Comparing NDVI to maximum latewood density of annual tree rings in a boreal coniferous forest in North China

Jicheng He, Xuemei Shao, Lili Wang
Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Building 917, Datum road3, Anwai Street, Beijing 100101, People's Republic of China
hejc@igsnrr.ac.cn

Abstract: In boreal conifers in China's Northeast area, maximum latewood density (MXD) of tree-ring varies in response to growing season temperature. Forest net productivity can be estimated using the Normalized–difference Vegetation Index (NDVI) calculated from satellite sensor data. MXD from the Mohe site in this area was compared with estimates of NPP for 1982-1999 produced by the NDVI model, which was established based on the relationship of leaf area index (LAI) and NDVI. The result shows that the MXD series correlated significantly with the NDVI model estimates series, suggesting that MXD appeared to be an appropriate index for productivity or canopy growth in region where forest productivity is strongly temperature-related.

Keywords: Maximum latewood density, NPP, Mohe.

1. Introduction

The world's boreal forests have been the subject of recent questions about unusual or changing forest growth patterns in the past few decades, as observed both in tree-ring [1] and satellite sensor [2] data. Intercomparison of these two data types may help deepen our understanding of the response of the boreal forest to recent warming trends. China's Northeast area is the most temperature-sensitive area in China, but until now, no similar research works have been developed. In the background of climate change, it is beneficial to chose a high-latitude boreal conifers forest site to study the forest productivity.

Tree-ring data provide valuable information about how tree growth responds to climate change in boreal forests and elsewhere [3]. Malmstrom et al. [4] show that tree-ring data captures year-to-year variation in satellite derived net primary productivity (NPP) rates by 1-degree resolution grid cell. In boreal conifers, annual ring widths often reflect conditions from previous non-growing–season periods as well as from the current season [5]. A second type of tree-ring data, annual MXD, provides somewhat different information. MXD is an annual tree ring parameter based on the highest density of the cells formed at the end of the season of radial growth. Boreal conifer MXD usually correlates positively with monthly temperatures from May through September, making MXD a good proxy for warm season temperature [6]. D'arrigo et al. [7] correlated MXD of tree-rings and the NDVI based estimates of forest productivity in boreal conifers, which suggests that MXD may be an appropriate measure for forest productivity.

It is relatively straightforward to evaluate interannual variation in NDVI at desert calibration sites or to compare NDVI-based estimates of NPP against production data from selected agricultural regions [8]. However, comparisons of NDVI with tree-ring data originally collected for dendroclimatology can be hampered if the tree-ring series are not spatially representative of a large area.

Malmstrom et al. [4] evaluated NDVI-based estima tes of NPP by the CASA (Carnegie-Ames-Stanford-Approach) model. They found significant correlation between detrend NDVI-base NPP estimates and are a-weighted ring-width indices derived from paper bi rch and white spruce data collected at Fort Richard son, Alaska.

D'aarigo et al. [7] found the significant positive correlations between MXD data and NDVI-based NPP estimates occurred even at the sites where the species sampled represented a relatively small fraction of the regional vegetation. Their results suggested that, in the absence of multi-species or spatially extensive data, a tree-ring parameter from a single tree species may be an appropriate index to regional production if both the tree-ring parameter and regional production are limited by the same environmental factor.

In this paper, we compared MXD series from conifers at Mohe site with NPP estimates produced by the NDVI model based on NOAA Advanced Very High Resolution Radiometer (AVHRR) monthly composite product with 8km resolution. The scope of this article is to investigate whether we can find the same conclusion as D'arrigo's and test their hypothesis in Northeast of China, and firstly use tree-ring data to evaluate NDVI in China.

2. Methods

1) Tree-ring Data

Maximum latewood density (MXD) series were derived from Mongolian scoth pine (*Pinus sylvestris* L. var. mongolica Litv, an evergreen) at Mohe in North of Mount. Daxinganling in Northeast of China. The sampling site locates in a mountain slope facing East (with 8-10 degree slope angular) and its geographical coordinate is 52.47°N and 121.34°E. X-ray densitometry was used to measure the density values. Standard techniques were used in the chronology development [9]. MXD series were developed from 12 trees at the sampling location.

2) NDVI-based estimates of NPP

The NDVI is a useful tool for assessing extent and condition of vegetation [10]. It is calculated as (NIR-R)/(NIR+R), where NIR is relative radiance in near infrared wavelengths and R is relative radiance in red wavelengths. Satellite-sensor-borne instruments, such as the AVHRR, yield global-scale NDVI time series for estimating interannual changes in vegetation activity [11]. Estimates of annual NPP for 1982-1999 were produced by the NDVI statistical model:

$$NPP=-0.6394-67.064\ln(1-NDVI)$$

This model was established by Zheng et al. [12] to simulate the NPP of forest vegetation in China according to a comparison of forecasted with observed forest NPP data for spruce forest, pine forest, evergreen broad-leaved forest, deciduous and evergreen broad-leaved forest, mixed coniferous broad-leaved forest etc. correspondence with observed data was very well. Meanwhile, the model can gives better forecasted results than the Chikugo and Synthetic models at a general level. [13]

3) Comparisons

In the study, from internet (http://www.daac.nasa.gov), we downloaded the monthly 8km resolution AVHRR NDVI data set from January 1982 to December 1999 for the northeast area in China. We converted the original Goode projection to geographical (longitude/latitude) projection. Due to the satellite sensor wrong, the data for September 1994 to December 1994 missed. So we calculated the missed NDVI data in 1994 by averaging the corresponding monthly data in 1993 and 1995. By averaging the monthly NDVI data, we can acquire the yearly NDVI data series. Because the sampling site is 52.47°N and 121.34°E, we select the 0.5°×0.5°square area which center point is sampling site to generate the NDVI series and then compare the tree-ring MXD series with the NDVI series.

3. Results

There is a dynamic change of standard and residual index for maximum latewood from 1982 to 1999. In 1983, 1987, 1989, 1995 and 1999, low values occurred. In D'arrigo's paper, the MXD series from deciduous larch in Taymir, Siberia also appeared low values in 1983 and 1989. The difference between our research and D'arrigo's lies in: (1) his series span presented is shorter, that is from 1982 to 1990; (2) There is a higher value in 1985 in our series. The NPP change from 1982 to 1999 based on the NPP model. The NPP value is low in 1984, 1987, 1993 and 1999. The MXD indices in 1987, 1993 and 1999 are also low. The NPP series and the MXD series have the similar change trend. The standard MXD series from Mongolian scoth pine agrees well with the NPP estimates series. The p value for correlation coefficient is 0.039, which is less than the significant threshold 0.05. So a linear regression formula can be established between these two series, it can be expressed as: y=58.133x-35.988 (where y is NPP, x is standard MXD indices value). A significant correlation can also be found between residual MXD series and NPP series, although the correlation coefficient value (0.4792) is less than presented above. Similarly, a linear regression formula can be expressed as: y=55.765x-34.987 (where y is NPP, x is residual MXD indices value).

4. Discussion and conclusions

Our results show significant positive correlations between MXD data and NDVI-based NPP estimates, at site in China where temperature is the primary factor to limit gorwing. Malmstrom et al. [4] had previously shown the potential of using the tree-ring width parameter for comparison with NDVI-based NPP estimates, using a birch/spruce mix that represented a relatively large fraction of grid cell area. In our research area, Mongolian scoth pine covers small fraction, and the main fraction is covered by dahurian larch. The correlations we found with MXD occurred even at site where the species sampled represented a relatively small fraction of regional vegetation. So we found the same conclusion as D'arrgo's.

Our results confirms once more the D'arrgo's suggestion, which is that in the absence of multi-species or spatially extensive data, a tree-ring parameter from a single tree species may be an appropriate index to regional production if both the tree-ring parameter and regional production are limited by the same environmental factor. Thus, MXD in boreal conifers may be an approximate index for production or canopy growth in regions where production is strongly temperature-limited. This study also demonstrates both the potential value and some limitations of using tree-ring data to evaluate NDVI. To do so, we must have confidence that the data adequately capture large-area growth responses (e.g. tree-ring width data in Malmstrom et al.) or that the series is a valid proxy for the regional limiting factor to growth (herein). Sampling strategies need to evaluate a range of tree-ring parameters, including MXD, and to consider the mix of species types, age classes, regional limiting factors, and landscape heterogeneity.

Acknowledgment

The authors thank the Distributed Active Archive Center (DAAC) at the Goddard Space Flight Center, Greenbelt, MD, 20771, for producing the data in their present form and distributing them, and grateful to the processing team headed by Ms. Mary James of the Goddard Global Change Data Center for producting the original data products under the NOAA/NASA Pathfinder program, to the AVHRR Land Science Working Group, chaired by Dr. John Townshend of the

University of Maryland for establishing the science algorithms. Goddard's contributions to these activities were sponsored by NASA's Mission to Planet Earth program.

References

[1] Briffa K. R., F. H. Schweingruber, P. D. Jones, et al., 1998. Reduced decadal thermal response in recent northern tree growth. Nature, 391: 678-682

[2] Myneni R. B., Keeling C. D., Tuck C. J., et al. 1997. Increased plant growth in the northern high latitudes from 1981 to 1991. Nature, 386:698-702

[3] Lara A., R. Villalba, 1993. A 3620-year temperature record from Fitzroya cupressoides tree rings in southern South America. Science, 260:1104-1106

[4] Malmstrom C. M., M. V. Thompson, G. Juday , et al.1997. Interannual variation in global-scale net primary production: testing model estimates. Global biogeochemical cycles, 11:367-392

[5] Jacoby G. C., R. D. D'arrigo, 1989. Reconstructed Northern Hemisphere annual temperature since 1671 based on high latitude tree-ring data from North America. Climate change, 14:39-59

[6] D'arrigo R. D., G. C. Jacoby, R. Free, 1992.Tree-ring width and maximum latewood density at the North a merican treeline: parameters of climate change. Can a dian journal of forest research, 22:1290-1296

[7] D'arrigo R. D., C. M. Malmstrom, G. C. Jacoby, et al. 2000. Correlation between maximum latewood density of annual tree rings and NDVI based estimates of forest productivity. International journal of remote sensing, 21:2329-2336

[8] Justice C. O., J. R. Townshend, B. N. Holben, et al. 1985. Analysis of the phenology of global vegetation using meteorological satellite data. International journal of remote sensing, 6:1271-1318

[9] Cook E. R., L. A. Kairiukstis, 1990. Methods of den drochronology, Applications in the environmental scie nces. Dordrecht: Kluwer Academic Press.

[10] Sellers P. J., S. O. Los, C. J. Tucker, et al., 1996. A revised land surface parameterisation (SiB-2) for atmospheric GCMs. Part 2: The generation of global fields of terrestrial biophysical parameters from satellite data. Journal of climate, 9:706-737

[11] Goward S. N., S. Turner, D. G. Dye, et al. 1994. The University of Maryland improved Global Vegetation Index product. International journal of remote sensing, 15:3365-3395

[12] Zheng Y. R., G. S. Zhou 2000. A forest vegetation NPP model based on NDVI. Acta phytoecologica sini ca, 24:9-12

[13] Zhou G. S., X. S. Zhang, 1996. Study on NPP of natural vegetation in China under global climate change. Acta phytoecologica sinica, 20(2): 113-119