Mitscherlich guiding equation (Equation 7) and drew site class index curve.

3.3. Found site class index table

(1) Calculation of tree height of site class index

Bases on standard tree age (30a), class interval (2m), the site class index was divided into 12 index grades, inc I、II、III、IV、V、VI、VII、VIII、IX、X、XI、XII etc., and their curve family was shown in Fig.3.
(2) Found site class index table

Bases on standard tree age (30a), class interval (2m) and adjustment value of border up index grades, the site class index table was set up (Table 2).

| Site class index table |
|------------------------|
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|----|-----|----|---|----|-----|------|----|---|---|-----|
| 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 |
| 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 |
| 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |

Figure 3 12 index grades and their curve family

Table 2 Site class index table of larch forest in Chifeng City, Inner Mongolia

(Standard tree age: 30a, class interval: 2m; index tree: 5 advantage trees)
4. Discussion

The guiding curve fitted by Mitscherlich model is the improvement and optimization of plant growth equation. Although there are amounts of guiding curves existed, they are lacking in botanical theory and basis, except that the unimolecule Mitscherlich guiding curve well fitted the growing trend of larch planted forest and divided its site class index.

Using Mitscherlich equation to fit site class curve family could avoid the contradiction between tree height and site class, thus guaranteed the biological significances of inflection points. Mitscherlich site class model fitted in larch planted forest well well with multiple correlation coefficient $R=0.9902$, which illustrated that Mitscherlich site class model gave adequate disclosure on the growing process of advantage trees in larch planted forest.

SPSS18.0 was appropriate to Mitscherlich model fitting not only because of its smaller fitting residual, but also provided a simpler method to be easily used in practical application without calculating partial derivative. The software could be used for quick reference and calculation adjustment.

There is no site class index table for larch planted forest in Chifeng, Inner Mongolia (standard tree age: 30 a, class interval: 2 m; index tree: 5 advantage trees) mentioned in previous studies until now, so the research results of this paper have practical significance and reference value.

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