Ecological Indicators 91 (2018) 511–522

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

MODIS detection of vegetation changes and investigation of causal factors in Poyang Lake basin, China for 2001–2015

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ARTICLE INFO

Keywords:
MODIS NDVI
Vegetation change
Abrupt change
Deforestation
Poyang Lake basin

ABSTRACT

In recent decades, vegetation has shown an overall greening trend in response to rising global temperatures. At the same time, vegetation browning is still worthy of attention, particularly in humid regions with dense vegetation coverage. This study used 15 years (2001–2015) of Terra Moderate-resolution Imaging Spectroradiometer (MODIS) normalized difference vegetation index (NDVI) data in an effort to detect the overall trends and abrupt changes in vegetation activity over the Poyang Lake basin, which is a typical humid region that contains the largest freshwater lake in China. MODIS NDVI data showed a vegetation greening trend over 94.9% of the basin land. Although the basin has been extensively afforested since the 1980s, there was still a vegetation browning trend over 5.1% of the basin land area, primarily as a result of urbanization. Abrupt vegetation decreases were observed over 7.9% of the basin land area from 2004 to 2012. Most of the decreases were likely caused by the nationwide snow storms in early 2008 and the widespread insect outbreaks as a result of abnormal hydrometeorological conditions. Abrupt vegetation increases were observed over 1.6% of the basin land area in the same period. Most of the increases were likely attributed to the continued efforts of afforestation that transformed large woody savanna lands to mixed forests. The results provided spatial details, time nodes and causal factors of vegetation changes, particularly vegetation decreases, which will benefit government organizations when taking remedial measures.

1. Introduction

Climate change and human activities may affect the regional distribution, structure, composition, diversity and productivity of vegetation (Nemani et al., 2003; Foley et al., 2005). Based on remote sensing techniques and *in situ* observations, most scientific studies report a general vegetation greening trend due to rising global temperatures and carbon dioxide concentrations (Cramer et al., 2001; Kawabata et al., 2001; Zhu et al., 2016). Despite this fact, many other factors also result in vegetation browning trends (Chakraborty et al., 2018). For instance, global warming may increase the probability of extreme meteorological conditions and drought events (Breshears et al., 2005; Xu et al., 2016). Therefore, forest fires may occur as a result of decreasing litter moisture (Overpeck et al., 1990; Thonicke et al., 2001). These extremes and abnormalities also trigger secondary disasters such as insect outbreaks, since the trees are less resistant to insect attacks due to water stress (Rouault et al., 2006). In addition, land use/land cover (LULC) changes are also an important driver of vegetation changes (Zhang et al., 2009; Zhu et al., 2016). Among various human activities, afforestation and deforestation activities are directly linked to vegetation changes (Zhang and Song, 2006).

The causal factors of vegetation degradation are regionally dependent. Precipitation is a critical factor to vegetation growth in arid and semi-arid regions (Lázaro et al., 2001). Plant photosynthetic activity decreased markedly in arid and semi-arid regions in the Southern Hemisphere from 1982 to 1990 because of a decline in rainfall (Kawabata et al., 2001). However, in humid regions, temperature is considered a more important factor (Tan et al., 2015). Although meteorological drought (less precipitation) may propagate to hydrological drought (less runoff) in some cases, it is less likely to evolve into soil moisture drought (less soil moisture) that is strong enough to affect vegetation growth in humid regions (Zhou and Liu, 2018). In addition, the dense population in humid regions may have an impact on vegetation growth by means of LULC changes. Brandt et al. (2017) showed that the dryland woody vegetation increases (1992–2011) in sub-Saharan Africa as a result of increased carbon dioxide concentrations were mainly offset by the concurrent population expansion in the humid regions. Overall, it is difficult to separate the causal factors of regional

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https://doi.org/10.1016/j.ecolind.2018.04.041
Received 22 January 2018; Received in revised form 21 March 2018; Accepted 16 April 2018

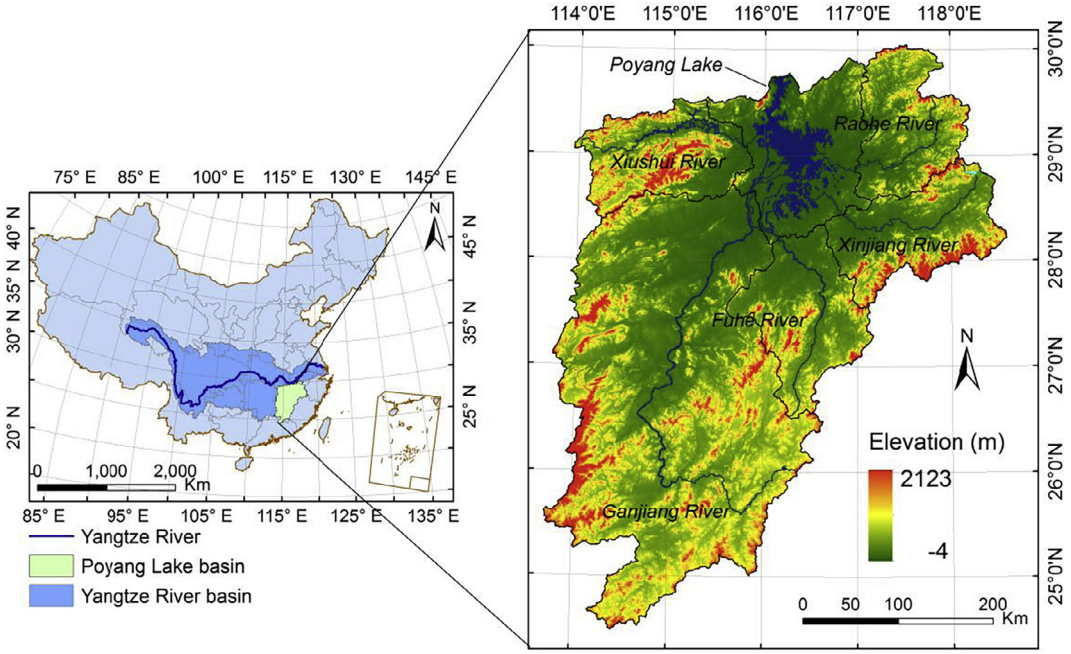

Fig. 1. Geolocation and digital elevation model of the Poyang Lake basin, China. The basin is in the eastern part of the Yangtze River basin, and Poyang Lake, which is China's largest freshwater lake, is connected to the Yangtze River in the north via a narrow outlet.

vegetation degradation. The difficulty also results from the fact that vegetation browning signals are usually covered by the overall vegetation greening trends. However, it is important to know the information of vegetation degradation to seek remedial measures.

The Poyang Lake basin is located in southeast China (mostly in Jiangxi Province) and contains China's largest freshwater lake. The lake is well known for its ecological, economical and hydrological significance (Liu et al., 2013; Wu et al., 2014). The basin is within a humid region and has experienced an extensive afforestation period by means of artificial planting and aerial seeding since the 1980s in response to government policies (Cao et al., 2011). As a result, the forest coverage rate increased steadily from 34.7% in 1983 to 63.1% in 2010 (website of the Statistic Bureau of the Jiangxi Province, China at http://www.jxstj.gov.cn/). These young and middle-aged trees may experience a fast growth period in the context of rising temperatures, and therefore, show an overall greening trend as derived from satellite remote sensing data (2001–2015) (Zhang et al., 2017). However, the changing meteorological and hydrological conditions in recent decades may affect vegetation growth in addition to the fast urbanization promoted by the Chinese government. Moreover, insect outbreaks in the forested areas and near urbanized areas may also pose great threats to tree survival and growth (Wang and Peng, 2011; Zhang, 2016). In addition to the generally poor soil conditions and insufficient management, vegetation changes in this basin area need careful inspection. Although many studies have reported a vegetation greening trend and the driving factors at global and national scales (Piao et al., 2015; Zhu et al., 2016; Hua et al., 2017; Pei et al., 2018), monitoring and analysis of vegetation browning trends on a regional scale may offer guidance for the planning of afforestation activities and the improvement of low-quality forests.

Vegetation changes have been monitored using a variety of data. The national forest inventories (NFIs) provide systematic and accurate information on forest distribution and change (Wilson and Ek, 2017). However, the data are generally led by government organizations and are not open to the public (Li et al., 2017). Instead of NFIs, satellite-derived normalized difference vegetation index (NDVI) datasets are widely used for monitoring vegetation changes. These datasets include the Global Inventory Modeling and Mapping Studies (GIMMS, now in the 3rd generation as GIMMS3g), the Advanced Very High Resolution Radiometer (AVHRR) NDVI dataset at 8-km resolution (Tan et al., 2015; Duo et al., 2016), the Moderate-resolution Imaging Spectroradiometer (MODIS) NDVI dataset at 250 m – 1 km resolutions (Petus et al., 2013; Eckert et al., 2015), and the Landsat data sets at 30-m resolution (Huang et al., 2010; Wang et al., 2017). However, the spectral band responses differ among AVHRR sensors (Fan and Liu, 2016; Fan and Liu, 2018), and the GIMMS3g dataset performs poorly in humid regions (Tian et al., 2015). Therefore, the MODIS NDVI dataset is generally favored for the detection of vegetation change in humid regions because of the finer spatial resolution and better spectral consistency over the GIMMS3g dataset. The MODIS dataset also outperforms the Landsat dataset, because long rainy days during the summertime may affect the acquisition of clear Landsat scenes in humid regions. Based on these datasets, a number of statistical methods have been developed to decompose NDVI time series data into seasonalities and trends that are separated by breakpoints (Verbesselt et al., 2010).

In the context of the general vegetation greening trend, the current study focused on vegetation degradation in the Poyang Lake basin, which is a typical humid region where substantial afforestation efforts have been made. For this purpose, the Terra MODIS NDVI dataset was used to investigate the overall vegetation trends and abrupt vegetation changes from 2001 to 2015. Subsequently, the trends and changes were discussed in regard to a variety of factors, including hydro-meteorological conditions, as well as insect attacks and human activities. Special attention was paid to the causal factors of abrupt vegetation decreases, which may provide valuable guidance on forest management for government organizations. The layout of this study includes the materials and methods described in Section 2, the results presented in Section 3, followed by a discussion on the main results in Section 4, and the conclusions summarized in Section 5.

2. Materials and methods

2.1. Overview of the study area

Poyang Lake (28°22′–29°45′N, 115°47′–116°45′E) is the largest freshwater lake in China and is well known for its ecological and economic importance (Huang et al., 2012; Dai et al., 2017). Poyang Lake is also a wetland of international importance under the Ramsar