Science Bulletin 62 (2017) 40–45

Contents lists available at ScienceDirect

Science Bulletin

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

Article

Two centuries of April-July temperature change in southeastern China and its influence on grain productivity

Jiangfeng Shi [a,*], Jinbao Li [b], David D. Zhang [b], Jingyun Zheng [c], Shiyuan Shi [a], Quansheng Ge [c], Harry F. Lee [b], Yesi Zhao [a], Jie Zhang [a], Huayu Lu [a]

[a] *Ministry of Education Key Laboratory for Coast and Island Development, School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210023, China*
[b] *Department of Geography, University of Hong Kong, Hong Kong, China*
[c] *Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*

ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form 10 October 2016
Accepted 14 October 2016
Available online 22 November 2016

Keywords:
Temperature
Grain productivity
Social disturbance
China
Tree-rings

ABSTRACT

China is a traditional agriculture based country and one main region for crop production is southeastern China where temperature is a dominant climate variable affecting agriculture. Temperature and social disturbances both influence crop production, yet distinguishing their relative impacts is difficult due to a lack of reliable, high-resolution historical climatic records before the very recent period. Here we present the first tree-ring based warm-season temperature reconstruction for southeastern China, a core region of the East Asian monsoon, for the past 227 years. The reconstruction target was April-July mean temperature, and our model explained 60.6% of the observed temperature variance during 1953–2012. Spatial correlation analysis showed that the reconstruction is representative of April-July temperature change over most of eastern China. The reconstructed temperature series agrees well with China-scale (heavily weighted in eastern China) agricultural production index values quite well at decadal timescales. The impacts of social upheavals on food production, such as those in the period 1920–1949, were confirmed after climatic influences were excluded. Our study should help distinguish the influence of social disturbance and warm-season temperature on grain productivity in the core agricultural region of China during the past two centuries.

1. Introduction

China has a long history as a traditional agriculture based country, and crop production has played a crucial role in socioeconomic development over the past centuries to millennia [1–3]. Crop production could be influenced by both climatic change and social disturbance [4–11]. However, it is always challenging to distinguish their relative contribution, partly due to their interwoven effects on agriculture [12]. China's major grain production area lies in the eastern monsoon climate zone where temperature is one of the key factors in determining agricultural production [13], as cooling could decrease grain yields by shortening the crop's growing season and reducing the effective farmland area [14]. However, annually resolved, long-term warm-season temperature variability in southeastern China is poorly understood till now for three main reasons: (i) the very limited period of instrumental data, (ii) the scarcity of long-term high-resolution warm-season temperature reconstructions from natural proxies, and (iii) the scarcity of historical records that offer reliable temperature information. Even when available, the historical records tend to reflect cold-season temperatures rather than warm season temperatures [15–17].

A potential solution to the lack of reliable long-term temperature records lies in the analysis of tree-ring records. Tree-ring based studies have revealed regional temperature variations in several parts of southeastern China. Winter-spring temperatures have been reconstructed in several areas of southeastern China from tree-rings [18–21]. The negative relationship between tree growth and the growing season temperature is mostly found at low-elevation sites in southeastern China [22–24]. The limiting effects of precipitation on tree growth are found only at few very dry, low-elevation sites in southeastern China [25]. At high elevation sites in southeastern China, the limiting effects of temperature on tree growth may extend even into the summer period [26,27]. It thus seems likely that tree-ring series from humid high-elevation sites in eastern China may provide a basis for warm-season temperature reconstruction, and a means to evaluate the influences of climate and social disturbance on crop production.

---

* Corresponding author.
E-mail address: shijf@nju.edu.cn (J. Shi).

http://dx.doi.org/10.1016/j.scib.2016.11.005
2095-9273/

The mountains are mostly at low to medium elevations in southeastern China (Fig. 1), which makes it hard to find clear upper tree line situation. However, trees might approach their upper limit tolerance at some relatively high-elevation sites. Indeed, we found strong warm-season temperature signals in two tree-ring width chronologies 1500 m above sea level (a.s.l.), 250 km away from each other, despite a relatively low sample replication [28]. Therefore, we consider that taking tree-ring samples at sites higher than 1500 m a.s.l. will help develop a regional chronology that contains strong warm-season temperature signals.

In this study, we aim to understand how long-term warm-season temperature has changed in southeastern China and to what extent temperature and social disturbances have affected grain productivity in history. Our objectives are (1) to build a regional chronology based on tree-ring samples from high-elevation sites in southeastern China, (2) to reconstruct the warm-season temperatures using the regional chronology, (3) to explore its spatial representativeness by comparing with China-scale temperatures, and (4) to investigate the connections between temperature change and agricultural productivity in historical China so as to distinguish the relative influence of warm-season temperature and social disturbance.

2. Data and methods

2.1. Meteorological data

Southeastern China is an East Asian monsoon dominated region with a mild climate. Summer is hot and wet while winter is cool and dry. Generally, this type of temperature and precipitation pattern is suitable for crop growth. The average of Tunxi and Jingdezhen meteorological station data indicates that the annual mean temperature in the study area is 17.0 °C, and that annual total precipitation is 1747.2 mm (Table S1). The coldest month is January with an average temperature of 4.6 °C, while the hottest month is July with an average temperature of 28.6 °C (Fig. S1). The meteorological records were obtained from the China Meteorological Data Sharing Service System. The sampling sites have a much higher elevation (Table S2). Thus they should have experienced higher precipitation and lower temperatures than that recorded at the meteorological stations.

2.2. Tree-ring data

Tree-ring samples of *Pinus taiwanensis* Hayata were taken from three sites: SQG0204 (28°55′N, 118°03′E, 1550–1600 m a.s.l.) of Jiangxi Province, JLS01 (28°20′N, 118°51′E, 1530 m a.s.l.) of Zhejiang Province, and GNJ01 (30°03′N, 117°27′E, 1650–1700 m a.s.l.) of Anhui Province (Fig. 1 and Supplementary Table S2). SQG0204 samples were taken from the Sanqingshan National Geological Park in Shangrao, Jiangxi Province. The park is part of the Huaiyu Mountains with the highest peak at 1820 m a.s.l., the fifth highest in Jiangxi Province. JLS01 samples were taken from the Jiulongshan Natural Reserve with a southwest to northeast orientation in the western Suichang, Zhejiang Province. It is a branch of the Xianxia Mountains, with the highest peak at 1724 m a.s.l., the fourth highest in Zhejiang Province. GNJ01 samples were taken from the Guniujiang Natural Reserve in Shitai, Anhui Province. The mountains extend from east to west, with the highest peak at 1728 m a.s.l., the third highest in southern Anhui Province.

After crossdating the tree cores following standard dendrochronological methods [29] and deleting the ones shorter than 100 years, 114 cores from 62 trees were used in the following analyses, including 66 cores of 35 trees from SQG0204, 28 cores of 16 trees from JLS01, and 20 cores of 11 trees from GNJ01. The data of JLS01 and GNJ01 were previously used to analyze the responses of tree growth to climate [28]. Missing rings account for 0.79% of the total. The series intercorrelation is 0.53, and the average mean sensitivity is 0.30.

2.3. Methods

Age-dependent spline smoothing was used to detrend original tree-ring width series, and their ratio series were averaged using

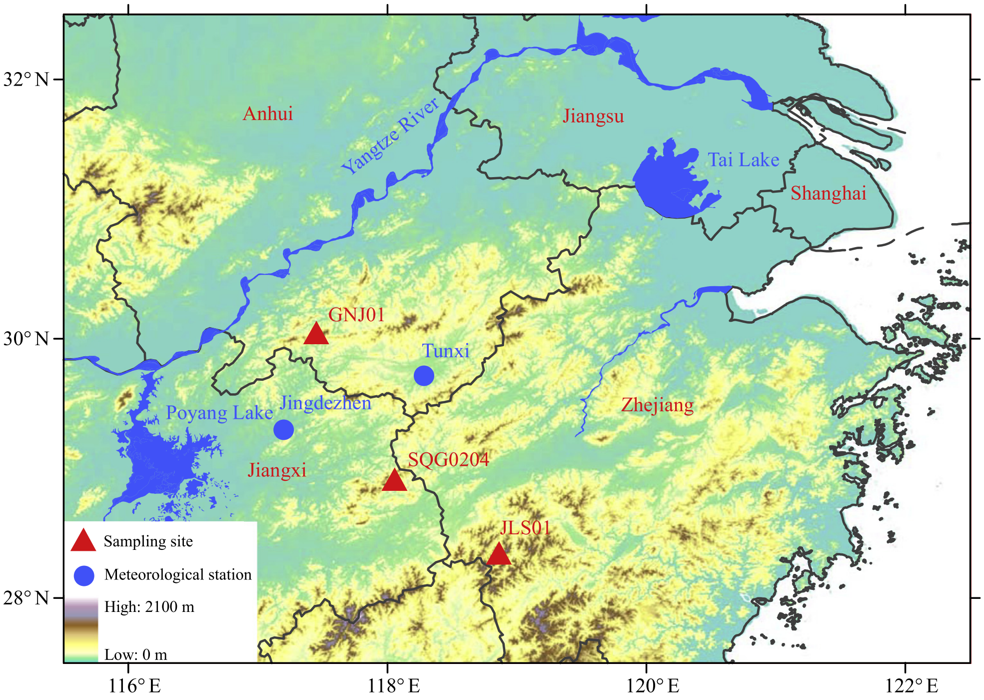

Fig. 1. Map showing the three tree-ring sampling sites and the two meteorological stations.