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ScienceDirect
Global and Planetary Change 61 (2008) 267–274
GLOBAL AND PLANETARY CHANGE
www.elsevier.com/locate/gloplacha

Spatiotemporal dynamics of forest net primary production in China over the past two decades

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Received 26 April 2006; accepted 18 December 2006
Available online 17 October 2007

Abstract

Forest ecosystems play an important role in global carbon cycle regulation. Clarifying the dynamics and mechanism of carbon sink is of both scientific and political importance. In this paper, we have investigated the spatiotemporal change of forest net primary production (NPP) in China for recent two decades based on the geographically weighted regression (GWR) with a cumulative remote sensing index, the maximum normalized difference vegetation index ($NDVI_{max}$). GWR is a recently developed regression method with special emphasis on spatial non-stationarity. Outputs of forest NPP at three different stages was generated by the GWR model with $NDVI_{max}$ for the 1980s, early and late 1990s which were consequently analyzed. Our results indicated a wave-like pattern of change in forest NPP in the three stages with a trough-like depression for the early 1990s. The average forest NPP increased by about 0.72% from the 1980s to the late 1990s. A continuously increasing trend at a pace of 0.07% and 0.22% yr^{-1} was observed in the tropical and subtropical zones from the 1980s to late 1990s respectively, while a continuously decreasing trend (−0.05% yr^{-1}) was noted for the temperate zone. From forest type perspective, only the deciduous broadleaf forests exhibited a continuously decreasing trend of 0.18% yr^{-1}. The complex spatiotemporal patterns revealed by this study suggest the need for further research in this direction in order to build in-depth insights into the revealed complexities.

Keywords: GWR; cumulative; NDVI; NPP; spatial; temporal

1. Introduction

Forest ecosystems play a leading role in global carbon cycle regulation because of their huge carbon stocks, storage capacity and productivity (Watson et al., 2000). The global assessment of inter-annual changes of net primary production (NPP) is a fundamental global climate and global change model input (Ruimy et al., 1994). However, large spatiotemporal heterogeneity of forest NPP limits the quantification of this change, which remains an important challenge at local landscape, regional and continental scales. Large scale NPP mapping thus remains difficult because of considerable limitations in direct measurement.

As a big and important country, China has diverse natural environmental conditions with rather complex NPP patterns. Earlier information on broad-scale NPP in China relies mainly on modeling approaches that were mostly based on climate inputs (e.g. Ni, 2000; Cao et al., 2003) or the combination of climate and satellite data (Fang et al., 2003). Few studies had ever had access to direct descriptions of broad-scale NPP distribution.

Remote sensing data has been a recognized principal tool for broad-scale NPP mapping and monitoring on annual bases in recent times (Ricotta et al., 1999). NDVI is a remote sensing index that responds strongly to healthy green vegetation, and approximately linearly related to the fraction of absorbed photosynthetically active radiation (FPAR) (e.g. Sellers, 1985), and therefore is a good proxy for photosynthetic activity analysis (Slayback et al., 2003). Among available remote sensing indices, cumulative indices, like the time-integral normalized

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doi:10.1016/j.gloplacha.2006.12.007

difference vegetation index (TINDVI) have become the principal tool for broad-scale NPP mapping and monitoring, which is a widely used surrogate to NPP in varied applications (e.g. Ricotta et al., 1999; Slayback et al., 2003). Cumulative remote sensing indices refer to those indices upscaled from time-series data to a composite index and therefore capable of representing the cumulative effect of remote sensing data over periods during which the data are compiled. Upscaling can dramatically reduce input data requirements but with the summarization of seasonality and vegetation dynamics.

Applied common approaches in earlier studies include NPP regression models and cumulative remote sensing indices, mostly based on the ordinary least squires (OLS) regression methods. However, spatial autocorrelation of NPP and remote sensing data in a large spatial context violates basic assumptions of the OLS (Wang et al., 2005), and hence needs revisiting using different approaches.

Geographically weighted regression method (GWR) is a recently developed regression method with special emphasis on spatial non-stationarity (Fotheringham et al., 2002), and therefore appropriate for application on large spatial NPP mapping through remote sensing data (Wang et al., 2005). Wang et al. (submitted for publication) investigated the relationships between Chinese forests NPP and various cumulative remote sensing indices based on both GWR and OLS approaches, and noted higher precisions in NPP simulation with GWR models over its OLS counterpart. The cumulative remote sensing indices reported in Wang et al. (submitted for publication) range from mean NDVI ($NDVI_{mean}$), maximum NDVI ($NDVI_{max}$), NDVI coefficient of variation ($NDVI_{cv}$), NDVI amplitude ($NDVI_{amp}$), NDVI magnitude (|NDVI|) to TINDVI. Among the models, GWR with $NDVI_{max}$ performed the best (Wang et al., submitted for publication).

In this paper, we used GWR in combination with the selected cumulative remote sensing index ($NDVI_{max}$) to explain changes in NPP for China's forests in recent two decades.

2. Methodology

2.1. Study area

We focused our study on China's forest ecosystems. China is a big country with diverse climate, supporting almost all major forest vegetation types of the northern hemisphere, ranging from boreal needleleaf and broadleaf forests, through temperate deciduous broadleaf forest and warm–temperate (subtropical) evergreen broadleaf forest, to tropical rainforest. As a big country undergoing strong reforestation and afforestation, quantifying the size and spatial pattern of NPP of its forest ecosystems certainly plays an important role in developing a better understanding of both regional and global carbon cycles. The spatial distribution of five main forest types in China is shown in Fig. 1. The grouping of the five main forest types was adapted from Piao et al. (2005), from the 1:4 000 000 China vegetation map. The five forest types include: the deciduous needleleaf forests, evergreen needleleaf forests, deciduous broadleaf forests, broadleaf and needleleaf mixed forests, and the evergreen broadleaf forests.

2.2. NPP dataset

Detail description of the NPP dataset used in this study can be found in Ni et al. (2001). Data was mostly derived from a 5-year national forest inventory between 1989 and 1993, and partly from previous forest inventories (1956–1970) and published reports and journals as recent as 1994 (Luo, 1996).

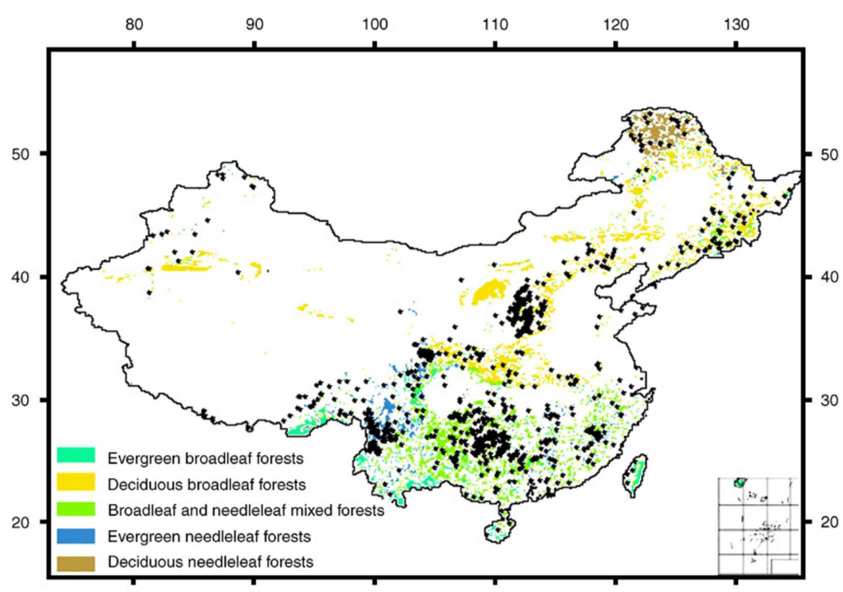

Fig. 1. Forest distribution and measured NPP data points in China. Forest grouped after Piao et al. (2005). (broadleaf forests, deciduous broadleaf forests, broadleaf and needleleaf mixed forests, evergreen needleleaf forests, and deciduous needleleaf forests).