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Geographical elements of seed plants suggest the boundary of the tropical zone in China

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ABSTRACT

The distribution patterns of geographical elements of seed plants from 135 regional floras that cover southern China were used to reassess the extent and boundaries of the tropical zone. The areas for which tropical genera account for >80% of the total genera in the flora are south of 22°30′N in southern and southeastern China, which corresponds closely to the northern boundary of the tropical monsoon forest and rain forest in southeastern China. The line at c. 22°30′N is therefore suggested to be the northern biogeographical boundary of the tropical zone in south and southeastern China. This line exceeds the northern boundary of marginal tropical climate, which implies that the tropical zone could have extended further north in the geological past than it does today. The study supports the suggestion from palaeoecological studies that tropical and subtropical broadleaved evergreen forests in eastern China shifted north during the mid-Holocene. It also shows that there are climatic and biogeographical disparities between southeastern and southwestern China due to their different topography and geology.

1. Introduction

The tropical region in China has generally been recognized to be the area on the northern edge of tropical Asia, including southeastern Xizang (Tibet), southern Yunnan, southwestern Guangxi, southern Taiwan, and Hainan Island (Zhu, 1997). Chinese meteorologist, Zhu Kezhen, suggested that south of the Nanling Mountains was the tropical area in China roughly south of 24°–25°N in southern China (Guangxi and Guangdong provinces) and up to 26°N in southeastern China (Fujian province), south of which there is no winter (Zhu and Wan, 1963). Chinese geographer, Ren Meie, suggested that vegetation and soil could be better indicators of bio-climate than a single climatic factor (Ren and Xiang, 1963; Ren and Zeng, 1991). He drew a demarcation line for the tropical area of China that generally corresponded with the Tropic of Cancer in southern China but extended north to 25°N in western Yunnan in southwest China and to c. 25°30′N at Putian in Fujian province in southeastern China, as well as including the whole of Taiwan. South of this line, there are 8–11 months with monthly mean temperatures >20 °C. Further south, a line at c. 21°30′N, with the annual effective accumulative temperature of 8000 °C, daily mean temperature >10 °C, and mean temperature of the coldest month >16 °C, has been suggested to be the climatic northern boundary of the tropical area in southern China (Institute of Geography, Chinese Academy of Sciences, 1959; Qiu and Lu, 1961; Qiu, 1986). The tropical areas in a narrow sense were suggested to be limited to southern Hainan and the southern margin of Taiwan, with a mean temperature of the coldest month 18 °C and an annual biotemperature 25 °C (Fang, 2001; Fang et al., 2002). This agrees with the Köppen–Geiger climate classification of the equatorial monsoon climate (Kottek et al., 2006). These four suggested demarcation lines for the northern boundary of the tropical zone in China are largely based on bioclimatic and agroclimatic parameters or macro-level vegetation boundaries and vary from less than 20°N in Hainan in southern China, to 26°N in southeastern China. They were summarized by Tang (1964) and later used by numerous authors from different disciplines (Fig. 1). Although Holdridge (1947) suggested a life zone system using a three-dimensional bioclimate classification based on biotemperature, precipitation, and an aridity index, the life zone system is rarely used in Chinese vegetational and climatic classifications. From the updated Köppen–Geiger climate classification (Kottek et al., 2006; Peel et al., 2007), the tropical monsoon climate is limited only to southern Hainan and the southern margin of Taiwan, but on the newly published high-resolution bioclimate map of the world (Metzger et al., 2012), the whole of southern China falls into the category of hot and wet tropical conditions. This uncertainty concerning the northern boundary of the tropical zone in China hinders objective regionalization in agriculture and physical geography, especially for determining the areas for tropical crops.

It has been found that floristic patterns are strongly associated with geographical (particularly latitudinal) factors in local floras across China (Qian et al., 2003, 2006; Zhu et al., 2007). A line at c. 22°30′N was tentatively suggested as the northern boundary of the tropical zone in south and southeastern China from the biogeographical patterns of Chinese seed plants, south of which regional floras are

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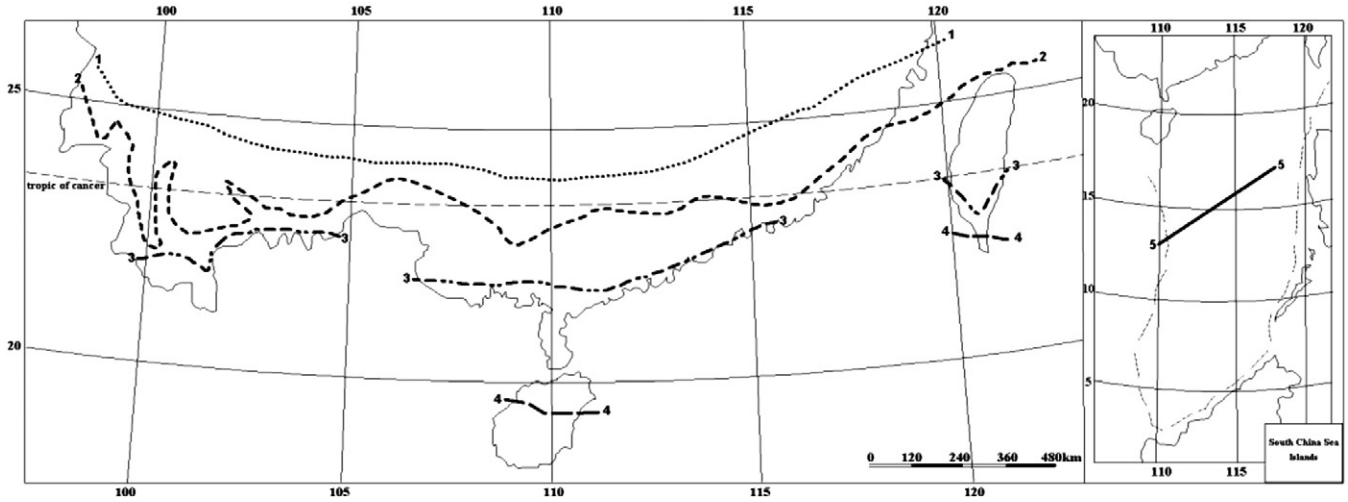

Fig. 1. Four suggested demarcation lines for the tropical zone in China (redraw from Tang, 1964. Line 1: Northern boundary of tropical zone in broad sense (without winter all the year round) (represented by Zhu and Wan, 1963; Tang, 1964). Line 2: Based on 8–11 months with monthly mean temperature over 20 °C (represented by Zeng, 1966; Ren and Zeng, 1991). Line 3: Based on effective accumulative temperature with >10 °C daily mean temperature of 8000 °C and mean temperature of the coldest month >16 °C (represented by Institute of Geography, Chinese Academy of Sciences, 1959). Line 4: Based on the lowest monthly mean temperature of 18 °C, annual biotemperature of 25 °C (Fang, 2001; Fang et al., 2002). Line 5: Equatorial tropic zone.

dominated by tropical genera (Zhu et al., 2007). This line corresponds well with the currently recognized northern boundary of the tropical monsoon and rain forests of China (Wu, 1980; Hou, 1981, 1988; Cao et al., 2006; Zhang, 2007; Zhang et al., 2010). It exceeds the northern boundary of the marginal tropical climate, and the local floras dominated by tropical elements are present in areas far north of the climatic tropics in southeastern China, which may imply that the tropical zone extended further north during geological history. In this article, we will discuss the boundary of the tropical zone of China biogeographically by analyzing the distribution patterns of geographical elements of seed plants from an updated database of regional floras in southern China. We will also discuss the palaeovegetation patterns of China from the implications of the distribution of geographical elements of seed plants.

2. Materials and methods

A database of 135 regional floristic works covering the areas of southern China south of 30°N was used to illustrate the distribution patterns of their floristic elements (see Appendix 1). The genera of Chinese seed plants were assigned to 15 distribution patterns, according to their worldwide geographical distributions, following the 15 geographical elements of Wu (1991). The genera from these regional floras were classified into 15 distribution types based on Wu's classification. For example, the flora of southern Yunnan consists of 1176 genera, which could be classified into 15 geographical elements (Zhu, 2008a), according to their worldwide geographical distributions, as follows: Cosmopolitan (59 genera), Pantropic (251), Tropical Asia and Tropical America disjunct (30), Old World Tropics (112), Tropical Asia to Tropical Australia (76), Tropical Asia to Tropical Africa (96), Tropical Asia (355), North Temperate (60), East Asia and North America disjunct (32), Old World Temperate (24), Temperate Asia (5), Mediterranean region, West to Central Asia (2), Central Asia (1), East Asia (62), and Endemic to China (11). Among these 15 geographical elements, six are tropical: (1) "Pantropic"—this distribution type includes the genera which are distributed throughout the tropics of the western and eastern hemispheres or those genera which have one or more distribution centers in the tropics, but with some species distributed in other regions. (2) "Tropical Asia and Tropical America disjunct"—included in this category are those genera which are disjunctly distributed in warm regions of America and Asia. (3) "Old World Tropic"—these are the genera which are distributed throughout the tropical areas of Asia, Africa, Australia, and their adjacent islands. (4) "Tropical Asia and Tropical Australia"—this distribution type is the east wing of the "Old World Tropic" distribution. Its western boundary is sometimes in Madagascar but never in continental Africa. (5) "Tropical Asia to Tropical Africa"—this distribution type includes the genera which are distributed from tropical Africa to the Indo-Malaysia region, as the west wing of the "Old World Tropic" distribution. (6) "Tropical Asia (Indo-Malaysia)"—this distribution type includes the genera which are distributed throughout the Tropical Asian (Indo-Malaysia) region, and its eastern boundary reaches Fiji or the islands of the South Pacific, but never Australia, and the northern boundary mostly reaches Southwest and South China and Taiwan. These six tropical elements from the regional floras are significant indicators of tropical environments in southern China and were used in our study.

The ArcView software was used for making frequency maps of geographical elements from the regional floras. The frequencies were grouped into five classes that were classified by natural breaks with breakpoints between classes identified using a statistical formula, Jenk's optimization, a default classification method in ArcViewGIS 3.1 that reduces variance within classes and maximizes variance between them. Graduated symbols were used. The frequency of the tropical genera in total was also grouped into two classes, classified by natural breaks and by arbitrary breaks respectively, to discuss geographical demarcations.

3. Results

The genera of tropical Asia distribution are typical tropical elements and one of the dominant floristic groups in regional floras in southern China. They account for 42.3% of the total genera in the flora of southern Yunnan at c. 21.5°N in southwest China, contributing to the highest proportion in all the regional floras of southern China. They account for 32.4% of the total genera in the flora of Hainan at c. 19°N in southeast China (Fig. 2). The frequency of these genera is related to latitude, generally declining in proportion with increasing latitude. The tropical genera in total (including all tropical distribution types) make up a majority in regional floras in southern China. They account for 94.4% of the total genera in the flora of southernmost Yunnan, having a similar frequency pattern to the tropical Asian distribution (Fig. 3). However, these tropical elements decrease