A Comparing Study on the Impacts of Climate Change on the Geographic Distribution of Pinus Koraiensis in China

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Abstract An ecological information system GREEN has been developed by the authors to determine the climatic conditions and elevation of distribution area of tree species Korean pine (Pinus koraiensis) in China. The potential distribution regions of the species under current climatic conditions and predicted climatic conditions were mapped using a Geographic Information System IDRISI. According to the averages of rainfall and temperarure predicted by 5 GCMs (GISS, NCAR, OSU, UKMO and MPI) for 2030 ("averaged" model) and a new model HadCM2, projections were made for the future distributions of Korean pine. The results show that the southern boundary of the potential distribution area of Korean pine will have a northward shift by 0.1 to 0.6 degrees of latitude, and the northern boundary will have a northward shift of 0.3-0.5 degrees, resulting an expansion of the potential distribution area by 3.4% based on 5 model's average. The distributions predicted by HadCM2 are for the annual increases of CO_2 concentrations by 0.5 % and 1 %, respectively. The potential distribution areas based on the two cases will be decreased by 12.1% and 44.9%, respectively.

1. INTRODUCTION

High correlations exist between spatial distribution of vegetation and climate patterns in a continental scale. Holdrige life zone indices [Holdridge, 1967] which link vegetation distribution and climate indices have been widely accepted in projecting impacts of climate change on vegetation distribution and productivity. Many studies have been published on the topic of climate change impacts on vegetation including forests [e.g. Solomon, 1986; Harrington, 1989]. Hulme et al. [1992] used a group of climatic parameters and predicted potential changes of the vegetation in China by the year 2050 based on compounded 7 GCMs scenarios. Pan & Zhang [1993] used similar method and projected the potential changes of China's vegetation.

Studies on single tree species have been also conducted. For example, Leverenz and Lev [1987] used mainly GISS scenario projected changes of distribution of 6 timber species in The United States. Miller et al. [1987] used a similar method and projected impacts of climate change on the distribution, survival rate and productivity of Pinus taeda.

The aim of this paper is to present the research results on the impacts of climate change on Korean pine (Pinus koraiensis Sieb. et Zucc) in China. Korean pine is a local coniferous species in China, which is mainly distributed in the northeastern part of Asia, ranging from the northeast of China to the west of Japan. It has been intensively studied because of its good quality of wood [Wu 1983; Li et al., 1997]. A model GREEN has been developed, coupling with a geographic information system IDRISI to project the impacts of climate change on its geographic distribution.

2. METHODS

2.1 Mapping program GREEN

The number of meteorological stations in China is not enough for accurate analysis on the distribution of tree species. Therefore the direct use of the stational climatic data may cause big errors. The estimates on precipitation may have even bigger errors due to the mountainous topography in China.

For giving better estimates on the climatic parameters at any locations in the species distribution region, a specially designed mapping program GREEN was developed [Yan, 1989; Yan et al., 1996]. Latitude, longitude, altitude, annual mean temperature, annual precipitation, mean minimum temperature in the coldest month, mean maximum temperature in the hottest month, duration of drought (month number with monthly precipitation less than 40 mm), and absolute minimum temperature at the meteorological stations all over China were collected as a data base [National Meteorological Bureau of China, 1985]. A thin plate surface interpolate method [Hutchinson, 1991] has been applied to interpolate climatic parameters. An 1/20th degree digital elevation model (DEM) of China was developed in ANU CRES by this interpolate program ANUDEM [Zuo et al., 1993], but only 1/10th degree of elevation data were used for GREEN so that a map would be produced that fits a standard VGA screen of an IBM compatible PC. With the estimates of elevation the mean values of temperature, annual precipitation, radiation, potential evapotranspiration were obtained for all locations in the 1/10th degree grid. The program GREEN can be used to map the distribution of a species according to selected climatic thresholds and altitude ranges.

2.2 Determination of thresholds

The potential distribution area is defined as the area beyond which only scattered single trees of the species can be found under the current climate condition. Korean pine is widely distributed in various locations in the northeastern part of China. The distribution of that Korean pine was thus determined by a set of climatic and altitudinal parameters at the upper limits and lower limits.

The geographic information of a specific species or a patch of forest can be found according to their zctual distribution. The data for real distribution of Korean pine are from literature [Wu, 1983; Li et al., 1997]. Then the program GREEN was used to obtain the climatic and altitudinal parameters by moving the cursor to the exact geographic locations of the species indicated on the computer screen. The distance between indicating point and the real recorded point should generally be not over 0.3 degree of longitude or latitude. All the climatic and altitudinal data for each pix can be shown on screen while the cursor moves around the boundary of the species. Based on the above data, by deleting the extreme values, the climatic ranges of determining the geographic distribution of Korean pine can be obtained (Table 1).

Table 1. The thresholds for the potential distribution of Pinus koraiensis determined by GREEN

Geographic and climatic factors	Range
Mean annual temperature (°C)	-2.5 ~ 6.0
Mean minimum temperature in coldest months (°C)	-32.0 ~ -17.0
Mean maximum temperature in warmest months (°C)	22.0 ~ 27.0
Annual precipitation (mm)	524~1024
Dry season (month)	5~7
Absolute minimum temperature (°C)	−47.6~−33.1
Dryness index	0.9~2.1
Altitude (m)	300~1200

The thresholds determined above has to be validated by developing a current potential distribution of a tree species with an actual distribution map.

2.3 Climate Change Scenarios in 2030

Two sets of GCMs are used in the this paper for predicting the climate changes. The first set is the average of 5 GCMs (GFDL, GISS, NCAR, OSU, UKMO) provided by Zhao [1990]. In these models an assumption of doubled atmospheric CO_2 concentration in 2030 was adopted. The second set is HadCM2 which was downloaded from IPCC Internet network [http://ipcc-ddc.cru.uea.ac.uk/cru_data/cru_index.html]. For HadCM2 the annual CO_2 concentrations were assumed to increase by 0.5% and 1% until 2030, respectively. Thus the predictions of climatic factors of annual precipitation, mean annual temperature, maximum temperature and minimum temperature in China by the year 2030 were obtained.

Same interpolate method was used for both set of data to develop 1/10th degree climate field base on land surface of DEM. The distributions of climatic elements in 2030 for different scenarios were mapped out by means of overlaying the predicted incremental climatic fields over the current climate fields.

3. RESULTS

3.1 Current Potential Distribution

The potential distributions of Korean pine under current climate is shown in Figure 1.

As shown in Figure 1 the currrent potential distribution of Korean pine in China is in the range of the latitude from 40.8°N to 49.0°N degrees and the longitude from 134.5°E to 124.0°E. The current potential distribution area is very well coincided with the map drawn manually based on the field investigation [Li et al., 1997].

Fig 1 Current distribution of *Pinus koraiensis*

Fig 2 Potential distribution of *Pinus koraiensis* in 2030 predicted based on 5 model averages

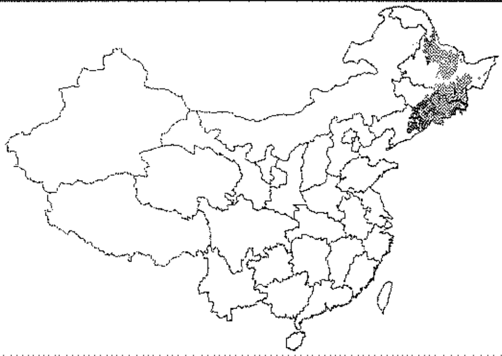

Fig 3 *Pinus koraiensis* 2030 0.5%

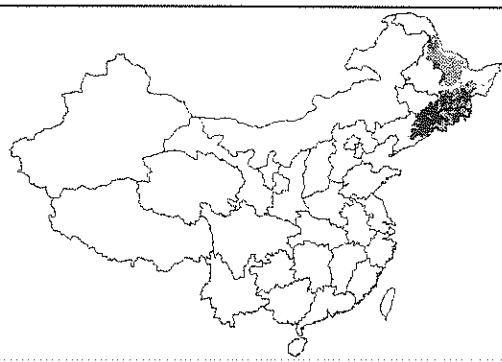

Fig 4 *Pinus koraiensis* 2030 1%

3.2 Impacts of Climate Change on the Potential Distributions

The potential distribution of Korean pine under climate change is shown in Figures 2, 3 and 4. The green area means unchanged, while the red area means an additional increment, and the blue area means an area of disappearance. By comparing the Figures 1 and 2, the potential distribution region of Korean pine under climate change predicted by 5 model's average will have a northward movement, though it is not significant. The south bounary of the current distribution region will move northward by 0.1° to 0.6° in latitude, and the north boundary will move northward by 0.3° to 0.5°. The other parts of the distribution region roughly remain the same. The area of potential distribution will increase by 3.4 % of the total distribution area compared with the area before climate change. As for the HadCM2, the predictions for the annual CO_2 increments of 0.5% and 1% appear different. Both of the predictions show sharp decreases in distribution areas, especially for the case of 1% CO_2 increment. For the former case the distribution area decreased by 12.1%, while for the case decreased by 44.9% of the original area before climate change.

4. CONCLUSIONS AND DISCUSSIONS

Warmth, rainfall and altitudinal conditions are shown to be the dominant factors determining the distribution of Korean pine, showing a good matching between the threshold-based distribution and the real distribution. The distribution areas of Korean pine based on these GCM scenarios tend to be decreasing.

There is a big discrepance of distribution areas of Korean pine between averaged model and HadCM2. This is probably caused by the offseting effect on the individual models by the 5 model's average. The big difference between the two cases of HadCM2 of 0.5% and 1% CO_2 increments shows that the sensitivity of the distribution area of Korean pine responding to the enhanced atmospheric CO_2 concentration and global warming.

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