

THE FLORISTIC RELATIONSHIPS OF THE TEMPERATE FOREST REGIONS OF CHINA AND THE UNITED STATES¹

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ABSTRACT

A diagrammatic illustration is used to explain the meridional shift of the constituents of the Chinese deciduous forests from one in Regions I and II with deciduous trees and few evergreen undershrubs to one in Region III with deciduous species forming the canopy and some evergreen undergrowth, and to one in Region IV with deciduous and evergreen trees mixed. Five samples from the temperate forests of Region III, IV, and VIII are selected to explain the altitudinal variation of the Chinese deciduous forests from eastern to western China, with their obvious limit in western Sichuan and the immediately adjacent portion of Yunnan. A list of the paired or closely related species dominant in the forests is provided to demonstrate the affinities of the deciduous forests of China and the United States. The exact nature of the floristic relationship is explained by distributional maps showing (1) disjunction of the species of *Clintonia* Raf. with centers of distribution in China, Japan, western United States and the eastern United States, (2) bicentric pattern of distribution of *Diphylleia* Michaux in eastern Asia and eastern United States, (3) bicentric distribution of *Kelloggia* Torrey ex Benth. & Hooker restricted to China (Yunnan) and the western United States.

SPECIAL FEATURES OF THE TEMPERATE FORESTS OF CHINA

South China is under the influence of a monsoon climate and its characteristic vegetation is one of mesophytic forests. Northwestern China is arid land occupied by steppes and deserts. Consequently, the vegetation of China is recognized as being composed of eight major types, Regions I–VIII (Fig. 1, Wu, 1980). Regions I to III and the northern portion of Region IV support temperate forests.

Based on the composition, structure, and physiognomy of the communities, these forests can be recognized as deciduous broad-leaved forests and coniferous forests. Generally speaking, the climate of the areas supporting deciduous forests is hot and rainy in the summer, and cold and dry in the winter. The mean annual temperature and precipitation for Regions II–IV are shown in Table 1.

There is an obvious meridional shift of the constituents of the increased number of evergreen species replacing the deciduous ones in the temperate forests of China. The composition of different forests is modified in accordance to the location of each community. From north to south, a few low evergreen shrubs enter the deciduous broad-leaved forests of Region II. As hydro-

thermal conditions gradually increase, evergreen trees enter the temperate forests in the southern areas as the second layer of the communities. As the hydrothermal condition increases continuously southward, evergreen and deciduous broad-leaved species become mixed in the forests. In still more southerly regions evergreen broad-leaved species replace the deciduous ones (Fig. 2).

Another outstanding characteristic of the temperate Chinese forests is the variation from east to west. For example, the deciduous forests of Huangshan in Anhui occur at an elevation of 1,000 to 1,600 m. In Shennongjia in western Hubei, the deciduous forests occur at 1,700 to 2,200 m. On the southern slopes of the Qinling Mountains the deciduous forests occur at 1,800

TABLE 1. Mean annual temperature and precipitation in Vegetation Regions II–IV.

Region	Mean Annual Temperature	Mean Annual Precipitation
	°C	mm
II	0.3–5.5	562.6–657.8
III	7.8–14.3	584.0–835.8
IVB	14.3–15.4	903.9–1,134.4

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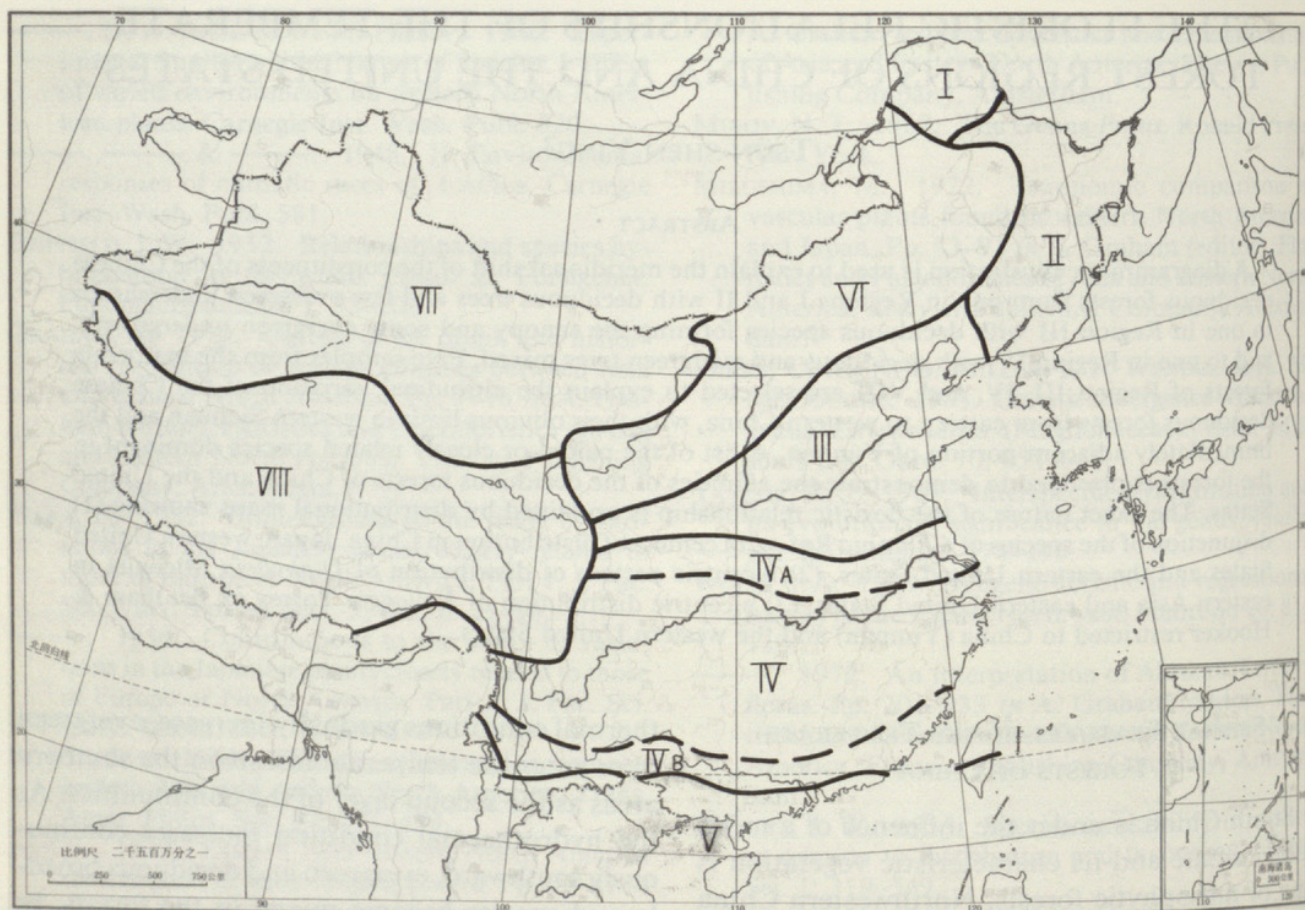


FIGURE 1. The vegetation regions of China (simplified from Wu, 1980). I = Cool temperate coniferous forest region; II = Temperate coniferous deciduous broad-leaved mixed forest region; III = Warm temperate deciduous broad-leaved forest region; IV = Subtropical evergreen broad-leaved forest region, IVA = North subtropical evergreen deciduous broad-leaved mixed forest subregion, IVB = South subtropical monsoon evergreen broad-leaved forest subregion; V = Tropical monsoon and rain forest region; VI = Temperate steppe region; VII = Temperate desert region; VIII = Qinghai-Xizang plateau vegetation region.

to 2,600 m (Chiu & Chin, 1957; Chow, 1965; Ying et al., 1979). The deciduous broad-leaved forests disappear in western Sichuan and north-western Yunnan Provinces (Fig. 3).

Complexity is another feature of the Chinese deciduous forests. Approximately 930 genera are

recognized in the temperate forests of China (Wu, 1965). Owing to geographic transformations and changing combinations of environmental factors throughout geological time, these genera have achieved different distributional patterns. They have been classified into the following types: (1)

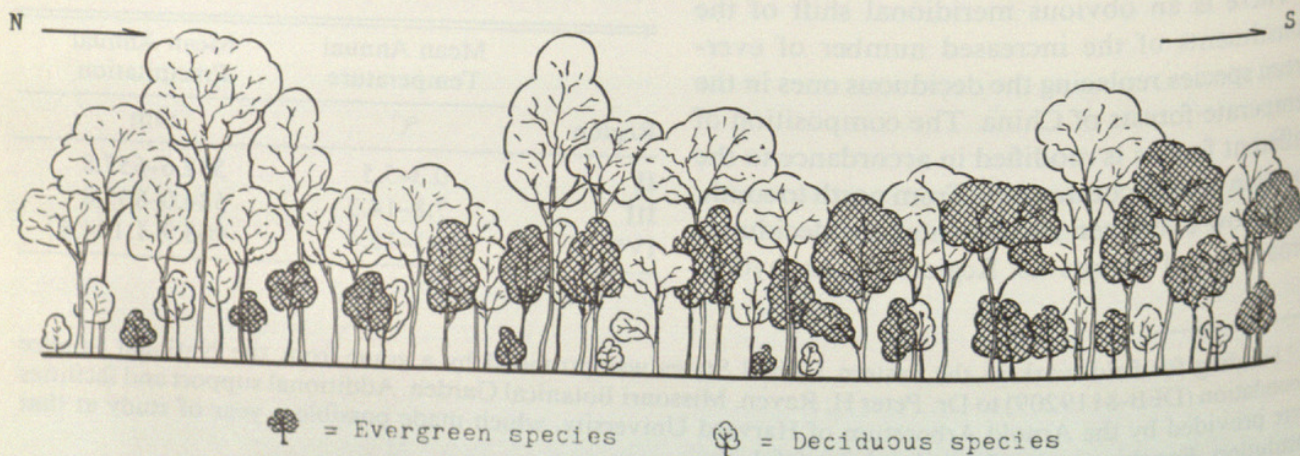


FIGURE 2. The gradual meridional change of constituents of the deciduous forests in China.

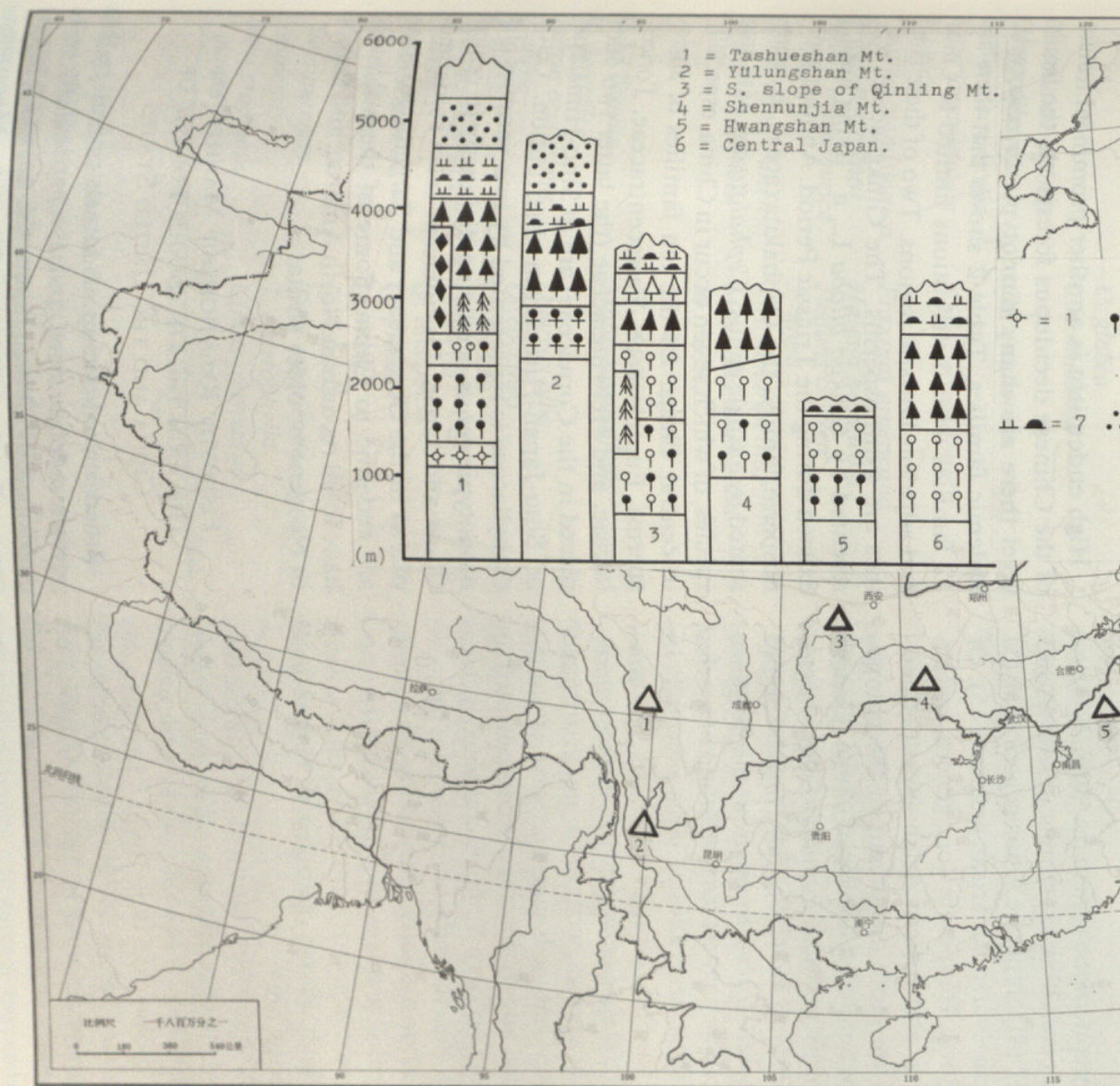


FIGURE 3. Altitudinal change of deciduous forests from east to west in eastern Asia. 1 = Succulent
 3 = Evergreen deciduous broad-leaved mixed forest; 4 = Temperate coniferous forest; 5 = Sclerophyll
 coniferous forest; 7 = Alpine meadow and bush-wood; 8 = Subnival open vegetation; 9 = Pine fo
 Deciduous coniferous forest; 12 = Subalpine scrub.

TABLE 2. Eastern Asian endemic families represented in the deciduous forests of China and adjacent floristic regions.

Family	Total Number of Genera/Species	Genera/Species in China	Range
Ginkgoaceae	1/1	1/1	China-Japan?
Cephalotaxaceae	1/9	1/7	China-Japan
Nandinaceae	1/1	1/1	China-Japan?
Cercidiphyllaceae	1/1	1/1	China-Japan
Trapellaceae	1/2	1/1	China-Japan
Sargentodoxaceae	1/1	1/1	China only
Eucommiaceae	1/1	1/1	China only
Davidiaceae	1/1	1/1	China only
Tetracentraceae	1/1	1/1	Sino-Himalayan
Toricelliaceae	1/3	1/2	Sino-Himalayan
Eupteleaceae	1/2	1/1	Sino-Himalayan-Japan
Helwingiaceae	1/4	1/4	Sino-Himalayan-Japan

North Temperate Zone genera (ca. 300); (2) eastern Asian genera (298); (3) temperate Old World genera (157); (4) temperate Asian genera (63); (5) eastern Asian-North American genera (115). Of these, the North Temperate Zone genera, eastern Asian genera, and eastern Asian-North American genera are more prominent in the composition of the temperate forests of China. Genera such as *Acer*, *Carpinus*, *Populus*, *Salix*, *Fagus*, *Castanea*, *Prunus*, *Sorbus*, and *Tilia* are found in the temperate forests throughout the northern hemisphere. The greatest concentration of species in some of these genera is in China, especially in central China. For example, the genus *Acer* contains about 200 species worldwide. Almost three-fourths of the species occur in China, distributed south of the Qinling Range and east of southeastern Tibet, and 42 species are concentrated in central China (eastern Sichuan and western Hubei). *Dipteronia*, the only other genus of the Aceraceae, is almost totally restricted to this same region. Another genus with similar species concentration is *Carpinus*, with 40 species worldwide, of which 25 are restricted to central and southwestern China.

Antiquity is another feature of the Chinese deciduous forests. For example, *Carpinus hupehana*, distributed in central China, is morphologically close to the fossil species *C. miofargesiana* (Tanai, 1972). Fossil species of *Carpinus* are also found in Tertiary deposits of North America and Europe. The occurrence of extinct and extant species of a genus in the same area is an indication of the antiquity of the community in which the living species occurs.

High endemism is another prominent feature of the Chinese deciduous forests. At the family level there are many monotypic or oligotypic, endemic families. Table 2 shows that there are 12 families with distributions limited to China and adjacent floristic regions. Two of these families are gymnosperms. The Ginkgoaceae, represented by *Ginkgo biloba* L., a "living fossil," existed during the Triassic Period. Another gymnosperm family, the Cephalotaxaceae, is represented by a single genus, *Cephalotaxus*, with nine species, of which seven occur in China, especially in central China. Of the ten families of angiosperms, Eupteleaceae, Tetracentraceae, Toricelliaceae, and Helwingiaceae (the latter two often placed in the Cornaceae) are of Sino-Himalayan or Sino-Japan-Himalayan distribution. Cercidiphyllaceae is represented by two varieties of a monotypic genus occurring disjunctly in central China and Japan. Davidiaceae (also sometimes placed in the Cornaceae) and Sargentodoxaceae are endemic to China. Some of these families have fossil records in North America and Europe in Neogene or older strata.

FLORISTIC RELATIONSHIP MANIFESTED THROUGH THE DECIDUOUS FORESTS OF CHINA AND THE UNITED STATES

Broad-leaved deciduous forests prevail in the north temperate zone and are particularly well developed in China, Japan, the eastern United States, Europe, and the Caucasus Mountains (Daubenmire, 1978; Numata, 1974; Wu, 1980). The similarities of the geographical characters,

TABLE 3. Comparison of the composition (trees) of the temperate deciduous forests in eastern North America and China. Not arranged according to dominance or closeness of relationship. (Derived in part from field work in China and the United States and from Fernald, 1950; Jepson, 1925; and Seymour, 1969.)

China	Eastern North America
<i>Acer buergerianum</i>	<i>Acer rubrum</i>
<i>A. mono</i>	<i>A. saccharum</i>
<i>Alnus japonica</i>	<i>Alnus maritima</i>
<i>A. nepalensis</i>	<i>A. serrulata</i>
<i>Aesculus chinensis</i>	<i>Aesculus octandra</i>
<i>Betula albo-sinensis</i>	<i>Betula alleghaniensis</i>
<i>B. chinensis</i>	<i>B. lenta</i>
<i>B. dahurica</i>	<i>B. nigra</i>
<i>B. platyphylla</i>	<i>B. populifolia</i>
<i>Carpinus turczaninowii</i>	<i>Carpinus caroliniana</i>
	<i>Carya cordiformis</i>
	<i>C. glabra</i>
	<i>C. tomentosa</i>
<i>Chosenia arbutifolia</i>	
<i>Cornus chinensis</i>	<i>Cornus florida</i>
<i>Cornus macrophylla</i>	
<i>Fagus longipetiolata</i>	<i>Fagus grandifolia</i>
<i>F. lucida</i>	
<i>Fraxinus mandshurica</i>	<i>Fraxinus americana</i>
<i>Halesia macgregorii</i>	<i>Halesia monticola</i>
<i>Juglans mandshurica</i>	<i>Juglans cinerea</i>
<i>J. cathayensis</i>	<i>J. nigra</i>
<i>Liriodendron chinense</i>	<i>Liriodendron tulipifera</i>
<i>Magnolia officinalis</i>	<i>Magnolia acuminata</i>
	<i>M. fraseri</i>
	<i>M. macrophylla</i>
	<i>M. tripetala</i>
	<i>Malus angustifolia</i>
<i>Malus baccata</i>	
<i>M. sieversii</i>	
<i>Quercus acutissima</i>	<i>Quercus alba</i>
<i>Q. aliena</i>	<i>Q. coccinea</i>
<i>Q. aliena</i>	<i>Q. falcata</i>
var. <i>acutiserrata</i>	<i>Q. laevis</i>
<i>Q. dentata</i>	<i>Q. laurifolia</i>
<i>Q. liaotungensis</i>	<i>Q. prinus</i>
<i>Q. mongolica</i>	<i>Q. rubra</i>
<i>Q. variabilis</i>	<i>Q. velutina</i>
<i>Tilia amurensis</i>	<i>Tilia americana</i>
<i>T. chinensis</i>	<i>T. heterophylla</i>
<i>Ulmus propinqua</i>	<i>Ulmus americana</i>
<i>U. pumila</i>	<i>U. rubra</i>

TABLE 4. Some common shrubs and herbs in Chinese and American temperate deciduous forests. Arrangement does not necessarily indicate close relationship. (Derived in part from Fernald, 1950; Jepson, 1925; and Seymour, 1969.)

China	United States
<i>Adiantum pedatum</i>	<i>Adiantum pedatum</i>
<i>Clintonia udensis</i>	<i>Clintonia umbellulata</i>
<i>Convallaria keiskei</i>	<i>Convallaria montana</i>
<i>Hydrangea umbellata</i>	<i>Hydrangea arborescens</i>
	<i>Kalmia latifolia</i>
<i>Maianthemum bifolium</i>	<i>Maianthemum canadense</i>
<i>Pyrola rotundifolia</i>	<i>Pyrola rotundifolia</i>
	var. <i>americana</i>
<i>Rhododendron</i>	<i>Rhododendron maximum</i>
micranthum	
<i>Ribes meyeri</i>	<i>Ribes cynosbatii</i>
<i>Tiarella polyphylla</i>	<i>Tiarella cordifolia</i>
<i>Trientalis europaea</i>	<i>Trientalis borealis</i>
<i>Vaccinium japonicum</i>	<i>Vaccinium erythrocarpum</i>
<i>V. uliginosum</i>	<i>V. constablaei</i>
	<i>V. vacillans</i>

uous forests of China and the eastern United States are often paired or closely related taxa of the same genera, as shown in Table 3.

The relationship is not limited to the dominant tree species. The understory shrub layer and the herbaceous species of the deciduous forests also contain many genera common to the two regions, as shown in Table 4.

In the temperate floras of China and the United States there are about 115 genera with disjunct distribution. Approximately 50 of these are oligotypic genera. In order to explain the floristic relationship between Asia and North America, the following genera restricted to China and/or Japan and eastern North America are selected: *Cornus* section *Thelycrania* (1:1); *Chionanthus* sensu stricto (1:1); *Caulophyllum* (1:1); *Decumaria* (1:1); *Diphylleia* (2:1); *Halesia* (1:3); *Hammamelis* (2:4); *Jeffersonia* (1:1); *Liriodendron* (1:1); *Menispermum* (1:1); *Mitchella* (1:1); *Sassafras* (1:1); *Stylophorum* (1:1); and *Kelloggia* (1:1). The figures in parentheses are the numbers of species in each area, eastern Asia to the left, eastern North America to the right.

The above species manifest some of the common characteristics of the flora of eastern Asia and eastern North America. These can be divided into three different distributional patterns: 1) eastern Asian-eastern North American (Fig. 4);

climatic conditions, and vegetation composition of the deciduous forests of China and the eastern United States are closer than those between China and Europe and the Caucasus. This phenomenon has attracted the interest of numerous phytogeographers. The dominant species of the decid-



FIGURE 4. Bicentric distribution of *Diphylleia* in eastern Asia and eastern North America.

2) eastern Asian–western North American (Fig. 5); and 3) eastern Asian–eastern and western North American (Fig. 6).

In addition, the monotypic or oligotypic families such as Schisandraceae, Itaceae, Saururaceae, and Illiciaceae are of special interest. In the deciduous genus *Schisandra*, the primitive section *Pleiosstema* and the advanced section *Sphaerostema* both have a disjunct pattern of distribution from China southward to Sumatra and Java (Smith, 1947). Only one species, *Schisandra glabra*, belonging to section *Schisandra* is

known in eastern North America; two species of this section are in eastern Asia (Smith, 1947). Likewise, in the genus *Itea*, most species occur in eastern Asia and thence southward to Java. Again, there is only one species in southeastern North America. The family Saururaceae contains seven species in three genera scattered in eastern Asia and North America. The genera *Houttuynia* and *Anemopsis* and the counterpart species *Saururus chinensis* and *S. cernuus* occur in the two widely separated regions. The genus *Houttuynia* is distributed in eastern Asia and



FIGURE 5. Bicentric distribution of *Kelloggia* in eastern Asia and western North America.

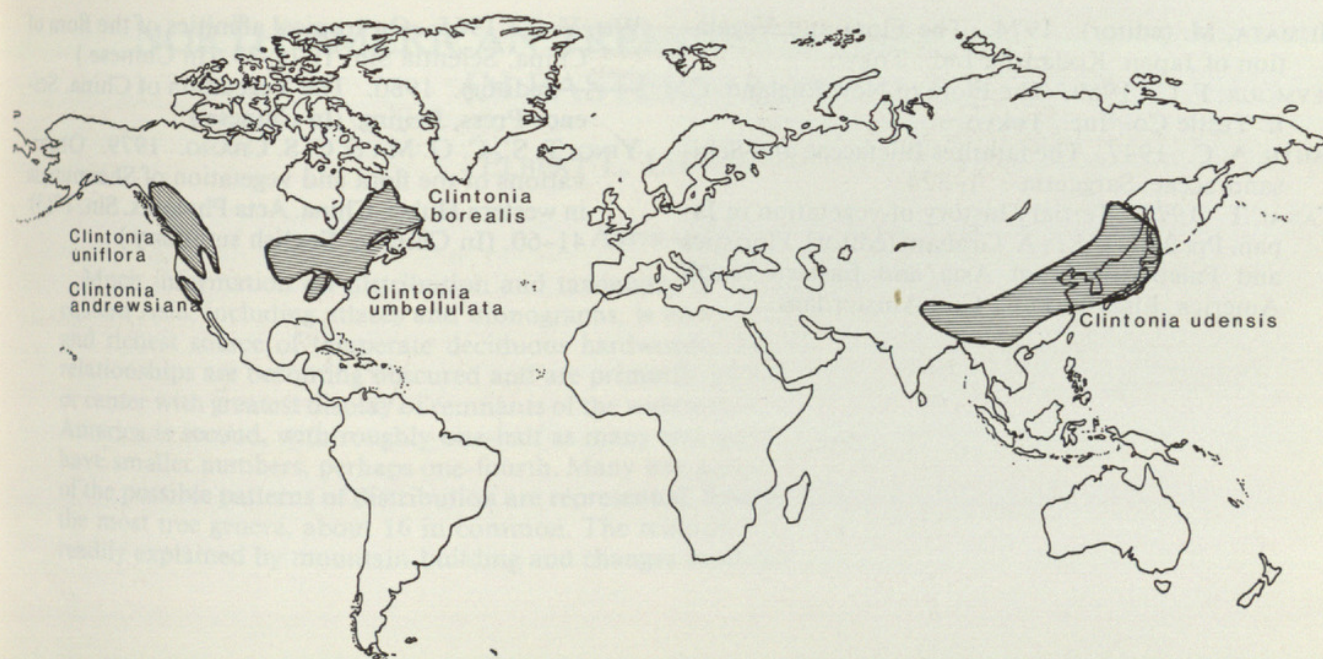


FIGURE 6. Tricentric distribution of *Clintonia* in eastern Asia and eastern and western America.

southward to Indonesia. The genus *Saururus* occurs in Vietnam. The genera restricted to North America and eastern Asia not only indicate a close floristic relationship between the two regions, they also provide reliable clues to their tropical origin.

Almost all of the plants mentioned above grow in temperate deciduous forests in both regions. Detailed studies, including morphology, coupled with ecology, plant sociology, and cytology, will provide many clues that will be of great importance in understanding the patterns of disjunction in plant distribution.

CONCLUSIONS

The deciduous forests of China represent a complex old flora. The dominant species belong to genera having a Tertiary history. There is an evident gradual meridional shift of the constituents from more evergreen species in the south to deciduous ones in the north. The areas occupied by deciduous forests in China were converted to farmland a thousand or more years ago. Remnants of the original forests in steep mountainous regions of Huanshan, Shennongjia, Qinling, Yulungshan, and Tashueshan indicate an altitudinal variation from east to west, accompanied by changes in composition.

Many of the genera have a widespread distribution in the temperate northern hemisphere. A large number of them are common to the deciduous forests of China and the United States. The

shared genera include the dominant trees, shrubs and herbaceous plants. Many of these shared plants are not limited to large genera with widespread distribution but often belong to small, oligotypic genera such as *Liriodendron* and *Sassafras*.

The nature of the floristic relationship between the deciduous forests of China and the United States is exhibited by a tricentric distributional pattern in such genera as *Clintonia* with species in China, Japan, western United States, and eastern United States, a bicentric distributional pattern as in *Diphylleia* with species in China, Japan, and the southeastern United States, and another pattern of bicentric distribution in genera such as *Kelloggia* with species in China and western North America.

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