Growth characteristics of natural and planted Dahurian larch in northeast China

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Abstract. Dahurian larch (*Larix gmelinii* Rupr.) is the dominant species in both natural and planted forests in northeast China, which situated in the southernmost part of the global boreal forest biome and undergoing the greatest climatically induced changes. Published studies (1965–2015) on tree aboveground growth of *Larix gmelinii* forests in northeast China were collected in this study, critically reviewed, and a comprehensive growth data set was developed from 123 sites, which distributed between 40.85 ° N and 53.47 ° N in latitude, between 118.20 ° E and 133.70 ° E in longitude, between 130 m and 1260 m in altitude. The data set was composed of 776 entries, including growth data (mean tree height, mean DBH, mean tree volume and/or stand volume) and the associated information, i.e., geographical location (latitude, longitude, altitude, aspect and slope), climate (mean annual temperature (MAT) and mean annual precipitation (MAP)), stand description (origin, stand age, stand density and canopy density), and sample regime (observing year, plot area and number). It

would provide quantitative references for plantation management practices and boreal forest growth prediction under future climate change. The data set is freely available for noncommercial scientific applications, and the DOI for the data is https://doi.org/10.1594/PANGAEA.880984.

1 Introduction

Boreal forests, the second largest biome in the world, cover about one-third of the Earth's forest area (Achard et al., 2006; Keenan et al., 2015). Dahurian larch (*Larix gmelinii* Rupr.) is a dominant tree species in Chinese boreal forest, which is distributed primarily in northeast China. *Larix gmelinii* forest is also the predominant timber source in China, occupying 55% of Chinese boreal forest area and accounting for 75% of Chinese boreal forest volume (Xu, 1998; Zhou et al., 2002). *Larix gmelinii* forest is situated in the southernmost part of the global boreal forest biome (Shugart et al., 1992) and undergoing the greatest climatically induced changes. Thus understanding the growth characteristics of *Larix gmelinii* forest in China are of critical need for management and prediction under future climate change.

With increased greenhouse effective and climate warming in recent years, forest carbon sink is payed more and more attention by the world (Bastin et al., 2017). Forestation is the main measure to offset the greenhouse gas emission and increase carbon sink. China has the largest area of forest plantations in the world, approximately 79 million ha or one-fourth of world total (FAO, 2015; Payn et al., 2015). The forest cover showed an increasing trend through reforestation in northeast China (Achard et al., 2006). *Larix gmelinii* is an important fast-growing and cold-tolerant tree species used in forestation in northeast China. *Larix gmelinii* is usually planted after fire or logging. The growth rates of *Larix gmelinii* plantations are important indexes in the assessment of forest recovery processes and carbon sequestration potentials, which could supply strategies for post-fire or post-harvest management. The data

set can provide basis for evaluating and predicting the carbon sequestration and its potential of the forestation activities.

Relating the easily measured variables (e.g. tree height, diameter) to other structural and functional characteristics, is the most common and reliable method for estimating forest biomass, net primary production and biogeochemical budgets (Luo, 1996; Fang et al., 2001). For larch forests in northeast China, synthesis studies mainly focused on biomass and net primary production with a small quantity of samples, for example, N=28 (Luo, 1996), N=17 (Wang et al., 2001a), N=18 (Wang et al., 2001b; Zhou et al., 2002), N=36 (Wang et al., 2005), N=83 (Wang et al., 2008). However, large numbers of growth measurements (e.g. tree height, DBH, volume) have scarcely been studied systematically at the large scale. Therefore, a comprehensive growth data set (N=776) of Dahurian larch in northeast China was developed in this paper.

2 Data and methods

2.1 Research origin descriptors

(1) Identity: Growth data set of natural and planted Dahurian larch in northeast China, version 1.0

(2) Originators:

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(3) Period of Study: From January 1965 to December 2015

(4) Objectives: We conducted a complete literature and book review of published studies on tree height, DBH, and/or volume in *Larix gmelinii* forests including natural and planted forests in order to develop a growth data set. The data set can be used to analyze growth

characteristics of *Larix gmelinii* forests and assess their potential productivity in future climate warming.

2.2 Site description

(1) Site type: Data were derived from 123 study sites in northeastern China. This region includes Heilongjiang, Liaoning, Jilin provinces and the eastern part of Inner Mongolia Autonomous Region (Fig. 1).

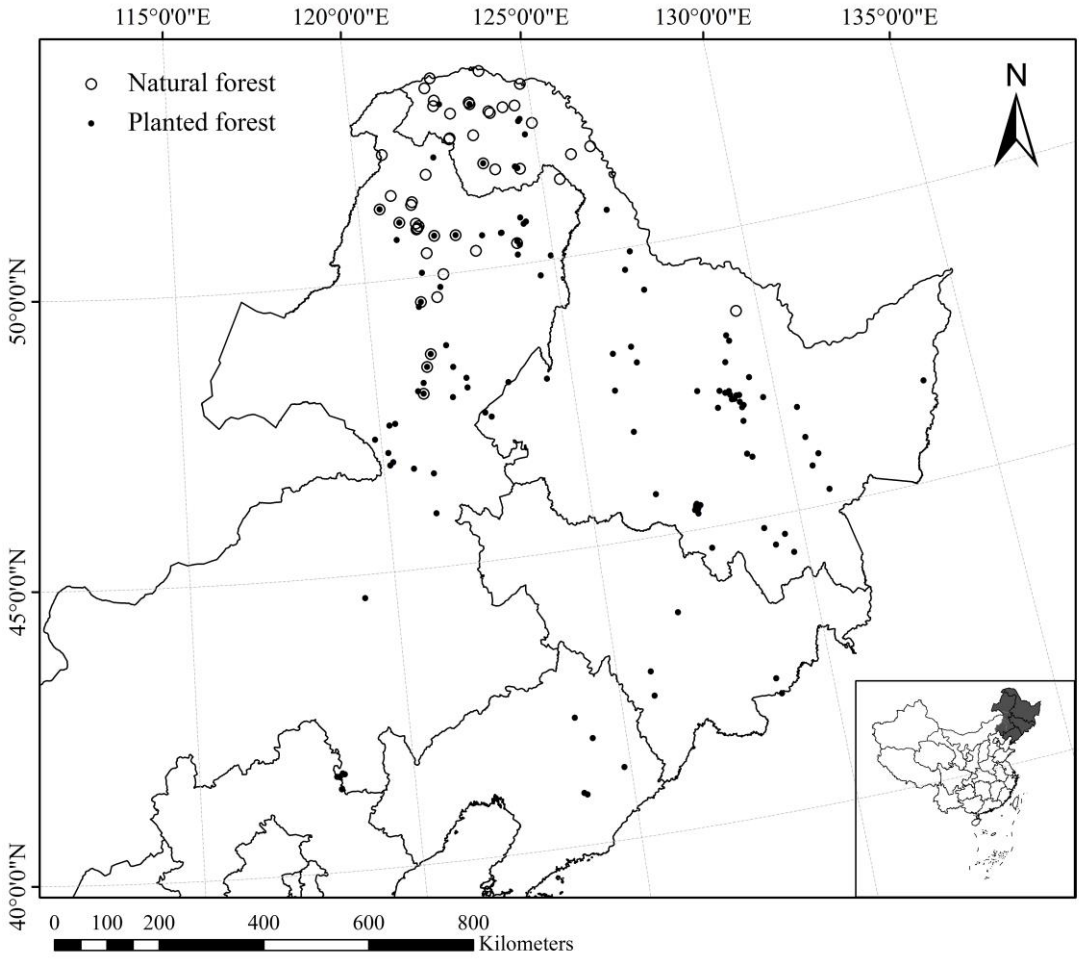

Figure 1. Study sites of *Larix gmelinii* across northeastern China, including Heilongjiang, Liaoning, Jilin provinces and the eastern part of Inner Mongolia Autonomous Region. Open circles represent natural forests and dots represent planted forests.

(2) Habitat: *Larix gmelinii* forest is naturally distributed in Great Xing'an Mountains of northeastern China. *Larix gmelinii* was usually planted in barren hills, post-fire or post-harvest area in northeast China.

(3) Climate: The climate in northeast China is controlled by the high latitude East Asia monsoon, changing from cool temperate to temperate zones from north to south, and from semi-arid to humid zones from west to east. Mean annual temperature (MAT) for these sites ranged from -6.1 to 7.0 ℃, and mean annual precipitation (MAP) from 355 to 926 mm.

2.3 Data sources

Published studies (1965-2015) were collected from available online full-text databases, including China Knowledge Resource Integrated Database (http://www.cnki.net/), China Science and Technology Journal Database (http://www.cqvip.com/), Wanfang Data Knowledge Service Platform (http://www.wanfangdata.com/), ScienceDirect (http://www.sciencedirect.com/), ISI Web of Science (http://isiknowledge.com/) and Springer Link (http://link.springer.com/). The different combination of the terms "Dahurian larch (or *Larix gmelinii*)" with "height", "diameter at breast height (or DBH)", "tree volume" and "stand volume" were searched in full text. Meanwhile, we also looked up the related books (e.g. Ma, 1992; Wang, 1992; Zhou, 1994; Yang, 2009). We attempted to compile a complete growth data set of natural and planted Dahurian larch in northeastern part of China (between 40.85 °N and 53.47 °N; between 118.20 ℃E and 133.70 °E).

2.4 Data collection criteria

A critical review of the literatures collected from the above-mentioned sources was conducted to obtain reliable growth data using the following criteria:

(1) Scope: The objective of this study was to provide the data for understanding growth characteristics of *Larix gmelinii* natural forests (pure *Larix gmelinii* or its proportion more than 50%) and monoculture plantations. Forest stands included in the data set were restricted to those not recently disturbed by logging, fire, or insect pests. Additionally, the following small numbers of special types were excluded: (i) *Larix gmelinii* afforestation in wetland (Li et al., 1985; Song & Li, 1990; Huang, 2011; Cui et al., 2013), pastureland (Duan, 2005), or

abandoned mine land (Yang et al., 2013); (ii) hybrid test between *Larix gmelinii* and other larch (Deng et al., 2010; Zhang et al., 2005); (iii) low-yield stands in hard environment, e.g. igneous rock forest (Wang et al., 1979), old man forest (Wang et al., 1991).

(2) Study design and sampling: Tree height and DBH were averaged from the measurement values of all trees in plots or with random/systematic sampling method. Tree regeneration layer, generally below 5 cm in DBH or 1.3 m in height, was neglected in sampled plots. Stem volume of individual tree was computed from felled-wood samples or local tree volume equations. Stand volume was usually calculated by multiplying mean individual volume with stand density. Besides the growth data (i.e. height, DBH and/or volume), the necessary information should be provided in the original sources, e.g., study site, stand orign, stand age, etc.

(3) Quality control: The data quality has been carefully reviewed by the authors. Data has undergone substantial checking, for example, cross-check for the relevant information from different sources, preliminary correlation analysis among growth variables.

Consequently, 776 records that met the above criteria were selected to develop a comprehensive growth data set of Dahurian larch in China. The data set includes growth characteristics of Dahurian larch (i.e. mean tree height (m), mean DBH (cm), mean tree volume (10^{-3} m^3) and/or stand volume (m^3/ha)). In addition, associate information was included, if available in original sources or ascertainable from other relevant literatures, i.e., geographical location (province location and locality name of study site, latitude (°), longitude (°), altitude (m), aspect and slope (°)), stand description (origin, stand age (years), stand density (trees/ha) and canopy density), climate (mean annual temperature (MAT, ℃) and mean annual precipitation (MAP, mm)), and sample regime (observing year, plot size and number).

2.5 Data structural descriptors

137 Table 1 Variable information in the data set.

Column code	Definition	Unit	Number	Range
ID	Unique identification number of each record	N/A	776	1—776
Province	Province location of study site	N/A	776	N/A
Study site	Locality name of study site	N/A	123	N/A
Latitude	Latitude of study site	°	776	40.85—53.47
Longitude	Longitude of study site	°	776	118.20—133.70
Altitude	Altitude of study site	m	776	130—1260
Aspect	Slope direction of study site, including flat slope (FL), sunny slope (SU: South), half-sunny slope (HSU: West, Southwest, Southeast), shady slope (SH: North) and half-shady slope (HSH: East, Northwest, Northeast)	N/A	300	N/A
Slope	Slope degree of study site	°	357	0—60
Origin	Stand origin was classified into natural and planted forests	N/A	776	N/A
MAT	Mean annual temperature, from original study or other related ference	℃	776	-6.1—7.0
MAP	Mean annual precipitation, from original study or other related reference	mm	776	355—926
Age	Stand age, which is generally defined as age since germination in natural forest and since planting in planted forest. Stand age is usually obtained from historical records or tree rings.	years	776	1—280
Height	Mean tree height	m	670	0.24—29.40
DBH	Mean diameter at breast height, base diameter was only given in some young forests and marked with [B]	cm	661	0.70—34.89
V_{tree}	Mean tree volume, the estimated tree volume data from the two-variable larch equation were marked with [E]	10^{-3} m^3 /tree	696	0.04—935.73
V_{stand}	Stand volume, the estimated stand volume data from the estimated tree volume and stand density were marked with [E]	m^3/ha	590	0.07—975.32
Density	Stand density/Canopy density, planting density was only given in some studies and marked with [P]	trees/ha %	656 150	213—13275 0.2—1.0
Area	Plot area	m^2	397	50—10000
Plot	Plot numbers, i.e. replications	N/A	573	1—25
Year	Investigation year	N/A	533	1954—2014
Reference	Data sources, the sources used to supplement climate information lacking in the original publications were added asterisks.	N/A	226	1965—2015

138

139 3 Data estimates and evaluation

140 3.1 Geographical location

141 Google Earth (Version: 7.1.8.3036) was used to estimate latitude, longitude, and/or altitude
142 when the geographic coordinates was unavailable in original sources.

143 3.2 Tree and stand volume

144 The missing tree and stand volumes were estimated with the available information (mean
145 DBH, mean tree height and stand density). Stem volume of individual tree was calculated

with the larch equation in northeast China (V_{tree}= 0.000050168241 $DBH^{1.7582894}$ $H^{1.1496653}$), the best method recommended by the national standard of China: Tree volume tables (LY 208-77) (Forestry Administration of China, 1978; Liu, 2017). Meanwhile, available 590 pairs of mean tree height and mean DBH in the data set were used to establish the linear H-DBH correlation (R^2=0.8377, see Fig. 2). To calculate tree volume from only one known variable of DBH, tree height was firstly calculated with the linear H-DBH equation in Fig. 2. The estimated stand volume was determined by multiplying the estimated tree volume with stand density.

The accuracy of tree volume was assessed by comparing the extracted data from references with the calculated data from the above-mentioned two-variable tree volume equation (Fig. 3). The coefficient of determination (R^2) was 0.9724 and the slope was 1.0737. Therefore, we were confident in applying the larch volume equation to interpolate tree and stand volume data in this study.

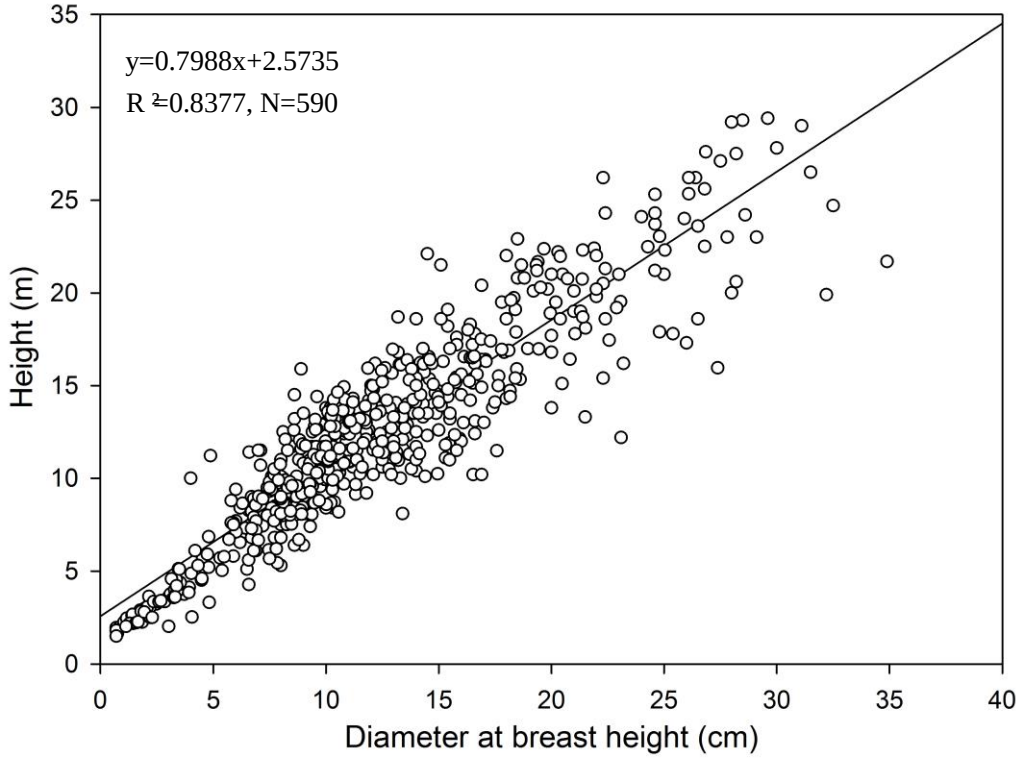

Figure 2. Relationship between mean tree height and diameter at breast height in the data set.

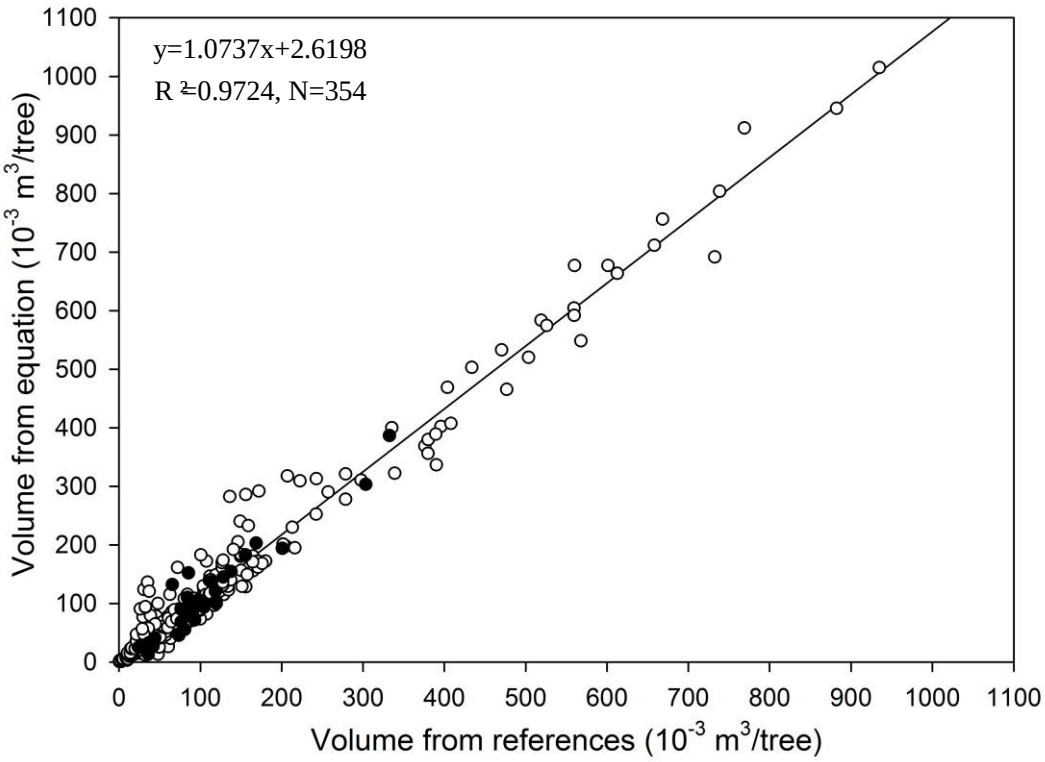

Figure 3. Comparison of available tree volume from references with simulated values from the two-variable tree volume equation (V_{tree}=0.000050168241 $DBH^{1.7582894}$ $H^{1.1496653}$). Open circles (N=317): tree height (H) and diameter at breast height (DBH) were available in the references, solid circles (N=37): DBH was only available in the references and H was estimated with the H-DBH correlation from Fig. 2.

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