Response of the distribution of forest constructive species of northeastern China to the climate changing

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Abstract - Global Climate Model, CGCM2 predicted that annual average temperature of northeastern China will rise about 3 in 2050 year, and about 6 in 2100 year, annual precipitation will change. To explore the response of Northeastern forests to the climate warming scenarios, Logistic regression models were developed to analyze the relationships between seven constructive species of northeast forest (*Larix gmelinii*, *Pinus koraiensis*, *Picea jezoensis*, *Abies nephrolepis*, *Larix olgensis* var. *changpaiensis*, *Quercus mongolica*, *Betula platyphylla*) and 11 environmental variables (annual average temperature, annual precipitation, altitude, slope, aspect, soil clay, soil silty, soil sand, soil depth, soil organic matter, soil total nitrogen). The predicted distributions of the seven species under the two global warming scenarios were derived on the logistic regression models. The result showed that in 2050, the coverage of all species would decrease in different degree, respectively. The *Picea jezoensis*, *Abies nephrolepis* would disappear. in 2100, another two species, *Larix gmelinii*, *Pinus koraiensis* would disappear. In whole, the climate warming could have great impact on the constructive species of northeast forest.

Key-words:- logistic regression model, constructive species, northeastern China, climate changing, CGCM2

1 Introduction

Global annual temperature has increased by approximately 0.6 during the past 100 years, and will continue to increase in the next 100 years [1]. Climate is the most dominant factor affecting species distribution across broad spatial scales [2]. Increasing attention has been paid to predict potential tree species distribution under climate warming [3~5].

The response of tree species distribution to climate warming is complex, varying by regions due to factors such as current species composition, site conditions and local microclimate. Results from paleontology research and observation data in the past revealed the northward or upward moving trend of most tree species [6~8] in response to climate warming.

Northeastern China is the most important forest region of China. According to the results of CGCM2 model, the climate here would raise remarkably. What effects of the warming climate on the potential distribution of the constructive species? In this paper, we developed prediction models for the seven constructive species for the entire Northeastern China. The models are based on the current distributions of the seven species and their relationships with environmental variables. We will then plug the warming climate scenario into the prediction models to predict potential distributions of the seven tree species under the warming climate.

2 Problem Formulation

2.1 Study area

Northeastern China is a large region from 115°05′E 38°40′ N in the southwest to 135°02′E 53°30′N in the northeast. The annual mean temperature varies from 11.26 in the southeast to –6.87 in the northwest Great Xing'an Mountains, and the annual precipitation from more than 880 mm in the southeast to less than 219 mm in the northwest. The great variations of the distribution of solar energy and available water are the primary causes of 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 / broad-leaved mixed forest in humid east, with a vast transition area of central plains where historical vegetation cover has long been converted into agriculture land use[9].

2.2 Spatial data sets

Seven constructive species' current distributions (presence/absence) were derived from the 1: 1,000, 000 vegetation atlas of China [10]. The terrain data (DEM, Slope and Aspect) are derived form the 1: 250 000 contour map and reference point map of Northeastern China. The soil data were derived from the 1: 1,000, 000 soil map, supplied by Institute of Soil Science, CAS[11]. The cliamte data were established on the recordings of 62 major weather stations for the past three decades and the predictions from Canadian Centre for Climate Modeling and Analysis (CCCMA). The cell size of all maps is at 100 m × 100 m (one ha).

2.3 Modeling approaches

Logistic regression model is a special general linear model that predicts the probability of a bivariate response variable based on a variety of explanatory variables [12]. It can be applied in large region like entire Northeastern China, and can be parameterized in a relatively easy way. Therefore, it has been widely applied in ecological research, and has been used for risk assessment [13], habitat evaluations [14], and the prediction of vegetation distribution [12,15].

In this paper, logistic regression models were developed to analyze the relationships between seven constructive species of northeast forest (*Larix gmelinii*, *Pinus koraiensis*, *Picea jezoensis*, *Abies nephrolepis*, *Larix olgensis* var. *changpaiensis*, *Quercus mongolica*, *Betula platyphylla*) and 11 environmental variables (annual average temperature, annual precipitation, altitude, slope, aspect, soil clay, soil silty, soil sand, soil depth, soil organization material, soil total nitrogen).

There are 5 indices for assess the prediction precision, percentage of correct (PerC,), sensitivity, specificity, false positive rate (FPR), and false negative rate (FNR)

Percentage of Correct (PerC) represents the total prediction accuracy. Sensitivity represents model's estimation ability for occurrence. Specificity represents for nonoccurrence. High values of these indices represent the high precision of the logistic regression models. FPR and FNR represent the error of the prediction. Low values of these indices represent the high precision of the models [16].

$$PerC = \frac{a_{11} + a_{22}}{A_{sum}} \times 100 \quad (1) \qquad Sensitivity = \frac{a_{11}}{A_{\bullet 1}} \times 100 \quad (2)$$

$$Specificity = \frac{a_{22}}{A_{\bullet 2}} \times 100 \quad (3) \qquad FPR = \frac{a_{12}}{A_{1\bullet}} \times 100 \quad (4)$$

$$FNR = \frac{a_{21}}{A_{2\bullet}} \times 100 \quad (5)$$

In the above equations, a_{11} represents true positive or presence, a_{12}, represents false positive or presence, a_{21} represents false negative or absence, and a_{22} represents true negative or absence. $A_{1\cdot}$ is the sum of a_{11} and $a_{12,}$ A_2 is the sum of a_{21} and $a_{22,}$ $A_{\cdot 1}$ is the sum of a_{11} and $a_{21,}$ $A_{\cdot 2}$ is the sum of a_{12} and $a_{22,}$ and A_{sum} is the sum of $A_{1\cdot}$ and $A_{2\cdot}$

3 Problem Solution

3.1 The coefficients of logistic regression models

Table 1 logistic regression analysis results coefficients and Goodness of fit

	Larix gmelinii	*Pinus koraiensis*	*Picea jezoensis*	*Abies nephrolepis*	*Larix olgensis* var. *changpaiensis*	*Quercus mongolica*	*Betula platyphylla*
Intercept	-4.80E-01*	-1.03E+01*	-1.29E+01*	-1.27E+01*	-1.01E+01*	-1.08E+00*	-1.05E+00*
Altitude	5.90E-04*	-2.60E-03*	-4.02E-03*	-3.90E-03*	1.90E-04*	-2.84E-03*	1.96E-04*
Precipitation	-6.62E-03*	1.74E-02*	2.14E-02*	2.76E-02*	1.45E-02*	3.11E-03*	4.75E-04*
Slope	3.90E-02*	6.68E-03*	2.33E-02*	2.37E-02*	-4.98E-02*	1.77E-02*	-2.19E-02*
Temperature	-8.80E-01*	-5.10E-01*	-1.07E+00*	-1.03E+00*	3.07E-01*	——	-1.34E-01*
Trasp-aspect	-3.24E-02*	9.44E-02*	——	——	-8.76E-02*	——	3.54E-02*
Soil Clay	-4.88E-03*	-2.21E-02*	5.25E-02*	5.82E-02*	——	——	1.99E-02*
Soil Depth	1.62E-03*	1.22E-03*	-8.19E-03*	-7.17E-03*	5.92E-03*	-7.63E-03*	——
Soil Om	2.98E-03*	-2.09E-02*	6.36E-02*	8.61E-02*	——	-1.91E-02*	4.74E-02*
Soil Sand	6.80E-03*	-7.07E-03*	——	——	-2.77E-02*	-1.31E-03*	-2.05E-02*
Soil Silty	——	——	-1.29E-02*	-1.50E-02*	-6.16E-03*	2.62E-02*	——
Soil Tn	5.63E-01*	——	-1.68E+00*	-2.16E+00*	-2.45E+00*	——	-1.84E+00*

* represents the regression coefficient is significant, $p < 0.001$

From table 1, we could see that temperature is the main factors controlling the distribution of all species, except for *Quercus mongolica*. All species, except the *Larix olgensis* var. *changpaiensis*, were negative affected by temperature. All species, except for *Larix gmelinii*, were positive affected by precipitation. Because the temperature and precipitation were high in southeastern and low in northwest, we could induce from the coefficients that *Larix gmelinii* was distributed in the northwest mountain area, where is low temperature and rainless, and *Larix olgensis* var. *changpaiensis* was distributed in the southeast mountain area, where is high temperature and rainy. *Pinus koraiensis, Picea jezoensis* and *Abies nephrolepis* were distributed in the east mountain, where are moderate temperature and rainy. The distributions of *Quercus mongolica* and *Betula platyphylla* were not as regular as conifer species.

3.2 prediction precision

Table 2 the predicted precision of logistic regression model

	PerC	Sensitivity	Specificity	FPR	FNR
Larix gmelinii	88.00	89.41	87.22	32.38	3.50
Pinus koraiensis	75.27	82.37	74.95	87.06	1.05
Picea jezoensis	77.82	87.45	77.62	92.73	0.32
Abies nephrolepis	78.13	85.30	77.99	93.09	0.36
Larix olgensis var. changpaiensis	67.42	97.70	66.95	95.56	0.05
average of conifer species	77.33	88.45	76.95	80.16	1.06
Quercus mongolica	63.49	74.04	58.47	54.09	17.45
Betula platyphylla	55.11	64.82	53.15	78.17	11.79
average of broadleaf species	59.30	69.43	55.81	66.13	14.62

From Table 2, we could see that, the PerC, Sensitivity and Specificity are higher for conifer species than for broadleaf species. FNR are lower for conifer than for broadleaf species. The results show that the logistic regression models of conifer species have higher prediction precision than that of the broadleaf species. The causation maybe that, the conifer species are commonly the zonal plants, and their habitats are characteristic. The broadleaf species are the dispersed species. The characters of their habitats are not obviously as that of the conifer species.

FPR are higher for all species. The causation maybe that, the logistic regression model does not considering the effects of ecological processes and the human activities on the distribution of species. Therefore, the predicted areas of all species are lager than their observed areas.

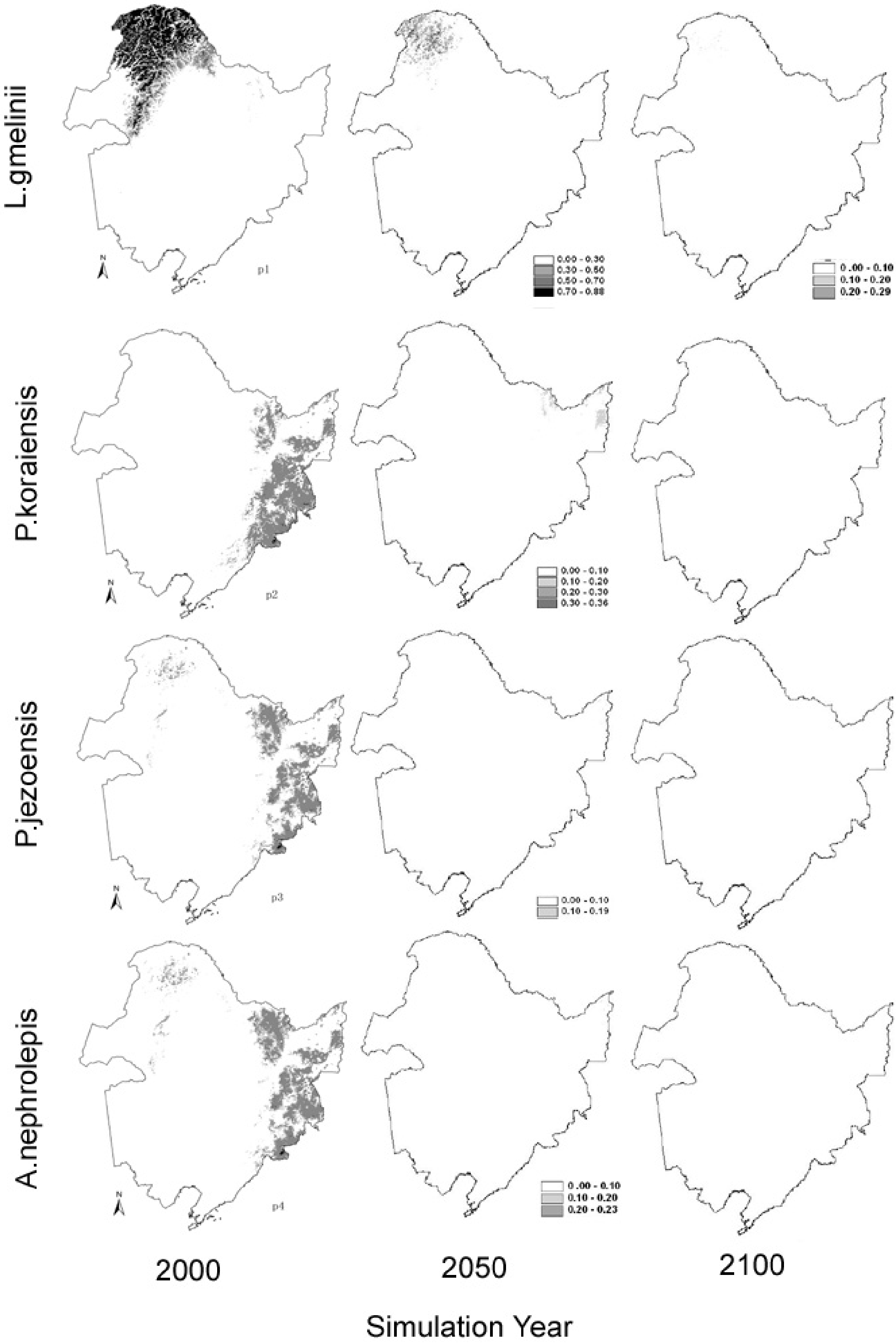
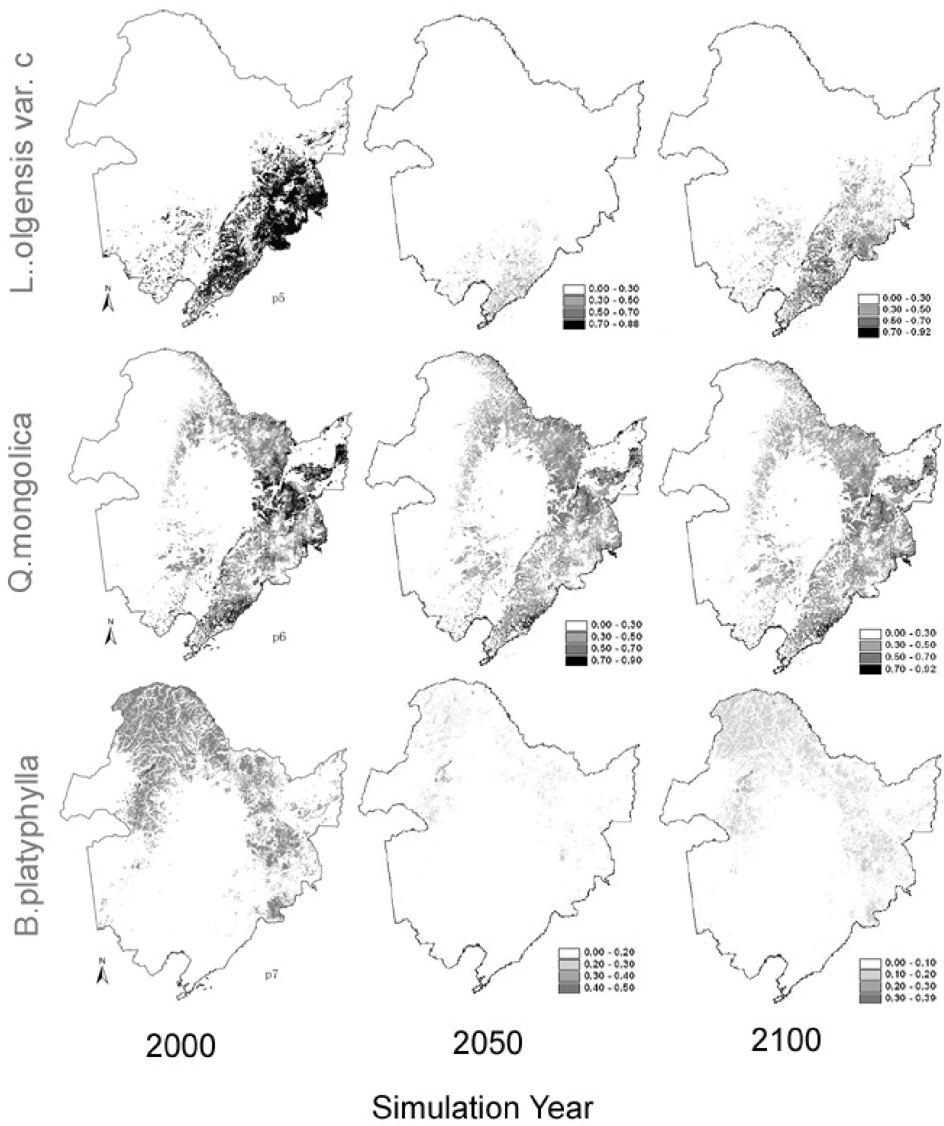


Fig. 1 the potential distribution of constructive species under climate warming

3.3 prediction map of seven species

Using the results of logistic regression model, we could map the distribution of the seven species in 2050 and 2100 year under climate warming. From Fig.1, we could see that, the occurrence probabilities of *Larix* *gmelinii*, *Pinus koraiensis*, *Picea jezoensis* and *Abies nephrolepis* decrease greatly in 2050 and nearly disappear in 2100.

The occurrence probabilities of *Larix olgensis* var. *changpaiensis* and *Betula platyphylla* decrease greatly in 2050, but increase a little in 2100. The occurrence probability of *Quercus mongolica* does not change too much in 2050 and 2100.



Continue Fig. 1

4 Conclusion

From the results of this analysis, we could see that the south boundary of *Larix gmelinii* and *Pinus koraiensis* shift northward greatly in 2050. Their distribution areas disappear in 2100 means that their south boundary have shift out of northeastern China. The Changes of *Picea jezoensis* and *Abies nephrolepis* are even more sharply. Their south boundaries migrate out of the study area early in 2050. Conifer species, *Larix olgensis var. changpaiensis* alone, would exist under the climate changing. But the area of high occurrence probability decrease acutely. There have no obviously northward shift of *Quercus mongolica*. *Betula platyphylla* is most special, which increase in the occurrence probability in 2100.

The viewpoint we need to point out is that the predicted distribution of constructive species are their potential distribution, rather than their actual distribution, for logistic regression model do not considering many other factors which also have effects on the distribution of tree species.

In spite of the shortcoming of itself, logistic regression models still seem to be a robust tool for predicting the potential distribution of tree species at the regional scale. The results of this research showed that future climate changing would have great effects on the distribution of constructive species of northeast forests. The prediction results provide regional view and reference points for revisiting current forest harvesting and afforestation plan that has not considered the effects of climate warming.

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