Preliminary Study on Plant Species Diversity in Mulun National Nature Reserve, Guangxi (Post-print)

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Abstract

Guangxi Mulun National Nature Reserve is located in the transitional zone between the Yunnan-Guizhou-Guangxi and South China floristic regions, and constitutes a central intersection between the Palearctic and Paleotropical floristic realms, occupying an irreplaceable position in China' s biodiversity conservation landscape. To comprehensively assess plant species diversity within the reserve, this study investigated the composition and characteristics of vascular plant diversity through historical literature review, field surveys, specimen collection and identification, and statistical data analysis. The results indicate: (1) The reserve harbors a total of 1,735 vascular plant species, comprising 218 lycophytes and ferns and 1,517 seed plants, reflecting rich vascular plant diversity and complex floristic composition. (2) The reserve contains 486 Chinese endemic species, 56 Guangxi endemic species, and 262 karst endemic species, demonstrating significant plant endemism. (3) The reserve includes 68 nationally protected wild plant species, 153 Guangxi protected wild plant species, 4 Chinese wild plant species with extremely small populations, 108 threatened species, and 144 species listed in the appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), indicating a high degree of plant rarity and endangerment. Collectively, these findings establish the reserve as a crucial karst plant gene bank in China with exceptional conservation value. This research provides an important foundation for reserve management and construction, plant conservation and utilization, and future scientific investigations.

Full Text

Primary Study on Plant Species Diversity in Guangxi Mulun National Nature Reserve

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Abstract

Guangxi Mulun National Nature Reserve is located in the transitional zone between the Dian-Qian-Gui flora and South China flora, and represents the core area where the Paleoarctic and Paleotropical floristic kingdoms intersect, occupying an irreplaceable position in China' s biodiversity conservation landscape. To comprehensively assess plant species diversity in the reserve, this study investigated the composition and characteristics of vascular plant diversity based on historical literature review, field surveys, specimen collection and identification, and statistical data analysis. The results show: (1) The reserve harbors 1,735 vascular plant species, including 218 lycophytes and ferns and 1,517 seed plants, demonstrating rich vascular plant diversity and complex floristic composition. (2) The area contains 486 Chinese endemic species, 56 Guangxi endemic species, and 262 karst endemic species, exhibiting significant plant endemism. (3) The reserve hosts 68 nationally protected wild plant species, 153 Guangxi key protected wild plant species, 4 Chinese extremely small population wild plant species, 108 threatened species, and 144 species listed in the CITES appendices, indicating a high degree of rarity and endangerment. In summary, the reserve serves as an important karst plant gene bank in China with extremely high conservation value. These findings provide crucial scientific basis for reserve construction and management, plant conservation and utilization, and other research endeavors.

Keywords: Mulun Reserve, species diversity, karst flora, rare germplasm resources, Guangxi

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Introduction

The karst region of southwestern China represents the largest and most intensively developed karst area among the world' s three major contiguous karst

zones, spanning both tropical and subtropical monsoon climate zones (Song et al., 2014). This region encompasses all karst areas within three biodiversity priority conservation zones designated in China' s Biodiversity Conservation Strategy and Action Plan: the southwestern Guangxi mountains, the western Guangxi-southern Guizhou mountains, and the Nanling range. As a globally significant region for biodiversity research and conservation (Myers et al., 2000; Liu et al., 2003; Hou et al., 2010), this area holds critical importance for karst biodiversity protection (Clements et al., 2006).

Guangxi represents one of China' s principal karst distribution areas. Over the past two decades, research on plant species diversity in Guangxi' s karst regions has attracted considerable attention, with new species continuously being discovered. Statistics show that more than 600 new plant species were reported in Guangxi between 2000 and 2019, the majority distributed across vast karst areas (Du et al., 2020). Most of these new species are endemic to Guangxi, not only enriching the province' s plant diversity but also providing important novel germplasm resources for innovative utilization while simultaneously revealing that Guangxi' s plant resource inventory remains incomplete, necessitating more intensive investigation and research. Consequently, targeted plant resource surveys in specific karst regions have been conducted, including studies on plant diversity composition and flora in Guangxi' s Nonggang National Nature Reserve (Wu, 2011; Huang et al., 2013), vascular plant diversity in Longhushan Nature Reserve (Yang, 2013), vascular plant species diversity in Yachang Orchid National Nature Reserve (Li, 2017), seed plant diversity in Guangxi' s karst border areas with Vietnam (Xu et al., 2018), and phytogeographical analysis of Baishi Tiankeng in Xing' an, Guangxi (Tang et al., 2020). These studies have significantly advanced our understanding of Guangxi' s plant resource baseline and the species composition and floristic distribution of karst plants.

Guangxi Mulun National Nature Reserve (hereafter "Mulun Reserve") and its northern neighbor, Guizhou' s Maolan National Nature Reserve (hereafter "Maolan Reserve"), are both located within the Nanling biodiversity priority conservation zone. They occupy China' s central biogeographical transition area where multiple biological systems converge, jointly forming the world' s largest known contiguous area of well-preserved, primary karst forest ecosystems (Lan et al., 2016) and holding an irreplaceable position in China' s biodiversity conservation network. Since plant species diversity forms the foundation of biodiversity conservation, clarifying the plant species composition in this region is crucial for maximizing its conservation and utilization value.

While numerous studies have reported on plant species diversity in Maolan Reserve, including analyses of seed plant geographical components (Chen, 1996), floristic comparisons with Fanjing Mountain (Yu, 2002), inventories of wild economic plants (Chen et al., 2005), comprehensive species diversity catalogs (Chen, 2013), and lycophyte and fern floristic characteristics (Hu et al., 2021), research on Mulun Reserve' s plant diversity has also progressed. Initial baseline surveys documented 906 vascular plant species (Zheng, 1999), while subsequent floristic

studies recorded 1,446 species (Peng, 2013). New species and new distribution records have continued to be reported (Liu et al., 2014; Shen et al., 2015; Huang et al., 2015; Tan et al., 2017), demonstrating that plant species numbers in the region continue to increase with ongoing research. However, the plant species diversity composition and characteristics of Mulun Reserve remain incompletely understood, significantly constraining the reserve' s functional effectiveness and its research, management, and conservation activities.

This study focuses on Mulun Reserve, employing literature review, supplementary field investigations, and statistical data analysis to compile, verify, and revise existing plant records, including synonyms and nomenclaturally invalid names. Our objectives are to clarify the reserve's plant species diversity composition, compare differences with neighboring karst forest national nature reserves, and analyze the composition characteristics of endemic families, genera, and species (including Chinese endemics, Guangxi endemics, and karst endemics) as well as rare and endangered plants (including nationally protected species, Guangxi key protected species, threatened and CITES-listed species, extremely small populations, and type specimens). This research provides scientific basis for reserve construction and management, plant conservation and utilization, and other scientific research activities.

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1. Study Area Overview

Mulun Reserve is situated in northwestern Guangxi within Huanjiang Maonan Autonomous County of Hechi City, extending from 107°54 01 to 108°05 51 E and 25°07 01 to 25°12 22 N. The reserve borders the upper reaches of the Gubin River to the east, approaches the Dagou River to the west, and connects with Maolan Reserve to the north. It encompasses portions of karst mountains in seven administrative villages (Dongshan, Xiarang, Leyi, Mulun, Baidan, Shecun, and Hedun) in Chuanshan Town, as well as the Banlantun rear mountain *Woonyoungia septentrionalis* protection plot, covering a total area of 10,829.7 hectares. The terrain slopes from higher elevations in the northwest to lower elevations in the southeast, with extremely well-developed karst geomorphology featuring diverse forms, predominantly peak-cluster depressions and peak-cluster funnels composed of conical and tower-shaped mountains. Bedrock exposure is extensive, with soil coverage less than 20% and soils occurring only in rock crevices; only depressions or valleys contain continuous soil patches. Located on the southern margin of the mid-subtropical zone, the reserve experiences a mid-subtropical monsoon humid climate. The combination of warm-humid climatic conditions, diverse karst landforms, and isolated island-like habitats provides excellent natural conditions for plant growth and reproduction, resulting in forest coverage of 94.7% and preservation of the most representative mid-subtropical karst forest ecosystem in China (Zheng, 1999).

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2. Methods

2.1 Literature Review We reviewed historical literature and herbarium specimens collected from Mulun Reserve, supplemented by data from the Chinese Virtual Herbarium (http://www.cvh.ac.cn/), to compile a preliminary checklist of recorded vascular plant species in the reserve.

2.2 Field Investigation Using line transect surveys, we collected plant specimens and recorded detailed distribution information and survey tracks. Survey lines were continuously adjusted as tracks accumulated to ensure coverage of various vegetation types and regions across the reserve. From April 2013 to July 2021, we conducted over 20 field surveys in Mulun Reserve, with survey tracks distributed relatively uniformly throughout the reserve' s various regions.

2.3 Plant Species Diversity Catalog Compilation Through specimen sorting and identification, we obtained a plant species diversity list from our surveys. This was combined with research results from Zheng (1999) and Peng (2013) for further supplementation and revision, culminating in a finalized vascular plant species diversity catalog for Mulun Reserve.

2.4 Statistical Analysis Methods Species distribution patterns were analyzed based on Lu' s (2007) classification for ferns and Wu et al.' s (2010) classification for seed plants, referencing *A Checklist of Vascular Plants of Guangxi* (Qin and Liu, 2010) and *The Endemic Genera of Seed Plants of China* (Ying and Zhang, 1994). We statistically analyzed Chinese endemic genera and Guangxi endemic genera of seed plants, Chinese endemic species of lycophytes and ferns, and Guangxi endemic species of seed plants. Karst endemic plant species were identified based on growth habits and distribution ranges. Nationally protected wild plants were analyzed according to the second batch of the National Key Protected Wild Plants List (released by the National Forestry and Grassland Administration and Ministry of Agriculture and Rural Affairs in 2021). Guangxi key protected wild plants were analyzed based on the first batch of the Guangxi Key Protected Wild Plants List (released by the Guangxi Zhuang Autonomous Region People' s Government in 2010). CITES-listed species were analyzed according to the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Threatened species were analyzed based on the "Threatened Species List of China's Higher Plants" (Qin et al., 2017) and the IUCN Red List Categories and Criteria (IUCN, 2012) and its guidelines (IUCN Standards and Petitions Committee, 2022).

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3. Results

3.1 Plant Species Diversity Composition Mulun Reserve contains 1,735 vascular plant species belonging to 211 families and 761 genera. These include

218 lycophytes and ferns in 36 families and 67 genera, 14 gymnosperms in 7 families and 12 genera, 1,229 dicotyledons in 163 families and 569 genera, and 274 monocotyledons in 40 families and 180 genera. The statistical summary of vascular plant families, genera, and species in Mulun Reserve is presented in Table 1.

Table 1. Composition of vascular plant species diversity in Mulun Reserve

Plant group	Family	Genus	Species	Wild species	Cultivated species
Lycophytes & Ferns	36	67	218	218	0
Gymnosperms	7	12	14	11	3
Dicotyledons	163	569	1,229	1,209	20
Monocotyledons	40	180	274	272	2
Total	**211**	**761**	**1,735**	**1,710**	**25**

3.2 Comparison with Adjacent Karst Forest National Nature Reserves Mulun Reserve represents the northernmost karst forest nature reserve in Guangxi, situated in China' s central biogeographical transition zone where multiple biological systems converge. Connected with Maolan Reserve to its north, they jointly form the world' s largest known contiguous area of well-preserved, primary karst forest ecosystems. Consequently, the reserve' s flora exhibits complex composition and extremely rich plant species. Due to its unique geographical location, its plant diversity composition differs significantly from other adjacent karst forest national nature reserves (Table 2).

Table 2. Comparison of plant diversity among Mulun Reserve and adjacent karst forest national nature reserves

Protected area	Lycophytes & Ferns	Gymnosperms	Angiosperms	Total	Area (km^2)
	F	G	S	F	G
Maolan Reserve (Chen, 2012; Zhang and Yao, 2017)	40	87	367	9	20
Yachang Reserve (Li, 2017)	28	46	111	7	13

Protected area	Lycophytes & Ferns	Gymnosperms	Angiosperms	Total	Area (km^2)
Nonggang Reserve (Huang et al., 2013)	32	56	165	8	15
Mulun Reserve	**36**	**67**	**218**	**7**	**12**
White-headed Langur Reserve	23	38	77	6	9
Encheng Reserve	27	40	80	7	12
Bangliang Reserve	22	34	65	6	9

Note: F = Family, G = Genus, S = Species. Yachang Reserve = Yachang Orchid National Nature Reserve of Guangxi; Nonggang Reserve = Nonggang National Nature Reserve of Guangxi; White-headed Langur Reserve = Guangxi Chongzuo White-headed Langur National Nature Reserve; Encheng Reserve = Encheng National Nature Reserve of Guangxi; Bangliang Reserve = Bangliang Gibbon National Nature Reserve of Guangxi.

Although Mulun Reserve connects with Maolan Reserve to form a contiguous forest with similar habitats, its much smaller area represents an important reason for their substantial differences in plant diversity composition. Among Guangxi' s karst forest national nature reserves, Mulun Reserve exceeds others in family and species numbers of lycophytes and ferns, family and genus numbers of gymnosperms, and family numbers of angiosperms. However, its genus numbers for lycophytes and ferns and species numbers for gymnosperms are only lower than Yachang Reserve, its angiosperm genus numbers only exceed Bangliang Reserve, and its angiosperm species numbers are only lower than Yachang and Nonggang Reserves. Overall, Mulun Reserve exhibits extremely high diversity in family, genus, and species numbers of vascular plants. Its total vascular plant species number being lower than Yachang and Nonggang Reserves relates not only to reserve area but also closely to geographical location, elevation gradients, and climatic characteristics.

3.3.1 Statistical Analysis of Endemic Families and Genera Mulun Reserve contains no Chinese endemic families or Chinese endemic genera of lycophytes and ferns. Wild seed plants include 15 Chinese endemic genera: *Woonyoungia*, *Gymnotheca*, *Tetrathyrium*, *Pteroceltis*, *Melliodendron*, *Camptotheca*, *Tetrapanax*, *Heteroplexis*, *Schnabelia*, *Eurycorymbus*, *Koelreuteria*, *Handeliodendron*, *Petrocodon*, *Ampelocalamus*, and *Indocalamus*. Two Chinese quasi-

endemic genera are present: *Calocedrus* and *Thyrocarpus*. All these endemic and quasi-endemic genera contain only one species each in the reserve, accounting for approximately 2.23% of total vascular plant genera and 0.98% of total vascular plant species—representing extremely small proportions.

Phylogenetically, these include both ancient relict genera (*Woonyoungia*, *Pteroceltis*, *Eurycorymbus*, *Koelreuteria*, *Handeliodendron*, *Calocedrus*) and neoendemic genera (*Petrocodon*, *Heteroplexis*). *Heteroplexis* is endemic to Guangxi and holds significant importance for studying the systematic evolution of Asteraceae. According to Ying and Zhang (1994), *Gymnotheca* likely differentiated in central China after the Tertiary period, while *Schnabelia* evolved from *Caryopteris*. In terms of life forms, 10 genera are woody and 4 are herbaceous, with woody types predominating—contrasting with the pattern in Chinese endemic genera where herbaceous types dominate (66%) (Ying and Zhang, 1994). This discrepancy primarily results from the reserve' s small area and specialized habitats.

3.3.2 Statistical Analysis of Endemic Species Plant distribution in nature does not align with administrative boundaries. This study defines endemic species as those primarily distributed in China or Guangxi, or currently found only in these regions with restricted distribution ranges.

(1) Chinese Endemic Plants

China contains over 1,200 endemic lycophyte and fern species, accounting for approximately 50% of China' s total lycophyte and fern diversity (Yan, 2011). Despite covering only 108.3 km^2, Mulun Reserve hosts 34 Chinese endemic lycophytes and ferns (2.83% of China' s endemic lycophytes and ferns). The ten families containing the most endemic species—Dryopteridaceae, Athyriaceae, Thelypteridaceae, Polypodiaceae, Aspleniaceae, Pteridaceae, Dennstaedtiaceae, Sinopteridaceae, Tectariaceae, and Angiopteridaceae—are all present in the reserve, reflecting its location in China' s central biogeographical transition zone and demonstrating the special nature of its habitats.

The reserve contains 452 Chinese endemic seed plant species belonging to 107 families and 262 genera. Based on species numbers per family or genus, we classified these into "multi-species families/genera" ($ $10 species), "medium families/genera" (5–9 species), "few-species families/genera" (2–4 species), and "single-species families/genera" (1 species). At the family level, 9 multi-species families (8.41% of families) contain 150 species (33.19% of species), while 22 medium families (20.56% of families) contain 148 species (32.74% of species). Together, multi-species and medium families (28.97% of families) contain 65.93% of species, indicating concentration in relatively few families with dominant families including Lauraceae, Orchidaceae, Lamiaceae, Rosaceae, and Gesneriaceae. At the genus level, only 1 genus qualifies as multi-species, with low proportions of medium genera. However, few-species genera represent 31.30% of genera but contain 45.80% of species, while single-species genera represent 63.36% of genera

but contain 36.73% of species (Table 3), demonstrating that Chinese endemic seed plants are dominated by few-species and single-species genera with high differentiation, playing important roles in enriching the regional flora.

Table 3. Quantitative structure of families and genera of Chinese endemic seed plants in Mulun Reserve

Family type	Family No.	Species No.	Genus type	Genus No.	Species No.	Proportion (%)
Multi-species family	9	150	Multi-species genus	1	12	2.65
Medium family	22	148	Medium genus	9	57	12.61
Few-species family	42	115	Few-species genus	82	207	45.80
Single-species family	34	39	Single-species genus	166	166	36.73
Total	**107**	**452**	**Total**	**258**	**442**	**97.79**

(2) Guangxi Endemic Plants

Mulun Reserve contains 5 Guangxi endemic fern species: *Cyclosorus pseudocunneatus*, *Arachniodes setifera*, *Polystichum ariticulatipilosum*, *Polystichum guangxiense*, and *Polystichum mulunense*.

The reserve hosts 51 Guangxi endemic seed plant species belonging to 31 families and 41 genera, representing approximately 3.36% of seed plant species and 11.28% of Chinese endemic seed plants in the reserve. No multi-species families or genera occur among Guangxi endemics, with extremely low proportions of medium families and genera. Few-species genera occupy a certain proportion but contain relatively few species. However, single-species families account for 64.52% of families, while single-species genera represent 82.93% of genera and contain 66.67% of species (Table 4), indicating that Guangxi endemic species are dominated by single-species families and genera. This pattern enriches the reserve' s plant diversity, demonstrating not only high seed plant endemism but also reflecting habitat complexity.

Table 4. Quantitative structure of families and genera of Guangxi endemic seed plants in Mulun Reserve

Family type	Family No.	Species No.	Proportion (%)	Genus type	Genus No.	Species No.	Proportion (%)
Multi-species family	0	0	0.00	Multi-species genus	0	0	0.00
Medium family	2	8	15.69	Medium genus	1	5	9.80
Few-species family	9	9	17.65	Few-species genus	6	12	23.53
Single-species family	20	34	66.67	Single-species genus	34	34	66.67
Total	**31**	**51**	**100.00**	**Total**	**41**	**51**	**100.00**

(3) Karst Endemic Plants

Mulun Reserve contains 262 karst endemic plant species (15.1% of vascular plants), including 46 karst endemic lycophytes and ferns and 216 karst endemic seed plants. At the family level, 79 families contain karst endemics, with Orchidaceae containing the most (42 species, 16.03% of karst endemics), followed by Dryopteridaceae, Urticaceae, Lauraceae, and Gesneriaceae (13 species each). Thirty-three families contain only one karst endemic species (41.77% of families). At the genus level, 158 genera contain karst endemics, with *Polystichum* and *Elatostema* containing the most (8 species each, 6.11% of karst endemics), followed by *Paphiopedilum* (5 species) and *Paraboea* (5 species). Ninety-six genera contain only one karst endemic species (60.76% of genera).

Among karst endemics, 59 species are nationally or Guangxi key protected plants, including 5 first-class national key protected species, 54 second-class national key protected species, and 51 Guangxi key protected species. In terms of endemism, 128 karst endemic species are Chinese endemics (48.85% of karst endemics), including 37 Guangxi endemics. Regarding threat status, 40 karst endemic species are threatened (Qin et al., 2017), with 5 classified as Critically Endangered (CR), 17 as Endangered (EN), and 18 as Vulnerable (VU). According to CITES, 42 karst endemic species are listed in the appendices, with 5 in Appendix I and 37 in Appendix II.

Karst habitats represent specialized environments with strong heterogeneity that nurture abundant karst endemic plants. As a typical karst landscape, Mulun Reserve' s distribution of numerous karst endemics demonstrates its significant karst floristic character. The high proportion of threatened, rare, and endangered species among these karst endemics highlights both the importance of karst regions for plant diversity conservation in China and the vulnerability of karst habitats, necessitating enhanced conservation awareness and sustained scientific protection measures for plant groups distributed in karst areas.

3.4.1 Statistical Analysis of Nationally Protected Plants Nationally protected plants represent important strategic resources and primary conservation targets in nature reserves. Mulun Reserve hosts 68 nationally protected plant species belonging to 26 families and 39 genera, including 5 lycophytes and ferns, 9 gymnosperms, and 54 angiosperms. Six species are first-class national key protected wild plants and 62 are second-class (Table 5). Despite covering less than 1/80,000 of China' s land area, the reserve contains approximately 6% of China' s nationally protected wild plant species, highlighting its important position in China' s biodiversity conservation.

Table 5. Quantitative structure of families, genera, and species of nationally protected plants in Mulun Reserve

Plant group	Family	Genus	Species	Level I	Level II
Lycophytes & Ferns	3	3	5	0	5
Gymnosperms	4	6	9	3	6
Angiosperms	19	30	54	3	51
Total	**26**	**39**	**68**	**6**	**62**

Regarding endemism, 21 of the 68 nationally protected wild plants are Chinese endemics, including 2 Guangxi endemics. According to IUCN Red List criteria, 4 species are Critically Endangered (CR), 14 are Endangered (EN), and 24 are Vulnerable (VU). Under CITES, 5 species are listed in Appendix I and 29 in Appendix II (Table 6).

Table 6. Nationally protected plants in Mulun Reserve

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
1	Huperziaceae	*Huperzia javanica*	II	-	-	-
2	Angiopteridaceae	*Angiopteris fokiensis*	II	-	-	-
3	Dicksoniaceae	*Cibotium barometz*	II	-	Appendix II	-
4	Cyatheaceae	*Alsophila spinulosa*	II	-	Appendix II	-
5	Pinaceae	*Keteleeria davidiana* var. *calcarea*	II	Endemic to China	-	-

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
6	Pinaceae	*Pinus kwangtungensis*	II	Endemic to China	-	-
7	Pinaceae	*Pseudotsuga brevifolia*	II	Endemic to China	-	-
8	Cupressaceae	*Calocedrus rupestris*	II	Endemic to China	-	-
9	Cupressaceae	*Xanthocyparis vietnamensis*	II	-	-	-
10	Podocarpaceae	*Podocarpus neriifolius*	II	-	-	-
11	Cephalotaxaceae	*Cephalotaxus hainanensis*	II	-	-	-
12	Taxaceae	*Amentotaxus yunnanensis*	II	-	-	-
13	Taxaceae	*Taxus calcicola*	I	Endemic to China	-	EN
14	Magnoliaceae	*Manglietia aromatica*	II	-	-	-
15	Magnoliaceae	*Woonyoungia septentrionalis*	I	Endemic to China	-	EN
16	Illiciaceae	*Illicium difengpi*	II	Endemic to Guangxi	-	EN
17	Berberidaceae	*Dysosma versipellis*	II	Endemic to China	-	EN
18	Fumariaceae	*Corydalis saxicola*	II	Endemic to China	-	-
19	Polygonaceae	*Fagopyrum dibotrys*	II	Endemic to China	-	-

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
20	Guttiferae	*Garcinia paucinervis*	II	Endemic to China	-	EN
21	Sterculiaceae	*Eriolaena kwangsiensis*	II	Endemic to China	-	CR
22	Rosaceae	*Rosa chinensis* var. *spontanea*	II	-	-	-
23	Papilionaceae	*Ormosia pinnata*	II	Endemic to China	-	-
24	Papilionaceae	*Ormosia saxatilis*	II	Endemic to China	-	-
25	Papilionaceae	*Sophora tonkinensis*	II	-	-	-
26	Hamamelidaceae	*Tetrathyrium subcordatum*	II	Endemic to China	-	-
27	Moraceae	*Morus wittiorum*	II	Endemic to China	-	-
28	Meliaceae	*Aglaia lawii*	II	-	-	-
29	Sapindaceae	*Eurycorymbus cavaleriei*	II	Endemic to China	-	EN
30	Hippocastanaceae	*Aesculus chiebodenodron*	II	Endemic to China	-	EN
31	Juglandaceae	*Annamocarya sinensis*	II	Endemic to China	-	CR
32	Trilliaceae	*Paris chinensis*	II	Endemic to China	-	EN
33	Trilliaceae	*Paris cronquistii*	II	Endemic to China	-	EN
34	Trilliaceae	*Paris dunniana*	II	Endemic to China	-	-

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
35	Trilliaceae	*Paris fargesii*	II	Endemic to China	-	-
36	Orchidaceae	*Anoectochilus calcareus*	II	Endemic to China	Appendix II	-
37	Orchidaceae	*Anoectochilus roxburghii*	II	-	Appendix II	-
38	Orchidaceae	*Anoectochilus zhejiangensis*	II	Endemic to China	Appendix II	-
39	Orchidaceae	*Bletilla striata*	II	-	Appendix II	-
40	Orchidaceae	*Cremastra appendiculata*	II	-	Appendix II	-
41	Orchidaceae	*Cymbidium cyperifolium*	II	-	Appendix II	-
42	Orchidaceae	*Cymbidium ensifolium*	II	-	Appendix II	-
43	Orchidaceae	*Cymbidium faberi*	II	-	Appendix II	-
44	Orchidaceae	*Cymbidium floribundum*	II	-	Appendix II	-
45	Orchidaceae	*Cymbidium goeringii*	II	-	Appendix II	-
46	Orchidaceae	*Cymbidium kanran*	II	-	Appendix II	-
47	Orchidaceae	*Cymbidium mannii*	II	-	Appendix II	-
48	Orchidaceae	*Cymbidium qiubeiense*	II	Endemic to China	Appendix II	-

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
49	Orchidaceae	*Cymbidium tortisepalum* var. *longibracteatum*	II	Endemic to China	Appendix II	-
50	Orchidaceae	*Dendrobium chrysanthum*	II	-	Appendix II	-
51	Orchidaceae	*Dendrobium cuculliatum*	II	-	Appendix II	-
52	Orchidaceae	*Dendrobium denneanum*	II	-	Appendix II	-
53	Orchidaceae	*Dendrobium densiflorum*	II	-	Appendix II	-
54	Orchidaceae	*Dendrobium fimbriatum*	II	-	Appendix II	-
55	Orchidaceae	*Dendrobium gibsonii*	II	-	Appendix II	-
56	Orchidaceae	*Dendrobium henryi*	II	-	Appendix II	-
57	Orchidaceae	*Dendrobium loddigesii*	II	-	Appendix II	-
58	Orchidaceae	*Dendrobium lohohense*	II	Endemic to China	Appendix II	-
59	Orchidaceae	*Dendrobium moniliforme*	II	-	Appendix II	-
60	Orchidaceae	*Dendrobium officinale*	II	-	Appendix II	-
61	Orchidaceae	*Gastrodia elata*	II	-	Appendix II	-
62	Orchidaceae	*Paphiopedilum barbigerum*	I	-	Appendix I	EN

No.	Family	Species	Protection level	Endemism	CITES	IUCN level
63	Orchidaceae	*Paphiopedilum emersonii*	II	-	Appendix I	CR
64	Orchidaceae	*Paphiopedilum hirsutissimum*	II	-	Appendix I	-
65	Orchidaceae	*Paphiopedilum malipoense*	II	-	Appendix I	EN
66	Orchidaceae	*Paphiopedilum micranthum*	II	-	Appendix I	-
67	Orchidaceae	*Phalaenopsis wilsonii*	II	-	Appendix II	-

Note: "-" *indicates not evaluated.*

3.4.2 Statistical Analysis of Guangxi Key Protected Wild Plants Mulun Reserve contains 153 Guangxi key protected wild plant species belonging to 16 families and 67 genera, including 137 orchid species (89.5% of Guangxi key protected plants in the reserve and 30.99% of Guangxi' s 442 wild orchid species and varieties) (Chen et al., 2016). Orchidaceae represents a characteristic plant group in Mulun Reserve, with species richness second only to Yachang Reserve in Guangxi. Although the reserve occupies less than 0.04% of Guangxi' s land area, it contains 30.99% of the province' s wild orchid species, indicating that the region is an important distribution center for wild orchids in Guangxi with extremely high orchid diversity.

Regarding endemism, 34 of the 153 Guangxi key protected wild plants are Chinese endemics and 4 are Guangxi endemics. According to IUCN Red List criteria, 3 species are Critically Endangered (CR), 23 are Endangered (EN), and 31 are Vulnerable (VU). Under CITES, five *Paphiopedilum* species are listed in Appendix I, while the remaining 132 orchid species are listed in Appendix II.

3.4.3 Statistical Analysis of Threatened and CITES-Listed Species According to IUCN Red List Categories and Criteria (Version 3.1) (IUCN, 2012) and the "Threatened Species List of China' s Higher Plants" (Qin et al., 2017), 108 seed plant species in Mulun Reserve are classified as threatened, including 11 Critically Endangered (CR) species (0.63% of vascular plants, 10.18% of threatened species), 37 Endangered (EN) species (2.13% of vascular plants, 34.26% of threatened species), and 60 Vulnerable (VU) species (3.46% of vascular plants, 55.56% of threatened species). Under CITES, 144 species are listed in the appendices (8.30% of vascular plants), with 5 *Paphiopedilum* species in

Appendix I and 139 species (2 ferns and 137 angiosperms) in Appendix II (Table 7). These statistics indicate both a high proportion and high threat levels among threatened species in the reserve.

Table 7. Statistics of threatened species and CITES-listed species in Mulun Reserve

Plant group	CR	EN	VU	CITES I	CITES II
Ferns	1	3	2	0	2
Gymnosperms	0	4	5	0	0
Angiosperms	10	30	53	5	137
Total	**11**	**37**	**60**	**5**	**139**

3.4.4 Statistical Analysis of Extremely Small Population Species Extremely small population plants refer to wild plant species with narrow or discontinuous distribution that have experienced long-term external threats, showing population decline or persistently small populations with extremely low numbers of individuals and populations that have fallen below the minimum viable population threshold for stable survival, making them imminently endangered (Ren et al., 2012). The vast majority are Chinese endemics with important ecological and economic value, having specialized habitat requirements and greater vulnerability to endangerment, representing some of the most easily lost biological resources. To protect these valuable resources, China' s State Forestry Administration identified 120 extremely small population wild plant species for priority protection in 2011, including 36 first-class national key protected species, 26 second-class species, and 58 provincial key protected species, with 32 species recorded in Guangxi.

Mulun Reserve contains 4 extremely small population plant species: *Annamocarya sinensis*, *Woonyoungia septentrionalis*, *Firmiana kwangsiensis*, and *Paphiopedilum emersonii*, representing 3.33% of China' s total and 12.5% of Guangxi-recorded extremely small population wild plants, underscoring the reserve' s important position in biodiversity conservation at both provincial and national scales.

3.4.5 Type Specimen Plants A type locality represents the original description site of a species, with type specimens collected from this location providing essential materials for botanical research, particularly plant taxonomy, and holding significant value for the flora of that region. To some extent, the number of type specimens from a region reflects the richness and value of its plant diversity.

Mulun Reserve's unique geographical location and complex natural environment have created a distinctive regional flora. Sixteen species have been reported with Mulun Reserve as their type locality (Table 8) (Chen, 1988; Wei, 1995; Wei and Wen, 1995; Wen, 1995; Fang and Xie, 2002; Li and Wei, 2003; Zeng and Liu, 2004; Wang and Wei, 2007; Xu et al., 2011, 2012; Han et al., 2013; Huang et

al., 2013; Wu et al., 2013; Hu et al., 2014; Shen et al., 2015). These newly discovered taxa constitute important components of the reserve' s flora, and their continuous discovery demonstrates both the region' s rich plant diversity and the complexity of its flora, necessitating sustained intensive investigation and strengthened scientific conservation.

Table 8. Plants with Mulun Reserve as type locality

Family	Species	Type specimen information
Dryopteridaceae	*Polystichum mulunense*	Jiang RH et al. ML1240 (IBK), 23 April 2012
Magnoliaceae	*Lirianthe mulunica*	Zeng QW 41 (IBSC), 5 June 2001
Lauraceae	*Litsea dorsalicana*	Huang YS et al. Y1330 (IBK), 20 April 2012
Lauraceae	*Beilschmiedia ovoidea*	Mulun comprehensive examination team M0333 (IBK), 24 August 1994
Berberidaceae	*Berberis uniflora*	Dian-Qian-Gui Team 70273 (IBK), 27 October 1991
Aristolochiaceae	*Aristolochia huanjiangensis*	Xu WB & Wu L 11102 (IBK), 28 February 2011
Aristolochiaceae	*Aristolochia mulunensis*	Huang YS et al. ML1425 (IBK), 27 April 2012
Euphorbiaceae	*Leptopus pachyphyllus*	Tan YS 4-3-424 (IBK), 23 April 1978
Mimosaceae	*Archidendron multifoliolatum*	Wei FN & Liu Y M0226 (IBK), 16 August 1994
Urticaceae	*Elatostema huanjiangense*	Wei YG 06128 (IBK), 19 April 2006
Rubiaceae	*Ophiorrhiza huanjiangensis*	Mo HW 4-3-410 (IBK), 15 April 1978
Gesneriaceae	*Hemiboea magnibracteata*	Mulun comprehensive examination team M0224 (IBK), 16 August 1994
Gesneriaceae	*Paraboea angustifolia*	Xu WB & Pan B 09537 (IBK), 3 June 2009
Gesneriaceae	*Petrocosmea huanjiangensis*	Liu Y & Xu WB 09549 (IBK), 3 June 2009
Lamiaceae	*Salvia petrophila*	Xu WB 09434 (IBK), 3 May 2009
Liliaceae	*Aspidistra huanjiangensis*	Project investigation team of *Aspidistra* 075 (IBK), 20 April 2000

4. Discussion and Conclusion

This study documented 1,735 vascular plant species in Mulun Reserve, representing an increase of 829 species compared to the first comprehensive plant survey (Zheng, 1999) and 289 species compared to Peng' s (2013) vascular plant inventory, substantially expanding the known vascular plant diversity and further clarifying the reserve' s plant resource baseline. Among Guangxi' s karst forest national nature reserves, Mulun Reserve ranks third in vascular plant species richness, after Yachang and Nonggang Reserves, and second in orchid species richness after Yachang Reserve, confirming the region' s rich plant diversity. The reserve' s capacity to support such abundant plant resources relates closely to its geographical location, karst geomorphology, and elevation gradients.

A region' s flora inevitably maintains close connections with surrounding floras, and complex floristic composition provides more variation patterns for species exchange, differentiation, formation, and evolution. Mulun Reserve lies on the southern margin of China' s mid-subtropical zone at the intersection of the Dian-Qian-Gui and South China floristic regions and the core transition area between Paleoarctic and Paleotropical floristic kingdoms, while also escaping direct impact from continental glaciation during the Quaternary. These factors have enabled the long-term preservation of rich plant species diversity during floristic evolution. Additionally, the reserve features diverse karst landforms including peak clusters, depressions, karst basins, caves, and tiankengs that create complex microhabitats favorable for plant survival and reproduction. The northwest-southeast elevation gradient from 1,028 m to approximately 250 m, though less than 800 m difference, creates significant vertical vegetation zonation in karst landscapes. Overall, the suitable mid-subtropical climate, diverse karst geomorphology, and substantial elevation range have created varied karst habitats that provide ample conditions for floristic formation and evolution, generating rich plant species diversity including numerous endemics, rare and endangered species, ancient relict endemic genera, and neoendemic taxa.

As an important component of China' s biodiversity, Mulun Reserve' s flora holds tremendous conservation and utilization value. As a significant species resource "gene bank," the reserve must strengthen efforts in research, conservation, and community harmony to fully leverage its plant resource advantages for sustainable conservation and utilization. Specific recommendations include:

(1) Continue systematic resource inventory and related research. Whether a region' s plant resource baseline is thoroughly understood forms the foundation and key to conservation and utilization. While geographical constraints, limited human knowledge, and unique biological characteristics may prevent complete documentation of all species diversity, sustained surveys can maximize our understanding. For species with high economic value, large populations, or significant scientific importance, research should be strengthened on resource storage, economic uses, and population dynamics to provide reliable data for conservation and sustainable development.

(2) Effectively protect existing germplasm resources. Germplasm resource richness directly reflects a region' s species diversity value, and co-occurring species show significant correlations. Therefore, effectively protecting existing germplasm resources represents the primary task for regional germplasm conservation. Germplasm resources containing endemics and rare, endangered species often possess important economic or strategic value and require prioritized in-situ conservation supplemented by near-situ and ex-situ conservation measures, based on thorough understanding of their distribution, population size, and dynamics.

(3) Continuously promote community harmony. Nature reserves and their surrounding communities are interdependent and mutually influential, making the conflict between conservation and development an issue that must be addressed. Conservation must remain the premise while emphasizing improved ecological awareness among community residents to foster understanding, support, and active cooperation with conservation efforts. Simultaneously, reserves should leverage resource advantages to promote community development, improve local economic conditions, increase residents' income, and enable them to fully appreciate the benefits of conservation, thereby continuously promoting harmonious coexistence between the reserve and communities.

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