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SPECIAL TOPIC ON REGIONAL CLIMATE CHANGE IMPACTS AND ADAPTATION

Impacts of Climate Change on Forest Ecosystems in Northeast China

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Abstract

This paper reviews the studies and research on climate change impacts on the forest ecosystems in Northeast China. The results show that in the context of global and regional warming, the growing season of coniferous forests has been increasing at an average rate of 3.9 d per decade. Regional warming favors the growth of temperate broad-leaved forests and has a detrimental effect on the growth of boreal coniferous forests. Over the past hundred years, the forest edge of the cool temperate zone in the southern Daxing'anling region has retreated 140 km northward. From 1896 to 1986, the northern boundary of broad-leaved forests in Heilongjiang province has extended northwestward about 290 km. Future climatic changes (until 2060) may lead to the northern deciduous needle forests moving out of China's territory altogether. The occurrence cycles of pests and diseases have shortened; their distribution ranges have expanded. The life cycle of tent caterpillars (*Malacosoma neustria testacea* Motschulsky) has shortened from 14–15 years in the past to 8–10 years now. The pine caterpillar (*Dendrolimus tabulaeformis* Tsai et Liu), which has spread within western Liaoning province and the nearby areas, can now be found in the north and west. Lightning fires in the Daxing'anling region have significantly increased since 1987, and August has become the month when lightning fires occur most frequently. Overall, the net primary productivity (NPP) of forest in Northeast China has increased. The NPP in 1981 was around 0.27 Pg C, and increased to approximately 0.40 Pg C in 2002. With the current climate, the broad-leaved Korean pine forest ecosystem acts as a carbon sink, with a carbon sink capacity of 2.7 Mg C hm^{-2}. Although the carbon sink capacity of the forest ecosystems in Northeast China has been weakened since 2003, the total carbon absorption will still increase. The forest ecosystems in Northeast China are likely to remain a significant carbon sink, and will play a positive role in the mitigation of climate change.

Keywords: Northeast China; forest ecosystem; climate change

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1 Introduction

Northeast China is located at the higher latitudes of the eastern end of the Eurasian continent. It contains Daxing'anling, Xiaoxing'anling, the Changbai Mountains, and other important forest regions (Fig. 1). Northeast China is an ecologically important forest region, a strategic forest resource reserve and an important ecological green barrier for China. Climate research for nearly a hundred years show that Northeast China is very sensitive to global warming and is one of the most significant warming areas in both China and the world [*Sun et al.*, 2006]. Studies have suggested that, as one of the main terrestrial ecosystems, forest ecosystems are extremely sensitive to climate change, and climate change impacts are very significant [*Zhao*

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et al., 2009d]. In this paper, the research progress in climate change impacts on the forest ecosystems in Northeast China is reviewed. The major technical methods used for climate change impact assessment and prediction, the major findings and the countermeasures to adapt to climate change are summarized. Study areas, such as plant phenology, vegetation compositions and distributions, pests and diseases, forest fires, vegetation productivity and ecosystem carbon budgets are also presented. The uncertainty in current researches is analyzed. Forest ecosystem research that should be strengthened in the future are discussed in order to provide a reference for formulating proper climate change policies.

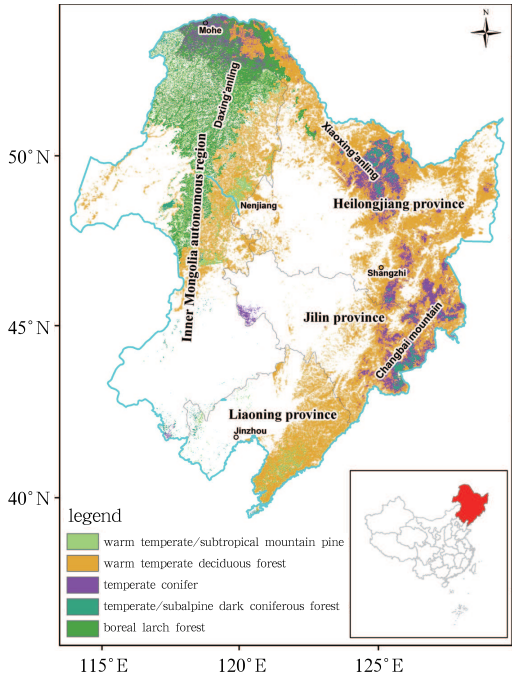

Figure 1 The location and distribution of main forests in Northeast China (based on www.geodata.cn)

2 Main methods used in climate change impact assessment and prediction

2.1 *Phenology*

Two methods have been used to study climate change impacts on plant phenology in the forests of Northeast China. The first one is the statistical analysis of long-term phenological observation data [*Zheng et al.*, 2002; *Xu et al.*, 2006; 2008; *Li and Zhou*, 2010]. The second method is the spatial analysis using a geographic information system (GIS) in conjunction with the statistical analysis of the vegetation index from satellite remote sensing data [*Guo et al.*, 2010a; 2010b]. In studies applying the above mentioned methods, two problems were identified. First, the ground phenology observation data is very limited. Second, the ground observation data are often used to validate the remote sensing data, which inhibits inconsistent scale problems.

2.2 *Vegetation composition and distribution*

Studies on timberline change are mainly based on transect investigations and tree ring analyses [*Wang et al.*, 2004]. The major methods used to study vegetation composition and distribution change include transect investigations [*Zhou et al.*, 2002] and the reanalysis of data from historical forest maps [*Chen*, 2000]. Methods for future predictions include related models based on field observations [*Mu*, 2003], statistical models [*Leng et al.*, 2007], biogeographic models, e.g. MAPSS, life zone classification and climate classification [*Zhao et al.*, 2002; *Wu*, 2003; *Wu et al.*, 2003; *Liu et al.*, 2007; *Li et al.*, 2006], and forest gap models, e.g., FAREAST, LINKAGES and BKFP [*Cheng and Yan*, 2008; *Zhou et al.*, 2007; *Liu and Jin*, 2005; *Hao et al.*, 2001]. Different climate scenarios have been used to predict forest succession dynamics and vegetation distribution trends in Northeast China.

2.3 *Pests and forest fires*

So far, studies on forest pests in Northeast China mainly used the pest monitoring data [*Zhao et al.*, 2003; *Zheng and Wang*, 2004]. Information on forest fires in Northeast China mostly comes from the government and forestry fire departments or from remote sensing data.

2.4 *Productivity and carbon budgets*

Model simulations are often used to study the productivity and carbon budget of forest ecosystems in Northeast China. Models used include biogeochemical model, e.g., Sim-CYCLE (simulation model of Carbon