Preliminary Study on the Outstanding Universal Value of Potential World Natural Heritage Sites in Hainan (Postprint)

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Abstract

World Natural Heritage sites represent the globally most valuable protected areas, emphasizing the integrity of Outstanding Universal Value and global uniqueness. World Natural Heritage contributes to better protecting ecosystem integrity and authenticity, and promoting sustainable development between humans and nature. Based on extensive literature, this study evaluates the Outstanding Universal Value of the potential World Natural Heritage site in Hainan (Hainan Tropical Rainforest National Park) by examining its native flora, fauna, and vegetation communities (tropical rainforest at the northern margin of Asia) from the perspective of bioecological processes including vegetation types, species diversity, floristic composition, and endemic species. The results show that: (1) The potential World Natural Heritage site in Hainan is home to 3,653 species of wild vascular plants with abundant resource plant species. There are 540 species of terrestrial vertebrates, with various wildlife categories accounting for 10%–30% of the national totals, indicating extremely high biodiversity. (2) The flora is distinctive; the tropical rainforest vegetation zoning of Hainan Island belongs to the Indo-Malayan rainforest formation, with the Malayan region component exhibiting tropical characteristics and co-origin with South China mainland, displaying evident tropical marginal properties, representing a transitional type between the South China flora and Asian tropical rainforests. (3) Plant species endemism in the flora is relatively low, with only 7 endemic genera and endemic species accounting for only about 1/10 of the island's flora; this low endemism indicates its continental origin characteristics, representing an irreplaceable element of biodiversity with distinctive environmental indicator features. This study clarifies the Outstanding Universal Value of the potential World Natural Heritage site in Hainan within a global context, providing scientific basis and technical support for Hainan's future World Heritage nomination.

Full Text

Preamble

Exploration on the Outstanding Universal Value of Hainan's Potential World Natural Heritage Site

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Abstract

World Natural Heritage sites represent the most valuable protected areas globally, emphasizing the integrity and uniqueness of outstanding universal value. World heritage designation helps better protect ecosystem integrity and authenticity while promoting sustainable development between humans and nature. Based on extensive literature review, this study evaluates the global outstanding universal value of Hainan's potential world natural heritage site (Hainan Tropical Rainforest National Park) by examining its native flora, fauna, and vegetation communities (tropical rainforest at the northern margin of Asia) across multiple dimensions including vegetation types, species diversity, floristic composition, and endemic species. The results demonstrate: (1) The site harbors 3,653 species of wild vascular plants and 540 species of terrestrial vertebrates, with wildlife accounting for 10%–30% of national species totals, indicating exceptionally high biodiversity. (2) The flora exhibits unique characteristics, with Hainan's tropical rainforest vegetation classified within the Indo-Malayan rainforest formation. The Malayan region component demonstrates both tropical nature and common origin with mainland South China, showing distinct marginal tropical characteristics and representing a transitional type between South Chinese flora and Asian tropical rainforests. (3) Plant endemism is relatively low, with only seven endemic genera and approximately one-tenth of species being endemic, reflecting its continental origin while representing irreplaceable elements of biodiversity with distinctive environmental indicator value. This study clarifies the outstanding universal value of Hainan's potential world natural heritage site within a global context, providing scientific basis and technical support for future world heritage nomination.

Keywords: nature reserve, world heritage site, Hainan Tropical Rainforest National Park, species diversity, outstanding universal value

Introduction

World Natural Heritage sites are areas with one or more special natural values within a defined territory. Compared with national or provincial nature

reserves and forest parks, they represent the most valuable protected areas globally, emphasizing the uniqueness and integrity of outstanding universal value. World heritage status is not an independent management category but rather an international designation that may overlap with other protected area types. World Natural Heritage designation helps better protect ecosystem integrity and authenticity, promoting sustainable development between humans and nature.

Outstanding Universal Value (OUV) is the core concept of world heritage, meaning the heritage possesses high representativeness and prominence of global significance—"rare values of cultural and/or natural importance that transcend national boundaries and are significant to all humanity, both present and future." The essence and purpose of world heritage protection is to preserve and maintain this outstanding universal value.

Currently, several national park pilot areas in China are already World Natural Heritage sites, including Shennongjia, Wuyishan, Giant Panda, and Sanjiangyuan National Parks. World Natural Heritage sites and national parks share commonalities: both must have conservation attributes, and in China, both rely on nature reserves and scenic areas. After the establishment of national parks, some nature reserves have been integrated into them, creating overlaps between national parks and world heritage sites. In terms of conservation capacity, there is no essential difference. However, differences exist in conservation objectives: World Natural Heritage aims to protect natural landscapes and/or cultural relics with outstanding universal value, while national parks protect other important biological or natural landscapes beyond those with outstanding universal value. In China, national parks receive the strictest protection, while globally, World Natural Heritage represents the highest level of protection under international supervision. World heritage, recognized by all humanity, constitutes a common asset transcending national boundaries, while national parks represent national symbols. Successful world heritage nomination elevates national parks to globally significant heritage status, conferring supreme international honor while enabling global experience sharing in protection and utilization.

Hainan Island is identified as one of 34 global biodiversity hotspots, possessing China's most concentrated, best-preserved, and largest contiguous tropical rainforest, representing an important component of global tropical rainforests with both national representativeness and global conservation significance. Based on preliminary research, experts believe that Hainan's biodiversity and ecological processes meet the requirements for World Natural Heritage nomination, conforming to criterion (ix) as an outstanding example of significant ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal, and marine ecosystems and communities, and criterion (x) as the most important natural habitat for in-situ conservation of biodiversity, including habitats of endangered species of outstanding universal value from scientific and conservation perspectives. For example, the Hainan gibbon (*Nomascus hainanus*), a nationally protected and critically endangered species with only 36

individuals remaining, survives in the pristine tropical rainforest of the national park. Therefore, we should actively promote Hainan's world heritage nomination to better protect tropical wildlife. Furthermore, as a national ecological civilization pilot zone, Hainan's lack of a World Natural Heritage site does not match its ecological status.

This study takes the entire Hainan Tropical Rainforest National Park as the research area, following the Operational Guidelines for the Implementation of the World Heritage Convention. By collecting and reviewing historical literature on Hainan's tropical rainforest, this paper examines vegetation types, species diversity, floristic composition, and endemic species to address: (1) Whether Hainan's potential world natural heritage site represents an outstanding example of ongoing significant natural environmental and evolutionary processes in terrestrial ecosystems and communities; (2) Whether it possesses unique flora and fauna diversity within its biogeographic province and serves as a primary distribution area for endangered species. This analysis demonstrates the outstanding universal value of Hainan Tropical Rainforest National Park to provide reference for world heritage nomination.

1.1 Study Area Overview

Hainan Tropical Rainforest National Park, officially approved in 2021, represents Hainan Island's biodiversity hotspot with forest coverage reaching 95.85%. Natural and primary forest coverage exceeds 55% and 95% respectively, making it the most likely candidate for future world heritage status. This study therefore uses the entire designated national park boundary as its research scope. The park is located in central Hainan with a dome structure [Figure 1: see original paper], spanning 108°44 32 –110°04 43 E and 18°33 16 –19°14 16 N, encompassing 19 national and provincial nature reserves and forest parks including Bawangling and Jianfengling, as well as state-owned forest farms such as Maorui, covering a total area of 4,269 km^2.

According to the internationally recognized Udvardy (1975) biogeographic classification system, Hainan Tropical Rainforest National Park lies within the Indo-Malayan Realm, one of eight global biogeographic realms, specifically within the South Chinese Rainforest biogeographic province among 193 such provinces worldwide.

[Figure 1: see original paper]

1.2 Research Methods

This study collected and reviewed important domestic and international publications on the biology, ecology, and geology of Hainan Tropical Rainforest National Park. Data on avian, insect, and mammalian diversity were compiled from existing literature. Species lists, distribution data, vegetation types, and information on endangered species such as the Hainan gibbon were gathered to identify unique characteristics and representativeness. The study examined

how many species in the park are listed as endangered on the IUCN Red List, how many are included in CITES appendices, and how many are nationally protected. As no publicly available animal resource survey specifically for the national park exists, animal data used in this study are based on island-wide records. Relevant indicators were compared with other World Natural Heritage sites in the same biogeographic province.

2.1 Vegetation Types

Hainan's stepped ring-shaped topography (high in the center, low around the periphery) influences vegetation distribution. Vegetation types include lowland rainforest, tropical monsoon forest, montane rainforest, tropical cloud forest, tropical coniferous forest, and hilltop scrub. The vertical vegetation zonation is distinct, with tropical rainforest and monsoon forest in horizontal zones, and four different vegetation types forming a complete vertical spectrum from low to high elevations .

Lowland rainforest, also called tropical humid rainforest (including lowland gully rainforest), is the most representative zonal vegetation in Hainan. Dominant species include *Vatica mangachapoi*, *Amesiodendron chinense*, *Heritiera parvifolia*, *Podocarpus imbricatus*, *Diospyros hainanensis*, and *Litchi chinensis*. The elevation range of lowland rainforest varies among reserves. For example, according to *Vegetation of Hainan* (Yang et al., 2019), lowland tropical rainforest in Jianfengling occurs mainly on slopes and in gullies at 400–700 m elevation, while in Wuzhishan it occurs in gullies or on slopes at 700–1,000 m.

Montane rainforest is another zonal vegetation type in Hainan, together with lowland rainforest forming the island's tropical rainforest system. Montane rainforest is distributed throughout Hainan's mountainous areas with slight variations among reserves. In Diaoluoshan and Wuzhishan it occurs at 1,000–1,400 m, in Limushan at 800–1,300 m, and in Bawangling and Jianfengling at 800–1,200 m. Dominant species include *Dacrydium pectinatum*, *Podocarpus imbricatus*, *Madhuca hainanensis*, *Canthium dicoccum*, *Lithocarpus fenzelianus*, *Cyclobalanopsis bambusifolia*, and *Syzygium araiocladum*.

Tropical cloud forest, also called tropical dwarf forest, occurs at higher elevations with relatively short, crooked trees and well-developed moss on trunks. Hainan's cloud forests are distributed in various reserves, generally above 1,200 m on mountain tops or ridges, with dominant species including *Pinus kwangtungensis*, *Lithocarpus hancei*, *Syzygium buxifolium*, *Castanopsis tonkinensis*, and *Symplocos poilanei*.

Hilltop scrub is the only zonal primary scrub in Hainan, mainly distributed above 1,700 m with relatively simple species composition. Dominant plants include *Rhododendron simiarum*, *Lyonia rubrovenia*, *Diospyros chunii*, *Schefflera octophylla*, and *Ilex rotunda*.

2.2 Plant Diversity

Hainan Tropical Rainforest National Park hosts 3,653 wild vascular plant species, approximately 11.7% of China's total. This includes 522 pteridophyte species (about 20% of the national total), 26 gymnosperm species in 10 genera and 6 families (about 10% nationally), and 3,105 angiosperm species in 1,027 genera and 172 families (about 20% nationally). Seven species are under first-class national protection and 142 under second-class protection. Resource plants are abundant, including 1,303 medicinal species (about 30% of China's total) and 1,390 ornamental plants (550 ornamental flowers including 258 wild orchids, 210 fruit-ornamental species, and 630 foliage/form-ornamental species).

Wuzhishan National Nature Reserve contains 1,887 seed plant species and 259 pteridophyte species. Yinggeling National Nature Reserve has 2,034 seed plant species and particularly rich pteridophyte diversity with 289 species, the most abundant among all reserves within the national park and a key area for pteridophyte conservation in China. It hosts 32 nationally protected plant species, 147 CITES-listed species, 145 species in China's Species Red List, and 14 IUCN Red List species. Bawangling National Nature Reserve contains 2,523 wild vascular plant species. Diaoluoshan National Nature Reserve has recorded 2,127 vascular plant species in 959 genera and 239 families. Jianfengling branch contains 2,849 wild and commonly cultivated vascular plants, including 150 pteridophytes, 56 gymnosperms, and 2,643 angiosperms, of which 2,286 are wild vascular plants. Bawangling shows higher vascular plant diversity than other reserves within the national park .

2.3 Animal Diversity

Hainan Tropical Rainforest National Park has recorded 540 terrestrial vertebrate species, accounting for 18.62% of China's total, including the Hainan gibbon (*Nomascus hainanus*), a Hainan endemic more precious than the giant panda. Butterfly diversity reaches over 600 species (29% of China's total), exceeding Taiwan's renowned "butterfly kingdom" and including the only nationally protected butterfly—*Teinopalpus aureus*. Insect diversity comprises 5,840 species (about 10% of China's known insect fauna). Despite Hainan's land area representing only 0.35% of China's total, its wildlife accounts for 10%–30% of national species totals, demonstrating extremely high biodiversity.

Wuzhishan National Nature Reserve has recorded 60 mammal species, 283 bird species, 52 amphibian and reptile species, 67 fish species, over 1,700 insect species, and more than 200 butterfly species, including 59 nationally protected species (9 first-class, 50 second-class). Yinggeling National Nature Reserve has documented 512 terrestrial vertebrate species, with 74 under national protection (9 first-class, 65 second-class), including newly discovered species such as *Zhangixalus yinggelingensis* and *Goniurosaurus zhoui*. Yinggeling shows higher animal diversity than other Hainan tropical rainforest areas, with high species

richness, strong forest primordiality, and numerous unrecognized species. Jianfengling National Nature Reserve hosts 400 terrestrial vertebrate species including 9 first-class protected species. Bawangling National Nature Reserve contains 416 terrestrial vertebrate species, over 130 bird species, and more than 2,100 insect species. Diaoluoshan has recorded 369 vertebrate species across 5 classes, 35 orders, and 115 families. Recent scientific expeditions continue to discover new species, with Hainan's species diversity data continuously increasing .

2.4 Floristic Composition

Hainan Island connected with the northern landmass during the mid-Triassic period of the Mesozoic era approximately 200 million years ago. Tectonic activities during the Tertiary to Quaternary periods of the Cenozoic era about 20 million years ago led to large-scale uplift and movement, gradually forming the Qiongzhou Strait and separating the island from the mainland. Hainan's tropical rainforest vegetation belongs to the Indo-Malayan rainforest formation, but due to its relatively northern latitude and monsoon influence, the canopy shows seasonal variation between dry and wet periods, with abundant lianas and prominent buttress roots.

The island's flora comprises Southeast Asian tropical elements, with tropical species accounting for 83%. Approximately 70% of species are shared with Vietnam, while a smaller proportion is shared with Taiwan and the Philippines, and most are shared with Guangxi, Guangdong, and southern Yunnan. The Malayan region component shows tropical characteristics and common origin with South China, displaying distinct marginal tropical properties and representing a transitional type between South Chinese flora and Asian tropical rainforests.

2.5 Endemic Species

Hainan's unique island geography and maritime climate have fostered the evolution of endemic species. However, studies show relatively low plant endemism, with only seven endemic genera and approximately one-tenth of species being endemic, reflecting continental origin characteristics. Among 3,653 vascular plant species, 419 are Hainan endemics. Due to geographic isolation, Hainan's terrestrial vertebrate fauna has differentiated, producing species and subspecies distinct from adjacent mainland populations, primarily distributed in central Hainan.

Hainan Island has 698 terrestrial vertebrate species, including 23 endemics. Among amphibians, 14 endemic species have been discovered, including *Micryletta immaculata* identified in 2021, along with *Tylototriton hainanensis*, *Leptobrachium hainanensis*, and *Zhangixalus yinggelingensis*. Seven endemic reptile species occur on Hainan, including three *Goniurosaurus* species: *G. bawanglingensis*, *G. hainanensis*, and *G. zhoui*, plus *Ophisaurus hainanensis*, *Achalinus hainanus*, and *Lycodon rosozonatus*. Four endemic bird species have been identified: *Arborophila ardens*, *Phylloscopus hainanus*, *Polyplectron*

katsumatae, and *Garrulax owstoni*. Six endemic mammals include the Hainan gibbon, *Neohylomys hainanensis*, *Mogera insularis hainana*, *Niviventer lotipes*, and *Lepus hainanus*.

In addition to endemic species, Hainan's fauna includes numerous endemic subspecies, such as over 50 avian subspecies including *Gallus gallus jabouillei* and more than 30 mammalian subspecies including *Cervus eldii hainanus* and *Manis pentadactyla pusilla*. Hainan's diverse tropical environments provide ecological niches for evolution, while island isolation creates dispersal barriers. Over time, these endemic subspecies may differentiate into independent endemic species, representing irreplaceable elements of biodiversity with distinctive environmental indicator value.

3.1 Criterion (ix) Compliance

Hainan's tropical rainforest represents China's most typical pristine tropical rainforest, described by experts as the most concentrated, best-preserved, and largest contiguous tropical rainforest in China. The rainforest harbors extremely rich flora and fauna, constituting a species gene bank for China's tropical regions. Despite comprising only 0.35% of China's land area, Hainan hosts 11.7% of the nation's wild vascular plants, 18.6% of terrestrial vertebrates, and 10% of known insect species.

Hainan's tropical rainforest exhibits both mainland and island floristic characteristics, having evolved through 20 million years of island isolation with transitional features from tropical rainforest to subtropical evergreen broadleaf forest. The flora contains proportions of subtropical and temperate families, marking the transition from tropical to subtropical zones. The flora shows clear tropical Asian affinities, belonging to the paleotropical kingdom with marginal northern tropical characteristics, forming extreme-condition tropical rainforest types based on temperature, moisture, and elevation distributions. Biogeographically, it belongs to the paleotropical, Malesian subkingdom, with subtropical and ancient elements of the Cathaysian flora.

The fauna maintains close ties with the adjacent mainland while possessing unique characteristics. Avian fauna, for example, features rainforest and subtropical evergreen broadleaf forest species feeding primarily on fruits, insects, and nectar, showing strong similarities with Guangdong, Guangxi, Fujian, Taiwan, and southern Yunnan. Hainan's mammals show closest affinities with Vietnam, displaying biogeographic patterns similar to the flora.

Compared with other Chinese tropical rainforests such as Xishuangbanna, Hainan's tropical rainforest shows higher species diversity and different floristic classification, belonging to the East Asian flora region versus Xishuangbanna's tropical Asian region.

Compared with other tropical rainforest world heritage sites such as Australia's Wet Tropics of Queensland, Costa Rica's Cocos Island National Park, Ecuador's

Sangay National Park, Honduras's Río Plátano Biosphere Reserve, Indonesia's Ujung Kulon and Sumatra Tropical Rainforest Heritage, the Talamanca Range-La Amistad Reserves (Panama/Costa Rica), and Sri Lanka's Sinharaja Forest Reserve, Hainan's potential world natural heritage site is unique in: (1) its transitional characteristics from tropical rainforest to subtropical evergreen broadleaf forest; and (2) its continental island tropical rainforest features, backed by mainland China while exhibiting island biota characteristics. Therefore, Hainan's potential world natural heritage site should be further evaluated under criterion (ix) as an outstanding example of significant ecological and biological processes in ecosystem and community evolution.

3.2 Criterion (x) Compliance

First, Hainan's tropical rainforest exhibits rich species diversity with numerous endemics. The rainforest shares affinities with Southeast Asian tropical rainforests while maintaining mainland connections. Unlike other world heritage sites in tropical regions such as Indonesia's Lorentz National Park or Ecuador's Sangay National Park, Hainan's uniqueness lies in its rare insular tropical rainforest—the only "continental island type" tropical rainforest in the tropical rainforest and monsoon evergreen broadleaf forest ecotone. Compared with Southeast Asian tropical rainforests, Hainan's canopy is lower due to typhoon influence.

Relative to other Chinese tropical rainforests, Hainan's resources are richer and better protected, with a unique island ecosystem that has fostered numerous endemic species, making it an important region for tropical biodiversity conservation and a global germplasm resource gene bank. Hainan has different geological history from Xishuangbanna, which derives from Gondwana, while Hainan belongs to the Indochina plate of Laurasia. This unique geological history and island ecosystem have created distinctive species and communities.

Second, the insular tropical rainforest possesses special, rare, irreplaceable, and endangered ecological advantages. Once destroyed, recovery is difficult, demonstrating the ecological vulnerability of endangered tropical rainforests and extremely high conservation value.

Favorable climate conditions and unique geographic features have endowed Hainan Tropical Rainforest National Park with remarkable biodiversity and numerous ancient, endangered, and endemic species, serving as a type locality for many species and representing China's richest tropical rainforest plant region with outstanding conservation and scientific value. Hainan Island serves as a refuge for rich biodiversity, protecting 11.7% of China's vascular plants and approximately 20% of amphibians, 33% of reptiles, 20% of mammals, 29% of butterflies, and 10% of insects within just 0.35% of the country's land area. Since its establishment three years ago, the national park has discovered 19 new species (9 plants, 5 animals, 5 macrofungi), indicating numerous unknown species await discovery.

The park is the sole habitat for the critically endangered Hainan gibbon and endemic national first-class protected species such as the Hainan partridge and Hainan peacock-pheasant. The Hainan gibbon, endemic to China and Hainan Island, is distributed only in Bawangling. Its population declined from over 2,000 individuals in the early 1950s to just 7 in the 1980s, recovering slightly to 5 groups with 36 individuals in the 21st century, still facing extinction risk. The IUCN classifies the Hainan gibbon as Critically Endangered, ranking it first among globally endangered primates. As a flagship species, its status directly reflects ecosystem health.

IUCN data show that while global gibbon populations are declining, the Hainan gibbon population is slowly increasing. Its conservation holds important significance for Hainan's ecological protection and provides a global conservation demonstration model.

The Hainan partridge, classified as Vulnerable by IUCN, is a Hainan endemic under national first-class protection, commonly found in montane rainforests. The Hainan peacock-pheasant, an extremely rare and endangered endemic species under national first-class protection, inhabits the island's tropical rainforests, primarily in Bawangling, Jianfengling, and Limushan.

Therefore, Hainan's potential world natural heritage site should be further evaluated under criterion (x) as the most important natural habitat for in-situ conservation of biodiversity, including habitats of endangered species of outstanding universal value.

3.3 Conclusion

Hainan's potential world natural heritage site possesses favorable climate conditions, unique geographic features, remarkable biodiversity, and numerous ancient, endangered, and endemic species. As the sole habitat for the critically endangered Hainan gibbon and China's richest tropical rainforest plant region, it protects 11.7% of China's vascular plants within just 0.35% of the country's land area. With complete tropical vegetation types, complex flora and fauna, and rich primary and endemic species, the site demonstrates outstanding conservation and scientific value as a human treasure. However, as China's only tropical rainforest national park and an ecological civilization pilot zone, Hainan's lack of a World Natural Heritage site does not match its ecological status. Therefore, Hainan urgently needs to pursue world heritage nomination to support national park construction. Research on outstanding universal value cannot rely on a single paper alone; we recommend establishing a nomination text editing team promptly to conduct field investigations and multiple expert consultations to complete the nomination dossier.

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Note: Figure translations are in progress. See original paper for figures.