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## Outstanding Universal Value of Plant Diversity and Conservation at the Mount Emei World Heritage Site: Postprint

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### Abstract

World Heritage Sites play an important role in protecting biodiversity, rare and endangered species, and their habitats that possess Outstanding Universal Value. Based on the nomination text and extensive literature, this study examines the native plants and vegetation communities of the Emei Mountain World Heritage Site, analyzes and demonstrates the global Outstanding Universal Value of plant diversity at the Emei Mountain World Heritage Site from aspects including species diversity, species composition, flora, vegetation types, and vertical distribution patterns, and briefly outlines the current threatened status of plants and problems arising in conservation and development at the Emei Mountain World Heritage Site. The results show: (1) The Emei Mountain World Heritage Site currently harbors more than 3,200 species of higher plants in 242 families, rich in endemic and relict plant species; (2) Compared with other humid subtropical mountain forest vertical belts in China, the subtropical forest vegetation types at Emei Mountain are complete, with the eastern type of evergreen broad-leaved forest occupying a prominent position in the mountain vertical belt spectrum, featuring the highest altitude limit and greatest span, and exhibiting characteristics typical of forest communities in the eastern subregion of subtropical evergreen broad-leaved forest; (3) The flora is complex, containing both tropical, subtropical, and temperate floristic elements, as well as Sino-Japanese and Sino-Himalayan floristic distributions; (4) Affected by human activities (tourism development, infrastructure construction, etc.) and natural disturbances (climate warming, geological disasters, etc.), plant diversity at the Emei Mountain World Heritage Site has declined significantly, the threat level to rare and endangered plants has increased, the area of typical communities has degraded, and stability has decreased. It is recommended that, based on the designation of rare plant protection areas and specialized protection of plant

habitats, dynamic monitoring of plant diversity, environmental factors, and human activities be conducted to proactively protect its Outstanding Universal Value and achieve sustainable development of the World Heritage Site.

## Full Text

### Preamble

#### The Outstanding Universal Value of Plant Diversity and Conservation in the Emeishan World Heritage Site

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**Abstract:** World Heritage sites play a crucial role in protecting biodiversity, rare and endangered species, and their habitats that possess outstanding universal value. Based on the World Heritage nomination documents and extensive literature, this study examines the native plants and vegetation communities of the Emeishan World Heritage Site to assess the outstanding universal value of its plant diversity from perspectives including species diversity, species composition, flora, vegetation types, and vertical distribution patterns. We also summarize current threats to plants and emerging issues in conservation and development. The results demonstrate: (1) The Emeishan World Heritage Site hosts over 3,200 higher plant species across 242 families, with abundant endemic and relict species; (2) Compared with other humid subtropical mountain forests in China, Emeishan features complete subtropical forest vegetation types, with the eastern type of evergreen broad-leaved forest occupying a prominent position in the vertical zonation, reaching the highest altitude and spanning the greatest range, thus exhibiting typical characteristics of forest communities in the eastern subtropical evergreen broad-leaved forest subregion; (3) The flora is complex, incorporating tropical, subtropical, and temperate elements, as well as both Sino-Japanese and Sino-Himalayan floristic components; (4) Due to anthropogenic activities (tourism development, infrastructure construction) and natural disturbances (climate warming, geological disasters), plant diversity has declined significantly, threatened species face increased pressures, typical communities have degraded, and stability has decreased. We recommend es-

establishing protected areas for rare plants with specialized habitat conservation, while implementing dynamic monitoring of plant diversity, environmental factors, and human activities to proactively protect its outstanding universal value and achieve sustainable development of the World Heritage Site.

**Keywords:** Emeishan World Heritage Site; outstanding universal value; plant diversity; rare and endangered species; conservation

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## Introduction

Species diversity serves as the foundation for genetic resources and guarantees the healthy development of ecosystems and biological community balance, representing the core material basis for human survival and development. In recent years, human activities and global climate warming have intensified threats to species diversity and accelerated extinction rates to approximately 1,000 times that of fossil records. According to IUCN' s 2013 assessment of 70,294 species, 30% are endangered, with some already extinct in the wild. China' s latest evaluation of higher plant threats reveals that among 35,784 wild higher plant species, 41 angiosperms have gone extinct (including 9 extinct in the wild and 10 regionally extinct), while 3,879 species are threatened (CR, EN, VU)—comprising 614 critically endangered, 1,313 endangered, and 1,952 vulnerable species—plus 2,818 near-threatened species. Such losses not only reduce species numbers but also disrupt interspecific relationships, alter food webs, change energy flow pathways between trophic levels, and trigger cascading extinctions, ultimately leading to biodiversity loss, destruction of forest ecosystem structure and function, ecosystem imbalance, and indirect impacts on sustainable socioeconomic development.

World Heritage sites serve as critical conservation areas for biodiversity, rare and endangered plants, and important species habitats, representing the most valuable protected areas globally. As products of cultural and natural processes, they embody rare cultural and natural landscapes of outstanding universal value that transcend national boundaries and belong to all humanity. Studying natural heritage helps us understand life' s origins and human-nature relationships, promoting sustainable development. However, global environmental changes, frequent natural disasters, and particularly negative human impacts are degrading World Heritage resources and compromising their authenticity and integrity. IUCN reported in November 2017 that climate-threatened natural World Heritage sites increased from 35 to 62 within three years. Allan et al. (2017) analyzed human footprint data from 94 natural World Heritage sites and global forest monitoring data from 134 sites, revealing that 63% of sites experienced increased human pressure since 1993, and 91% suffered forest loss, with Asian sites most severely affected, particularly in buffer zones and boundary areas. This threatens natural resources, accelerates ecosystem structure and function degradation, and impacts sustainable human-nature development, drawing in-

creasing international attention to World Heritage conservation.

Understanding the current status of outstanding universal value is prerequisite for scientific World Heritage conservation. Previous Chinese research has focused primarily on scenic areas and forest parks rather than World Heritage sites' natural value and conservation. With growing environmental awareness and global World Heritage strategies, China has gradually emphasized World Heritage conservation research. For example, Xie et al. (2017) and Fan et al. (2017) conducted comprehensive studies on Shennongjia World Natural Heritage Site to investigate its outstanding universal value, biodiversity, archaic nature of seed plant families, and conservation strategies, aiming to establish baseline surveys for biodiversity and ecosystem function protection. The Emeishan World Heritage Site represents a complex of natural and human ecosystems, the product of synergistic interactions between multiple ecological systems. Its baseline conditions differ from other heritage sites. To comprehensively understand the status of plant diversity in Emeishan, this study examines native plants and vegetation communities, assessing the outstanding universal value of regional plant diversity from perspectives of species diversity, endemic and primitive species composition, flora, vegetation types, and spatial distribution patterns. Based on nomination documents and extensive literature, we summarize threats to species and vegetation communities and propose corresponding measures to provide theoretical foundations for Emeishan' s sustainable development.

## Study Area

The Emeishan World Heritage Site (29°16'30"-29°43'42" N, 103°10'30"-103°37'10" E) lies in the transitional zone from the Sichuan Basin to the Qinghai-Tibet Plateau in southwestern China. Its main peak, Jinding, reaches 3,099 m at Wanfoding, with an elevation range of 2,600 m from base to summit and a total scenic and buffer area of 623 km<sup>2</sup>. Climate is influenced by solar radiation, atmospheric circulation, and topography, forming a subtropical monsoon climate with pronounced vertical variation. Annual precipitation reaches 2,218.4 mm, average relative humidity exceeds 80%, and foggy days account for over 85% of the year, creating the famous "West China Rainy Screen" region. Soil types vary widely, with forest coverage at 87% and vegetation coverage at 93%. The mountain hosts nearly 5,000 plant species. In 1996, Emeishan-Leshan Giant Buddha was designated a World Cultural and Natural Heritage Site, boosting its profile and tourism. In 2014, the scenic area received 6.2032 million visitors, a 17.63% increase from 2013, generating 21.73% more tourism revenue. However, resource overuse and environmental pollution from tourism have exceeded carrying capacity, causing habitat fragmentation, loss of habitats, and threatening species survival and ecosystem balance.

## 2.1 Species Composition

Emeishan's unique topography and complex vertical climate zones support rich species composition. Literature data indicate the site contains over 3,200 higher plant species across 242 families, representing 10% of China's and 30% of Sichuan's total plant species. Seed plants comprise over 2,400 species in 154 families and 809 genera; pteridophytes include 425 species in 46 families and 110 genera, accounting for 73.0%, 48.2%, and 14.2% of China's fern families, genera, and species, respectively, and 88.5%, 86.6%, and 57.7% of Sichuan's; bryophytes include 349 species in 46 families and 161 genera, representing 75.41%, 44.85%, and 17.86% of China's moss families, genera, and species. Emeishan hosts over 320 endemic and Chinese endemic species, with more than 100 species named after "Emei" (e.g., *Microlepia omeiensis*, *Salix omeiensis*, *Elatostema omeiensis*, *Betula trichogemma*, *Dyosma omeiensis*). Due to topography and microclimate, Emeishan experienced minimal Quaternary glaciation impacts, preserving numerous ancient species from the Tertiary period and earlier with primitive characteristics, such as Jurassic *Alsophila spinulosa* and Tertiary relicts *Davidia involucrata*, *Cercidiphyllum japonicum*, *Tetracentron sinense*, and *Euptelea pleiospermum*. Tang and Ohsawa (2002) found that while only *Tetracentron sinense* occurs in the Chinese Himalayas and only *Euptelea pleiospermum* and *Cercidiphyllum japonicum* occur in Japan's Honshu Island, Emeishan uniquely hosts the complete assemblage of these Tertiary relict species.

## 2.2 Vegetation Types

Emeishan's unique geographic location, landforms, and air circulation create typical vertical vegetation zones with complete subtropical vegetation types. Tang and Ohsawa (1997) classified the vegetation into three types: Type I (660-1,500 m) is subtropical evergreen broad-leaved forest, dominated by Lauraceae, Magnoliaceae, and Fagaceae, occasionally with Symplocaceae. Below 750 m, secondary forests of *Castanopsis hystrix*, *Pinus massoniana*, and *Cunninghamia lanceolata* dominate, while above 750 m, natural evergreen forests prevail with high canopy closure, featuring *Machilus pingii*, *Phoebe zhenan*, *Michelia martinii*, and *Lindera megaphylla*. Type II (1,500-2,500 m) is mixed forest, including evergreen-deciduous broad-leaved mixed forest (1,500-2,000 m) and coniferous-broad-leaved mixed forest (2,000-2,500 m). The former features *Castanopsis platyacantha* and *Cyclobalanopsis oxyodon* in the canopy, with *Camellia* and *Eurya* in the shrub layer, while Tertiary relicts like *Davidia involucrata*, *Cercidiphyllum japonicum*, and *Tetracentron sinense* occur sporadically on slopes. The latter has patchy coniferous forests within broad-leaved forests, creating two- or three-life-form communities dominated by *Abies fabri* and broad-leaved species like *Betula platyphylla* and Aceraceae. Type III (2,500-3,099 m) is subalpine coniferous forest, dominated by *Abies fabri* patches among subalpine scrub and meadow, with *Fargesia spathacea* dominating scrub and meadows on flat, moist sites, plus *Sabina squamata*, *Rhododendron faberi*, and ancient rare plants like *Kingdonia uniflora* and *Trillium tschonoskii*.

Compared with other subtropical mountain forest vertical zones (southern Himalayas, southwestern Sichuan mountains, southern Daba Mountains, Huangshan), Li (1984) found that southern Himalayas have tropical rainforest as their base zone with completely different community structure. Other mountains share evergreen broad-leaved forest as their base, but southwestern Sichuan features drier western-type evergreen broad-leaved forest lacking evergreen-deciduous mixed forest. Southern Daba Mountains have similar vertical structure but are dominated by evergreen-deciduous mixed forest with incomplete vertical zones and lack coniferous-broad-leaved mixed forest. Huangshan has lower elevation, incomplete vertical zones, and is dominated by deciduous broad-leaved forest. Only Emeishan possesses relatively complete evergreen broad-leaved forest zones, with this type as its base zone, reaching the highest distribution limit and widest span among comparable mountains, occupying a prominent position in its vertical zonation and exhibiting typical characteristics of the eastern subtropical evergreen broad-leaved forest subregion .

### 2.3 Floristic Composition

Emeishan was located on the northern margin of the Kangdian ancient landmass, resulting in rich paleotropical flora. During Himalayan uplift and Tethys retreat, its flora interacted with Yangtze and Gondwanan elements. Since the Quaternary, neotectonic movements caused rapid uplift and river erosion, making the eastern Hengduan Mountains, including Emeishan, a refuge for many Tertiary ancient floras, while glacial-interglacial climate fluctuations promoted speciation, creating complex and diverse flora. Currently, Emeishan' s flora incorporates tropical, subtropical, and temperate elements, plus Sino-Japanese and Sino-Himalayan components. Gu et al. (2008) documented 110 fern genera across 12 distribution types , including 13 cosmopolitan, 32 pantropical, 4 Old World tropical, and others. Himalayan-Chinese subtypes include *Diphasiastrum veitchii*, *Allantodia gigantea*, and *Pseudocyclosorus esquirolii*, while Sino-Japanese subtypes include *Angiopteris fokiensis*, *Diplazium pinfaense*, *Onychium japonicum*, and *Dryothyrium unifurcatum*. Among 12 moss distribution types (Pei, 2006), 17 genera are cosmopolitan, 69 tropical, 130 temperate, and 29 Chinese endemic, with 39 Sino-Japanese genera like *Ptychomitrium linearifolium* and 17 Sino-Himalayan genera like *Dicranum lorifolium*. In Emeishan' s evergreen broad-leaved mixed forest seed plants (Gu et al., 2006), North temperate and East Asian distributions dominate at 19.1% and 18.4% (e.g., *Acer*, *Ilex*), followed by East Asian-North American, cosmopolitan, pantropical, and tropical Asian distributions at 13.1%, 12.5%, 12.5%, and 12.5% .

### 3. Threat Factors for Endangered Plants

Statistics show significant declines in Emeishan' s plant diversity and increased threat levels. Based on previous research and supplementary surveys, Zhuang et al. (1992) identified 142 threatened species across 69 families and 108 genera, in-

cluding 10 pteridophytes (all monotypic families and genera), 10 gymnosperms (5 families, 8 genera), and 122 angiosperms (54 families, 90 genera). By threat category, 10.56% are endangered, 51.41% vulnerable, and 38.03% rare. Synthesizing Qin et al. (2017) and national protected species lists, we assessed 31 first-batch nationally protected plants in Emeishan, finding 12 currently threatened: *Parakmeria omeiensis* and *Sibbaldia omeiensis* are critically endangered (CR); *Coptis omeiensis*, *Ormosia hosiei*, and *Salix magnifica* var. *magnifica* are endangered (EN); and *Cephalotaxus oliveri*, *Kingdonia uniflora*, and five other species are vulnerable (VU). All forest community types show decreasing area and increasing fragmentation, driven by both natural environmental factors and human activities.

### 3.1 Natural Factors

Moderate natural disturbance can increase community diversity and stability, as demonstrated by the preservation of Emeishan's relict *Davidia involucrata* through suitable geological disturbances that enhanced its competitive ability (Tang et al., 2002). However, excessive disturbance causes environmental degradation. Major natural threats to Emeishan's plant diversity include climate change, acid rain, and geological disasters. Tang et al. (2017) predicted that under climate change, *Davidia involucrata* distribution may partially persist or shift to higher western mountains by 2070, but warming will threaten its communities due to evolutionary conservatism and poor seed dispersal. The May 2, 2006 collapse disaster and 2008 Wenchuan earthquake exacerbated soil erosion and vegetation damage. Global warming and acid rain have caused mass mortality of *Abies fabri* and *Fargesia spathacea* from Jinding to Jiulaodong, eliminating moss layers and endangering shade-loving rare plants (Chen et al., 2006; Zhuang et al., 2002).

### 3.2 Human Activities

Allan et al. (2017) identified human stressors as the primary and increasingly dominant threat to natural World Heritage sites. In Emeishan, inappropriate tourism development and excessive visitor numbers impose tremendous pressure on ecosystems, while tourism facilities encroach upon or fragment plant habitats, causing retreat of wild plant populations. Large-scale medicinal plant cultivation has introduced extensive *Cryptomeria fortunei* plantations and Chinese medicinal herbs like *Coptis* in mid-low elevations, occupying space of native species and shrinking the area of Emeishan's baseline vegetation—mid-subtropical evergreen broad-leaved forest—and other forest types, leading to severe fragmentation and degradation (Gou et al., 2014; Zhang et al., 2014). Residential waste and urban construction pollutants alter wildlife habitats, while herb collection, mining, and reservoir construction severely impact vegetation, compromising the site's authenticity and integrity.

#### 4. Conservation Management of Plant Diversity OUV in Emeishan World Heritage Site

Located on the southwestern edge of the Sichuan Basin in the deeply dissected eastern Qinghai-Tibet Plateau, Emeishan possesses unique geological, topographic, and climatic conditions, with prominent plant species diversity and endemism, making it a global biodiversity hotspot. This limited area contains one-tenth of China's and one-third of Sichuan's flora, with abundant primitive and endemic species, complete subtropical vegetation types, complex flora, and numerous rare and endangered plants, offering valuable insights into floristic evolution, paleogeography, and plant succession, and possessing outstanding universal value for humanity.

To further protect this value and preserve biodiversity, endangered species habitats, vertical zones, and scenic landscapes, Emeishan authorities have implemented ecological restoration (resettlement, closing small coal mines), afforestation programs, and individual protection of ancient and famous trees. Five rare plant protection zones have been designated for *Rhododendron faberi*, *Davidia involucrata*-*Tetracentron sinense*-*Cercidiphyllum japonicum*, *Abies fabri*-*Kingdonia uniflora*-*Trillium tschonoskii*, *Phoebe zhennan*, and *Alsophila spinulosa* to protect natural vegetation and promote recovery. We recommend establishing dynamic monitoring of biodiversity, human activities, and environmental changes in collaboration with universities and research institutes to understand status and trends, enabling accurate assessment and proactive management. Additionally, digital infrastructure should control visitor numbers, enhance education to regulate tourist behavior, and strengthen community cooperation to coordinate conservation with economic development, achieving sustainable natural and social development of the Emeishan World Heritage Site.

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