

Response of larch species to climate changes

Wenfang Leng^{1,2}, Hong S. He^{1,3} and Hongjuan Liu⁴

¹ Group of Landscape Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China

² The Tourism Department, Qinghuangdao Institute of Technology, Qinghuangdao 066100, China

³ Department of Forest, School of Nature Resources, University of Missouri, Columbia, MO 65211, USA

⁴ Group of Information Management of Agriculture and Ecosystem, Center for Agriculture Resources Research, Institute of Genetics and Developmental Biology, Chinese Academy of Sciences, Shijiazhuang 050021, China

Abstract

Global warming has changed the distributions of forests of northeastern China. *Larix* are very important species in this area. Predicting the potential distributions of *Larix* species and their responses to climate change would attract more and more attention.

This paper predicted the potential distributions of three *Larix* species based on 'climatic-topographic' relationships by logistic regression. The results showed that *L. gmelinii* is predicted to retreat northwestward by 220 km by 2050 and by 270 km more by 2100; *L. olgensis* var. *changpaiensis* is predicted to retreat northwestward by 200 km by 2050 and by 190 to 300 km more by 2100; *L. principis-rupprechtii*

is predicted to retreat northeastward by 200 km by 2050 and by 250 to 400 km more by 2100. This indicated that *L. gmelinii* could have its optimum latitude moved into Russia, *L. olgensis* var. *changpaiensis* could move to the Small Xing'an Mountains and *L. principis-rupprechtii* would move to the middle part of the Great Xing'an Mountains.

Keywords: *Larix gmelinii* • *Larix olgensis* var. *changpaiensis* • *Larix principis-rupprechtii* • logistic regression • climate change • Northeastern China

INTRODUCTION

Studies of palaeoclimate have shown that the alternation of glacial and interglacial epochs has resulted in the shift of global vegetation ranges southward or northward (Iverson and Prasad 1998, 2002). Moreover, global warming caused by anthropogenic activities has had a significant impact on the distributions of tree species in the past century (Cao *et al.* 2005; Chang *et al.* 2003; Chen 2000). In particular, the temperature in northeastern China has been predicted to continue to increase in the future, which could have a profound impact on the forests in this region. Research results have shown that, if the temperature increase is <2°C, the abundance of Korean pine may increase, whereas that of *Larix gmelinii*, *Picea jezoensis* and *Abies nephrolepis* may decrease. If the temperature increase is >5°C, the dominant coniferous species could be replaced by broadleaf species (Hao *et al.* 2001; He *et al.* 2005; Yan *et al.* 1999).

Predicting the potential distributions of tree species and their responses to climate change is an increasingly important field of global change research. Because *Larix* are important tree species in northeastern China, in this study we predict the potential distributions of three *Larix* species based on 'climatic-topographic' relationships. Our aims are to determine (i) the dominant factors that control the distributions of the three *Larix* species and (ii) the responses of the species to climate change.

STUDY AREA AND METHOD

Northeastern China is a large region extending from 115°05'E, 38°40' N in the southwest to 135°02'E, 53°30'N in the northeast. The extreme variations of solar energy and available water are the primary causes of the current vegetation distribution and are the major driving forces in the responses of vegetation distribution to regional climatic change. The general pattern of vegetation in the region is deciduous broad-leaved forests in the warm and humid southeast, coniferous forests in the cold northwest, temperate grasslands in the dry west and coniferous and broad-leaved mixed forests in the humid east, with a vast transition area of central plains where historical vegetation cover has long been converted into agriculture land use (Zhou 1997).

One special general linear model used to predict the probability of a bivariate response variable based on a variety of explanatory variables is the logistic regression model (Wang and Guo 2001). In this paper, logistic regression models were developed to analyze the relationships among three larch species (*L. gmelinii*, *Larix olgensis* var. *changpaiensis* and *Larix principis-rupprechtii*) and five environmental variables (mean annual temperature, mean annual precipitation, altitude, slope and aspect). The corresponding spatial data sets collected are shown in Table 1.

Three indices (sensitivity, specificity and percentage of correctness) were used to assess the prediction accuracy of the

Table 1: The spatial data sets

Data sets	Data sources
Distribution map of <i>Lg</i>	1:100 million vegetation map of China
Distribution map of <i>Loc</i>	1:100 million vegetation map of China
Distribution map of <i>Lpr</i>	1:100 million vegetation map of China
Digital elevation model (DEM)	1:25 million contour map of northeastern China
Annual average temperature map	Weather station data and DEM
Annual precipitation map	Weather station data and DEM
Slope map	DEM
Transition aspect map (TRASP)	DEM

All sets have a resolution of 100 m. *Lg*, *Larix gmelinii*; *Loc*, *Larix olgensis* var. *changpaiensis*; *Lpr*, *Larix principis-rupprechtii*.

logistic regression models. The climate warming scenario was adopted from the Second Generation Coupled Global Climate Model (CGCM2) from the Canadian Centre for Climate Modelling and Analysis.

RESULTS

As predicted in the climate-warming scenario, the mean annual temperature of the northern part of the Great Xing'an Mountains will rise by $\sim 3^{\circ}\text{C}$ by 2050. Under this scenario, the southeastern boundary of suitable areas for *L. gmelinii* is predicted to retreat northwestward by 220 km (Fig. 1b). By 2100, the temperature of this region is predicted to increase by $>6^{\circ}\text{C}$, and the southeastern boundary of suitable areas for *L. gmelinii* is predicted to retreat northwestward by >270 km, at which time *L. gmelinii* will only occur in the northern part of Mohe and E'er'gula counties, the most northeastern part of China (Fig. 1c).

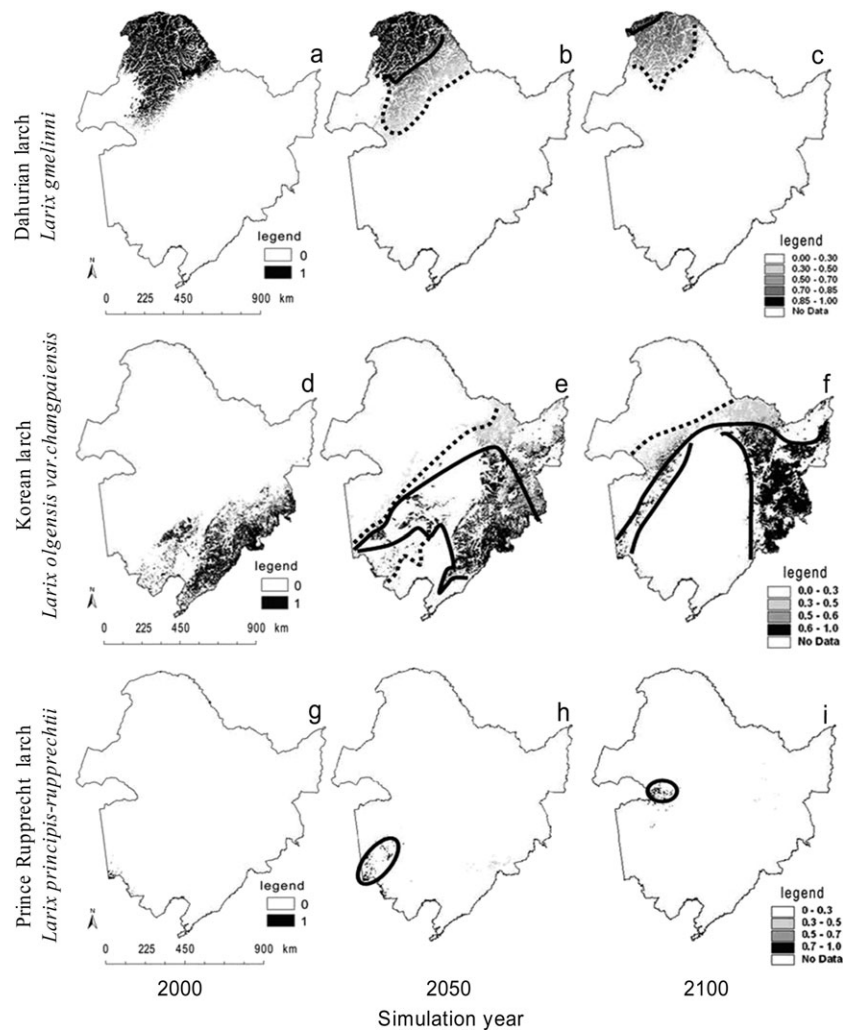


Figure 1: Potential distributions of three larch species under the CGCM2 climate change scenario in 2050 and 2100. The solid line represents the boundary of the distribution area where the probability of larch species is greater than the threshold. The broken line represents the boundary of the distribution area where the probability of larch species is smaller than the threshold.

The mean annual temperature in the Changbai Mountains area will rise by $>2^{\circ}\text{C}$ by 2050. Under this scenario, the north-western boundary of suitable areas for *L. olgensis* var. *changpaiensis* is predicted to retreat northwestward by 200 km (Fig. 1e). By 2100, the temperature of this region is predicted to increase by $>5^{\circ}\text{C}$, and the northwestern and southern boundaries of suitable areas for *L. olgensis* var. *changpaiensis* are predicted to retreat northwestward by >190 and 300 km, respectively, at which time *L. olgensis* var. *changpaiensis* will occur in the middle part of the Small Xing'an Mountains and in the Laoye Mountains (Fig. 1f).

The mean annual temperature of the southern part of the Great Xing'an Mountains will rise by $>3.3^{\circ}\text{C}$ by 2050. Under this scenario, the northern boundary of suitable areas for *L. principis-rupprechtii* is predicted to retreat northeastward by 200 km (Fig. 1h). By 2100, the temperature of this region is predicted to increase by $\sim 7^{\circ}\text{C}$, and the northern and southern boundaries of suitable areas for *L. principis-rupprechtii* are predicted to retreat northward by >250 and 400 km, at which time *L. principis-rupprechtii* will occur in the middle part of the Great Xing'an Mountains (Fig. 1i).

The output of a logistic regression model indicates that *L. gmelinii* could have its optimum latitude moved into Russia, *L. olgensis* var. *changpaiensis* could have its optimum latitude moved from the Changbai Mountains to the Small Xing'an Mountains and *L. principis-rupprechtii* could have its optimum latitude moved from the southernmost part to the middle part of the Great Xing'an Mountains. The average migration distance exceeds 400 km in 100 years.

DISCUSSION

Factors that impact species distribution are complicated, and models are merely an abstract expression of them. There are always some uncertainties in the modeling results. Logistic regression models do not take into account several important factors, including the physiological changes associated with changed temperature and precipitation, species longevity, reproduction, dispersal ability, interspecific competition and landscape fragmentation caused by human activity. In fact, species may adapt to the new environment to some extent. High-longevity species can remain in their current habitats for relatively long periods of time. Limited reproduction and dispersal ability would present problems for species in occupying potential habitat at further distances. Fragmentation makes the regional extinction of species that cannot keep up with the shift of suitable habitat more likely to occur. Thus, the results derived from the logistic regression models basically give the potential suitable habitats rather than the actual distribution area of the tree species. In addition, because the data sets (vegetation maps, relief maps and climate data) were limited by administrative divisions (national boundaries), the logistic regression models of the three larch species in this study were built based on their distributions in China as opposed to their whole natural distribution area. This may underestimate

the potential distribution area of larch species. In spite of these limitations, logistic regression models still seem to be a robust tool for predicting the potential distribution of tree species at the regional scale. The prediction results provide a regional view and reference points for revisiting current forest harvesting and afforestation plans in which the effects of climate warming have not been considered.

CONCLUSIONS

In this paper, we built logistic regression models of the distribution range of three larch species. The results showed that climate change would have great impact on the distribution ranges of the three larch species considered. In future work, we intend to use data mining techniques to analyze the uncertainty caused by our approach.

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