Mapping *Ex Situ* Conservation Gaps and Optimizing Botanical Garden Network for China's Plant Diversity

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Outline

- 1. Background
- 2. Datasets and Methods
- 3. Results and Discussion
- 4. Conclusions and Outlook

Background

The Importance of Botanical Garden

- **Botanical gardens maintain insurance populations for rare and threatened species.**
- **Their germplasm collections support research, restoration, and sustainable use.**
- **They raise public awareness of plant conservation.**



A refuge for rare species



A repository of bioresources



A platform for public education

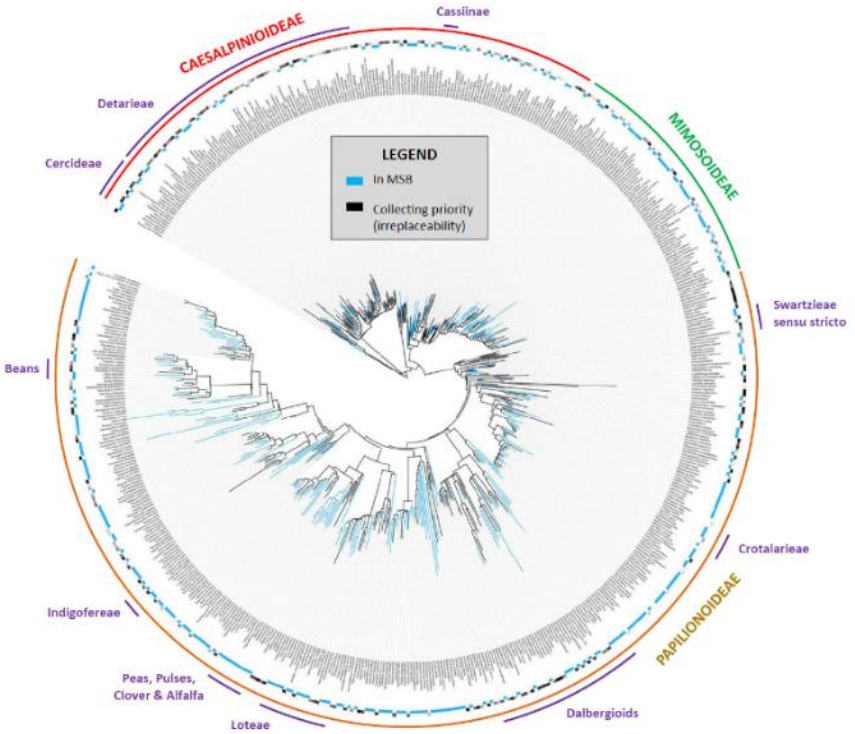
Images: China National Botanical Garden website

Background

Gaps in Existing Assessments

- **Previous estimates of China's *ex situ* conservation coverage vary widely.**
- **Most assessments emphasize species richness, with less attention to phylogenetic diversity and evolutionary distinctiveness.**

Study	Species	Share of China's flora
Xu et al. (2008) Huang (2011) Huang (2012, 2014)	20,000	20,000/30,000 = **66.7%**
Lin (2018)	13,941	13,941/32,784 = **42.5%**
Ren et al. (2022)	18,052	18,052/36,000 = **50.1%**

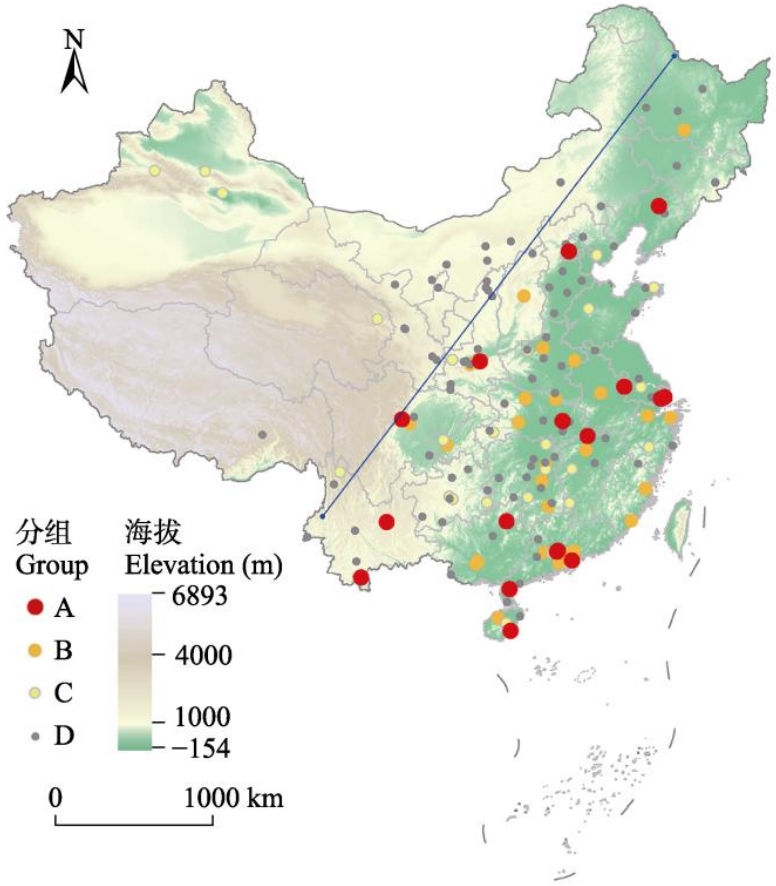


(Griffiths et al., 2015; Larkin et al., 2016)

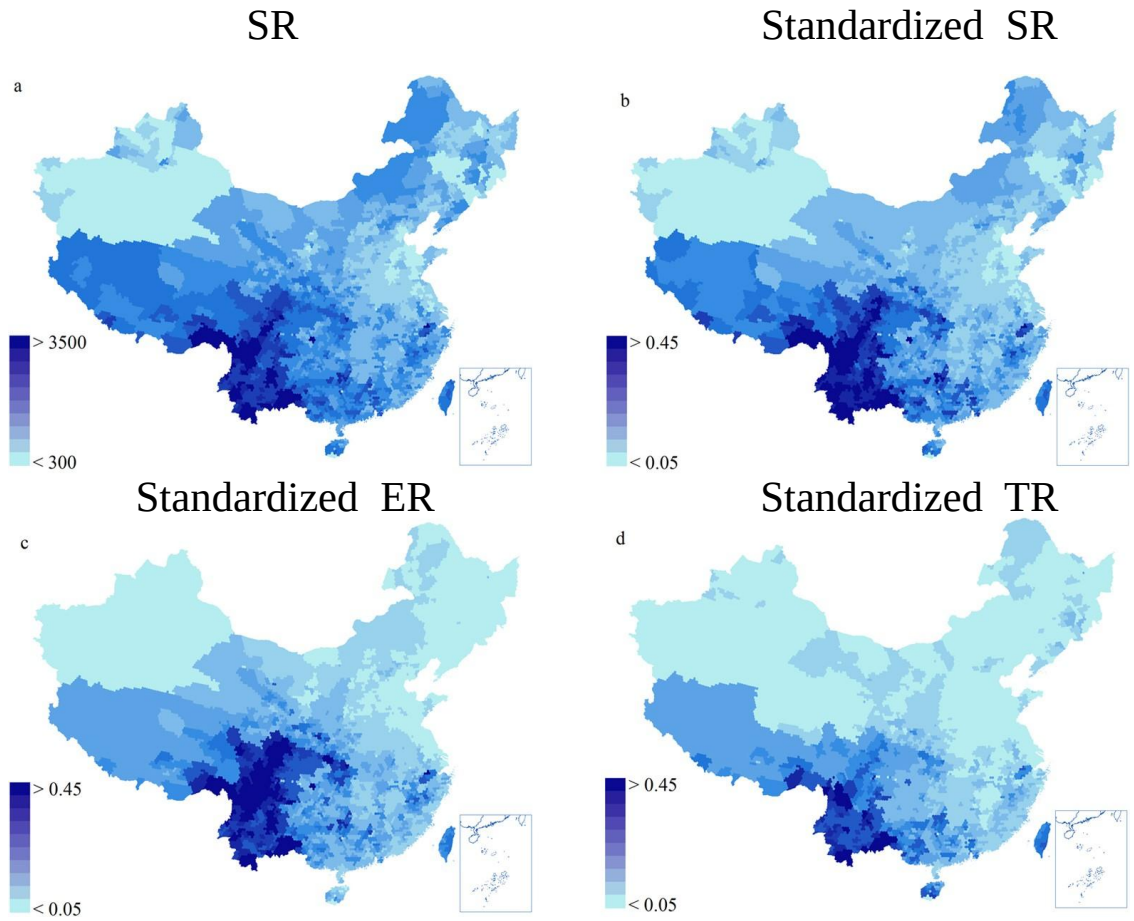
Background

Geographic Bias in Garden Locations

- **Botanical gardens are concentrated at low elevations and east of the Hu Huanyong Line**



Distribution of botanical gardens in China
(Jin et al., 2025)



China's higher plant distribution patterns
(Zhao et al., 2016)

Background

China’s National Garden System

- **2021: China launched a national system integrating *in situ* and *ex situ* conservation.**
- **2023: The national layout plan proposed 14 additional candidate gardens.**



Beijing



Guangzhou



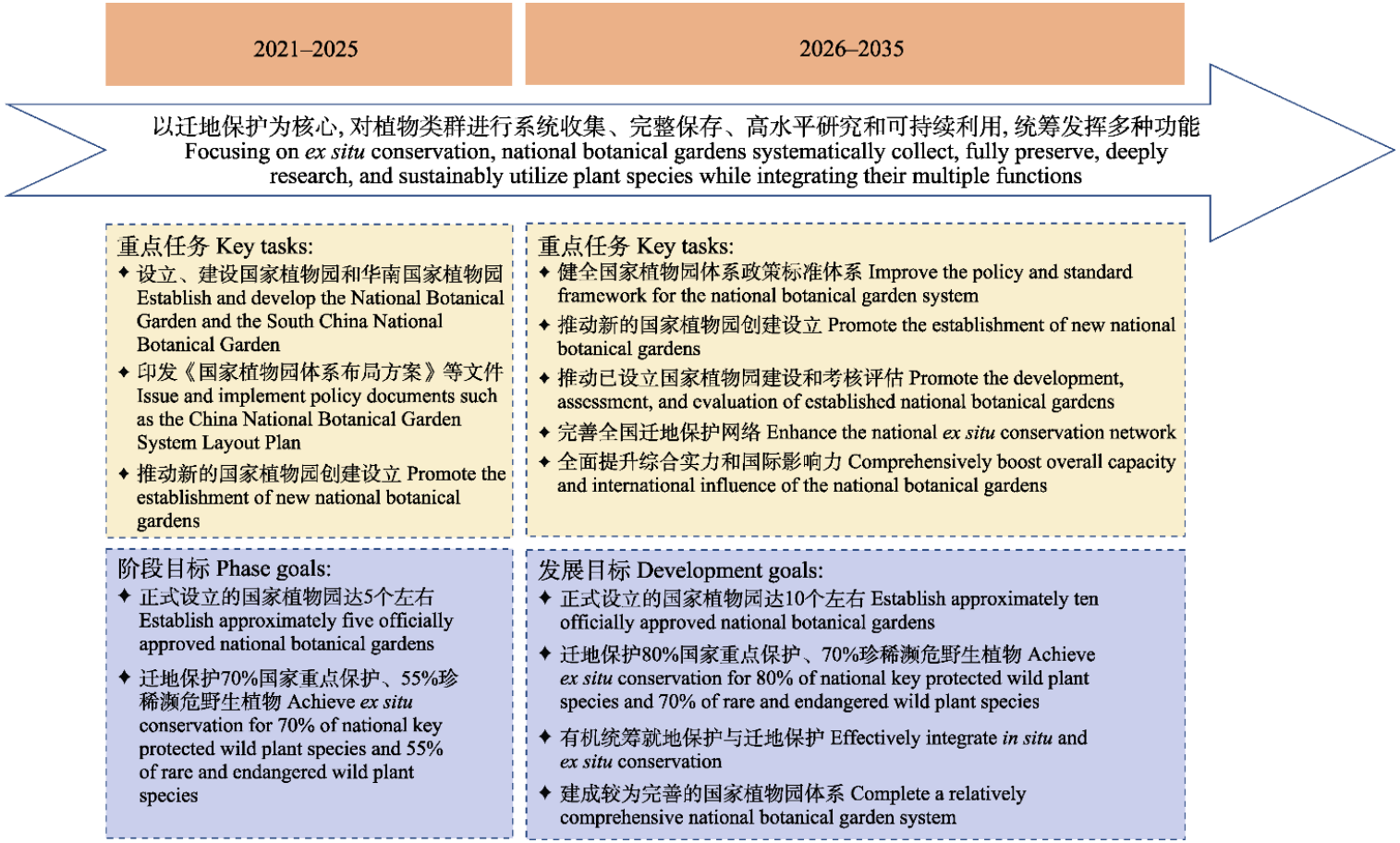
Images: official and public sources

Background

Quantitative Evidence is Still Limited

- **Optimal national botanic garden locations and functions have not yet been systematically assessed.**





Development roadmap for China's National Botanical Garden System (He et al., 2025)

Research Questions

- **Identify the gaps: How well is China's native plant diversity represented in *ex situ* collections, and where are the major gaps?**

- **Evaluate the network: How much does each garden contribute, and how complementary are their collections?**

- **Optimize the network: How can the network be optimized to improve conservation coverage with limited additional resources?**

Datasets

Integrated Data Sources

Native Plant Distributions

- ~1.56 million distribution records
- 30,299 native vascular plant species
- 2,377 counties → 943 grids of 100 km × 100 km



Living Collections

- 49,308 records from 29 botanical gardens
- Garden locations and collection inventories

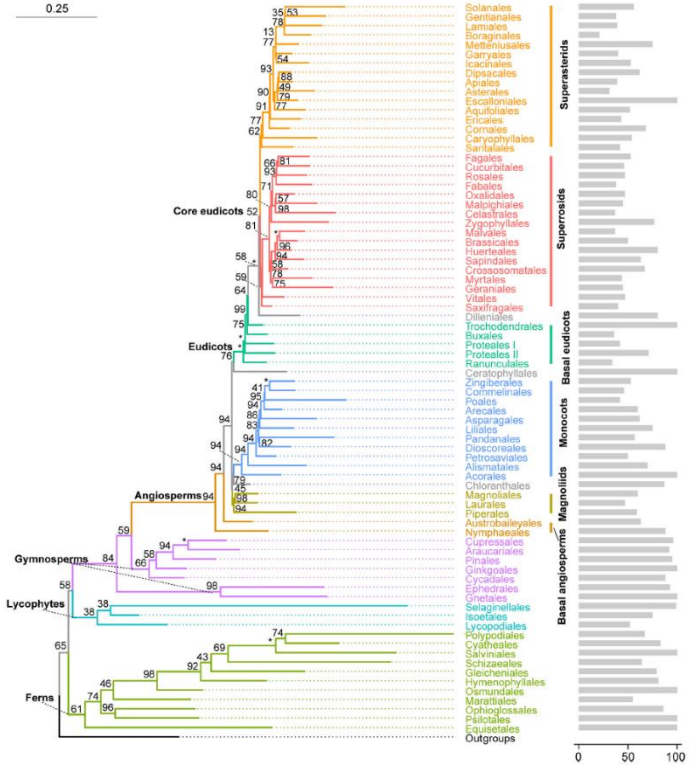


Datasets

Phylogeny and Priority Plant Groups

Phylogenetic Framework

- Source tree: Hu et al., 2020
- Missing species inserted using V.PhyloMaker
- Final tree: 30,494 native vascular plant species

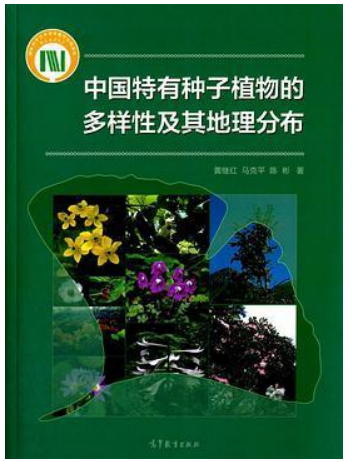


Priority Plant Groups

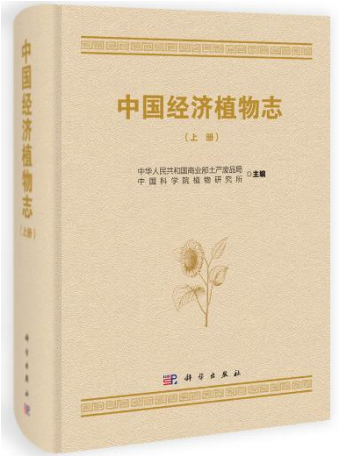
- 3E species
  - Endangered
  - Endemic
  - Economic



Endangered



Endemic



Economic

Methods

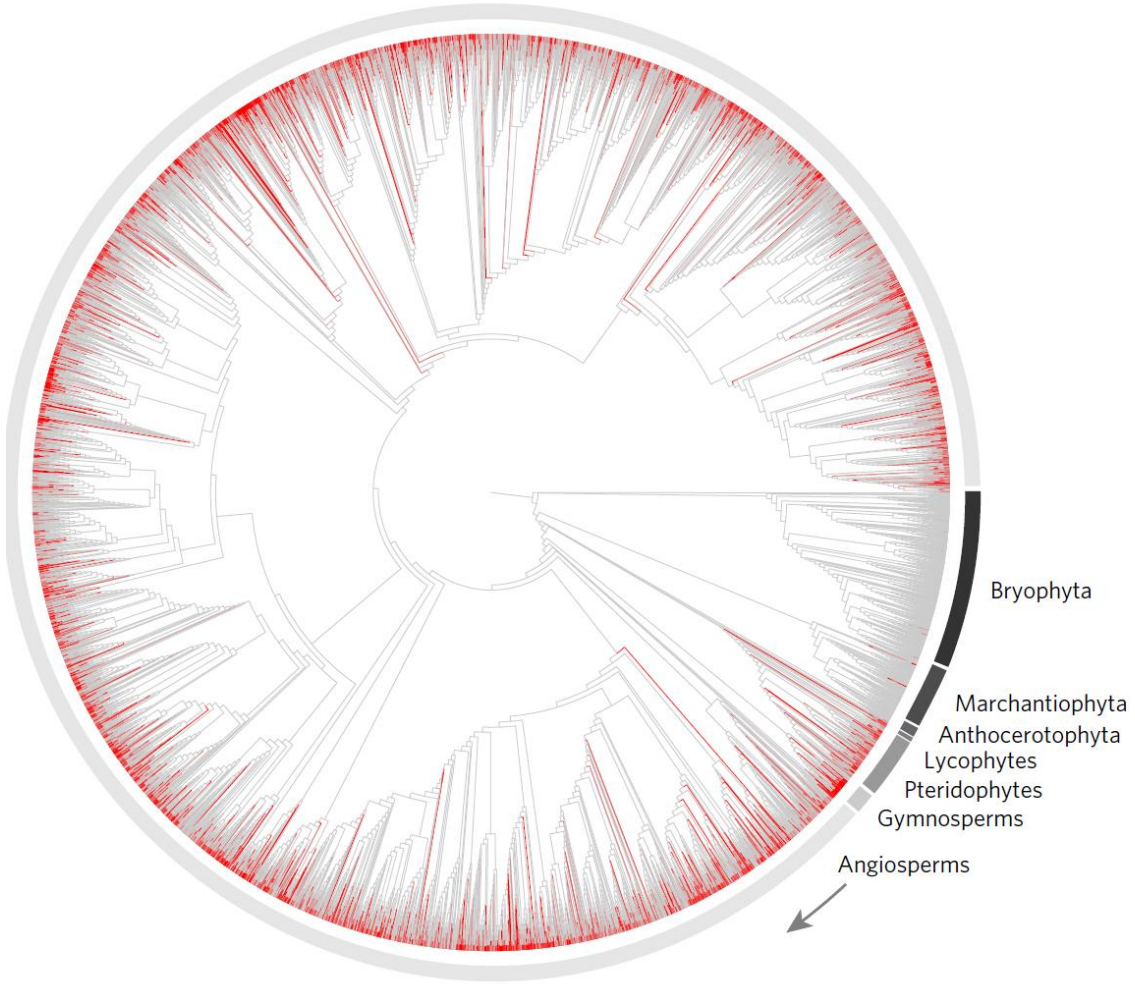
Assessing *Ex Situ* Coverage

National Scale

- Species, genus, and family coverage
- Phylogenetic diversity represented
- Major missing clades: monophyletic clades of ≥5 unrepresented genera
- Evolutionary distinctiveness (ED) ranking of unrepresented genera

Garden Scale

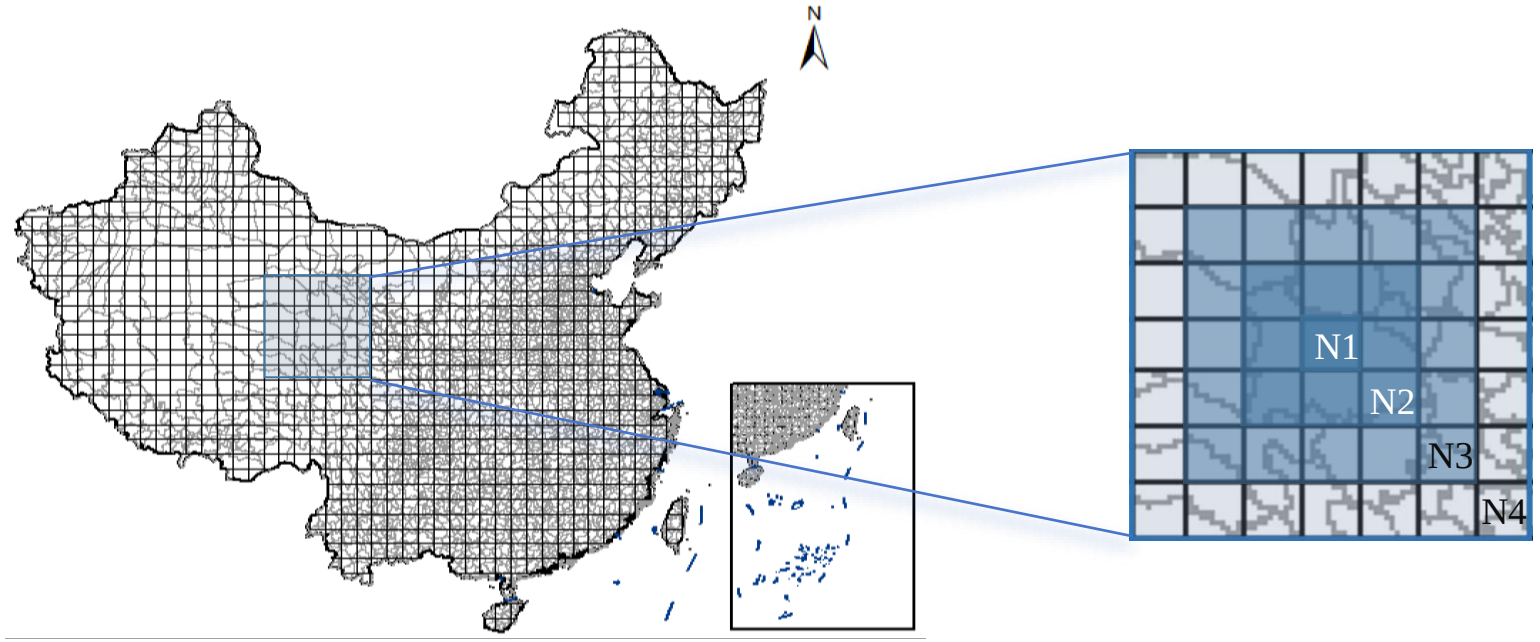
- Native species richness in each garden
- Coverage of 3E species



Red branches: genera absent from *ex situ* collections
Grey branches: genera represented in *ex situ* collections

Methods

Mapping Gaps and Conservation Coverage of Local Flora



N_1: 1×1
N_2: 3×3
N_3: 5×5
N_4: 7×7

National Conservation Gaps

For each grid:

- Missing species richness
- Proportion of missing species
- Missing 3E species and evolutionary distinctiveness

Conservation Coverage of Local Flora （CCLF）

$$CCLF = \frac{N_{native\ in\ collection}}{N_{native\ in\ region}}$$

- Calculated at four nested scales: N1–N4
- How well each garden represents its local flora

Methods

Collection Similarity and Network Structure

Species Composition

Composition similarity among gardens

- Turnover: species replacement
- Nestedness: one collection forming a subset of another

$$\beta_{sim} = \frac{min(b,c)}{a + min(b,c)}$$

$$\beta_{nes} = \frac{|b - c|}{2a + b + c} \times \frac{a}{a + \min(b,c)}$$

a: Number of shared species

b, c: Number of unique species for each

$$\boldsymbol{\beta_r = \beta_{sim} / (\beta_{sim} + \beta_{nes})}$$

Garden Distinctiveness

- LCD: mean turnover between one garden and all others
- Higher LCD indicates a more distinctive collection

Network Structure

- Clustering and ordination analysis

- $\boldsymbol{\beta_r}$ < 0.5: The two botanical gardens have largely overlapping species collections.

Methods

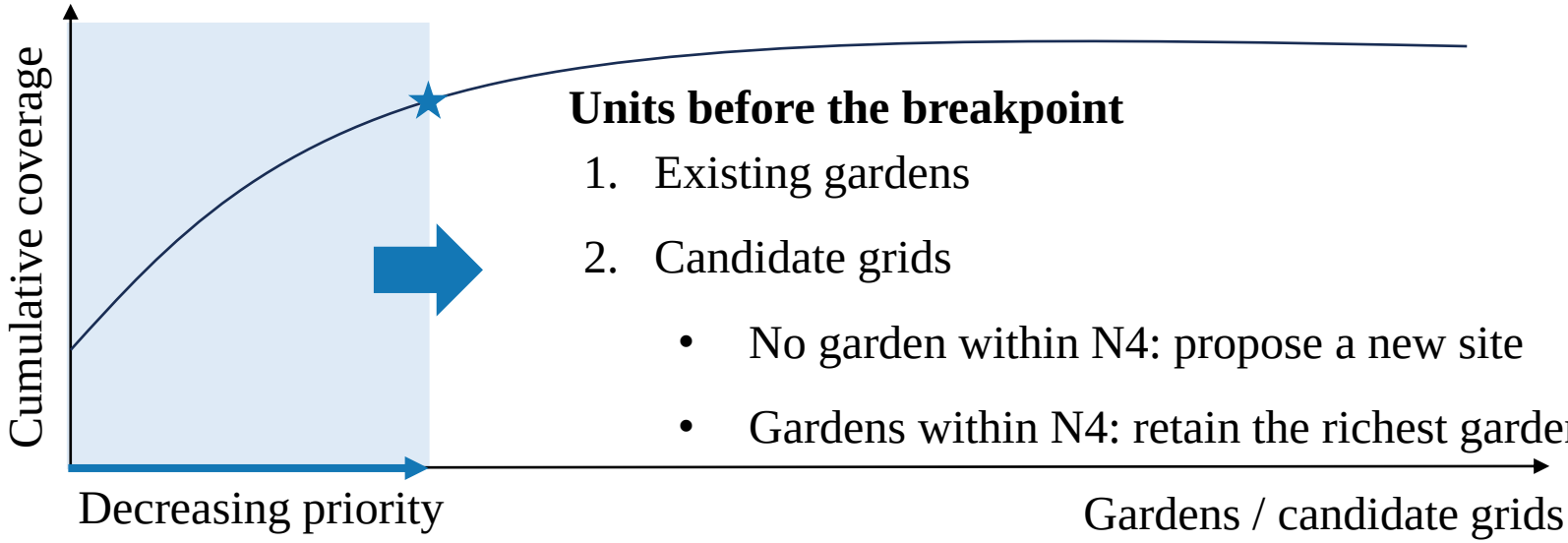
Selecting Priority Gardens and Grid Cells

Gardens / grids → Priority ranking → Cumulative coverage

Based on species richness

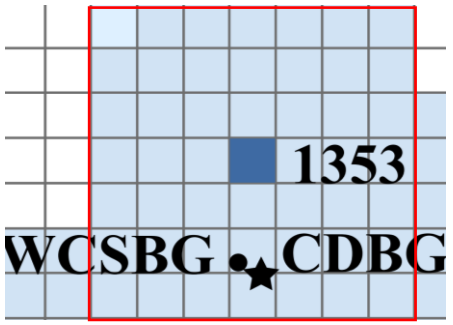
Coverage contributed by this unit and all higher-priority units

Identify the curve breakpoint with k-means



Units before the breakpoint

1. Existing gardens
2. Candidate grids
   - No garden within N4: propose a new site
   - Gardens within N4: retain the richest garden



Richness: CDBG > WCSBG

National Diversity Coverage

National Scale

Table 1 | Summary of *ex situ* conservation in the Chinese botanic gardens.

Plants category	Total	Present	Proportion of present species
All	30,496	12,716	41.70%

Table S1 | The representativeness of vascular families and genera conserved in the Chinese botanic gardens

Group	No. of genera in China	Proportion of genera in ex situ	No. of families in China	Proportion of families in ex situ
Lycophytes & Ferns	177	79.66%	40	100.00%
Gymnosperms	34	100.00%	8	100.00%
Angiosperms	2,860	77.62%	251	93.63%
Total	3,071	75.71%	299	94.31%

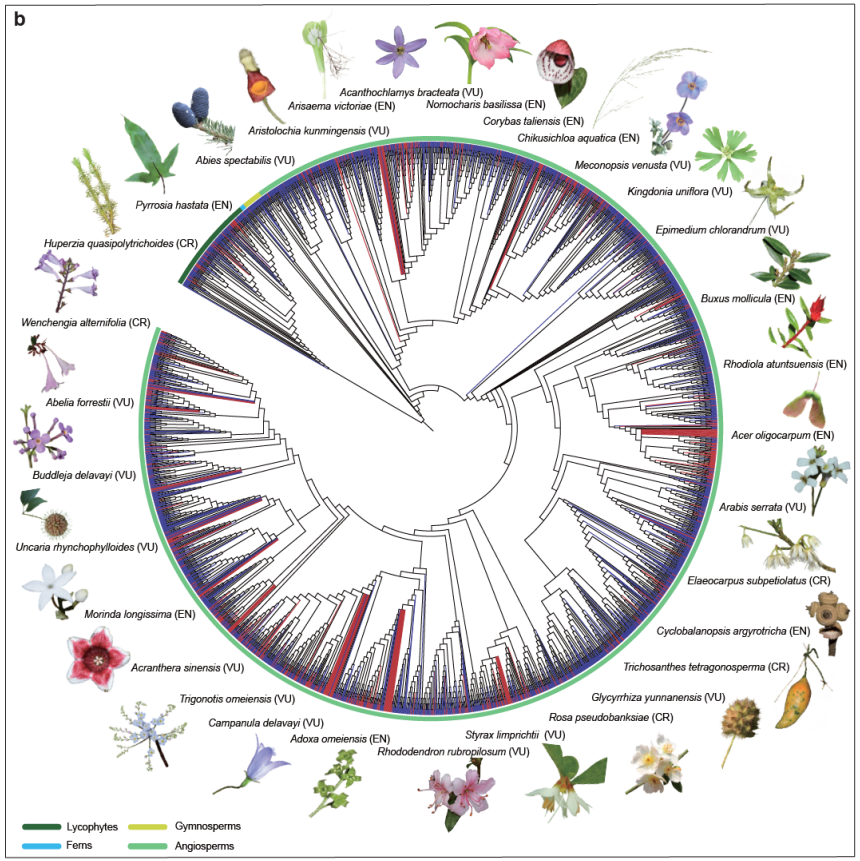
Chinese botanical gardens conserve about 12,716 native vascular plant species (41.70%).

Coverage reaches 75.71% of genera and 94.31% of families.

Phylogenetic Coverage

National Scale

- **Collections represent 46.77% of phylogenetic diversity.**
- **18 major clades in 10 families remain unrepresented.**



Family	Unrepresented clades
Brassicaceae	**6**
Asteraceae	3
Apiaceae	2
Amaranthaceae	1
Boraginaceae	1
Blechnaceae	1
Gentianaceae	1
Orchidaceae	1
Orobanchaceae	1
Polypodiaceae	1

Distribution of 696 unrepresented genera across the Chinese vascular plant tree of life (3,071 genera)

Garden Contributions

Garden Scale

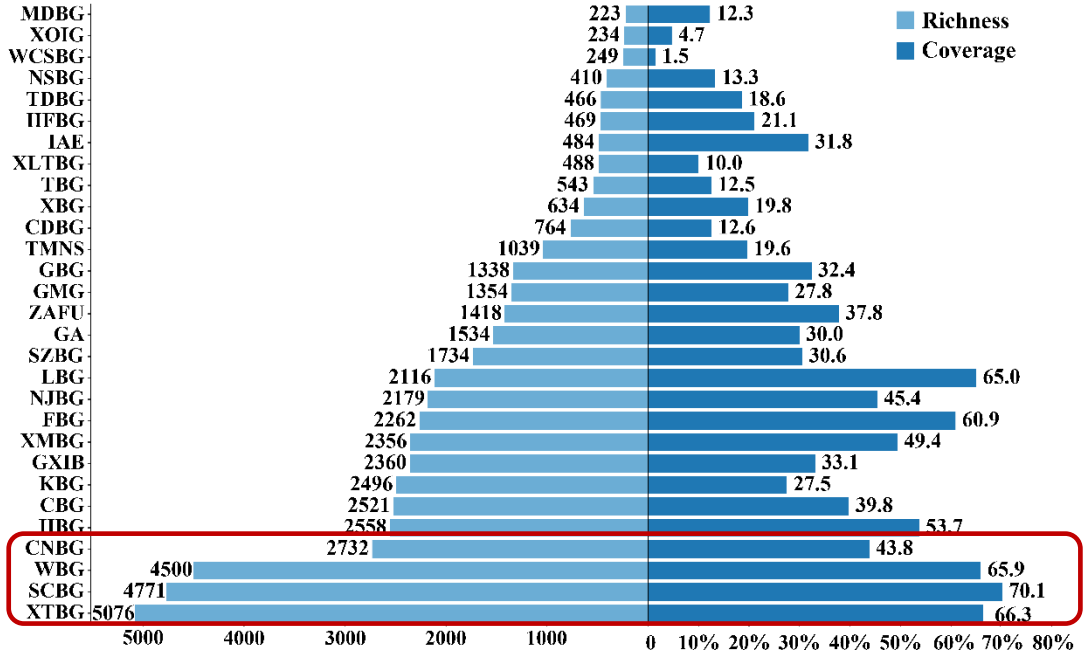
Leading botanical gardens:

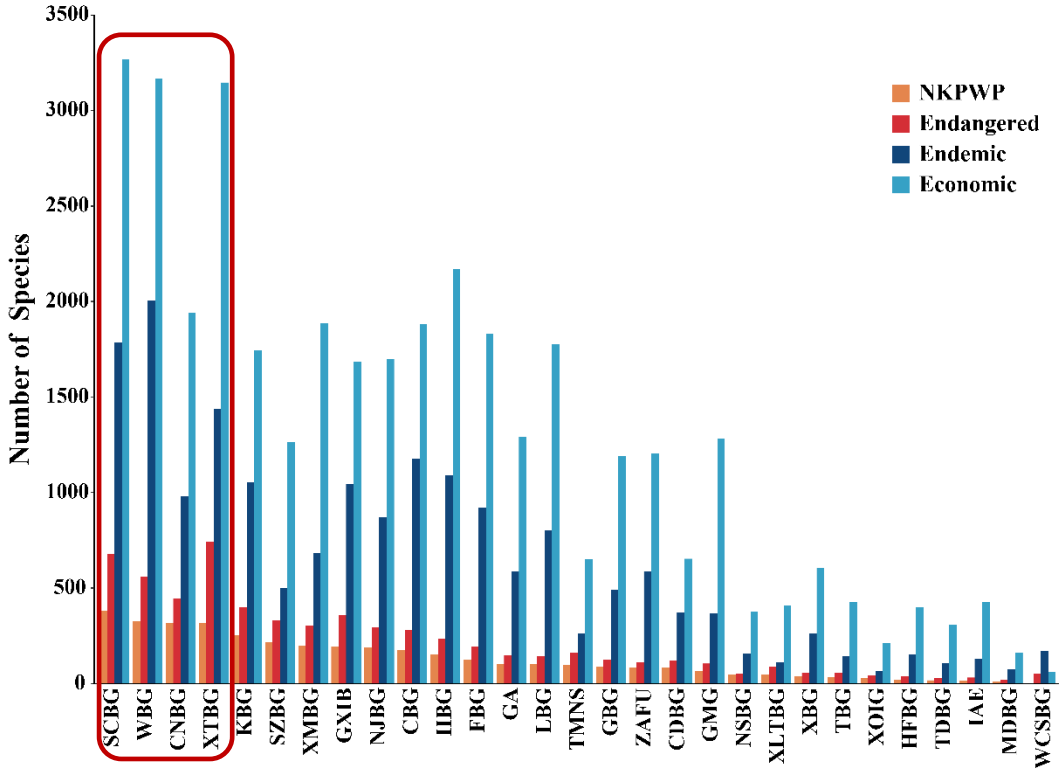
Xishuangbanna Tropical Botanical Garden (XTBG)

Wuhan Botanical Garden (WBG)

South China National Botanical Garden (SCBG)

China National Botanical Garden (CNBG)





Conservation capacity is concentrated in a few large, comprehensive gardens.

Results and Discussion

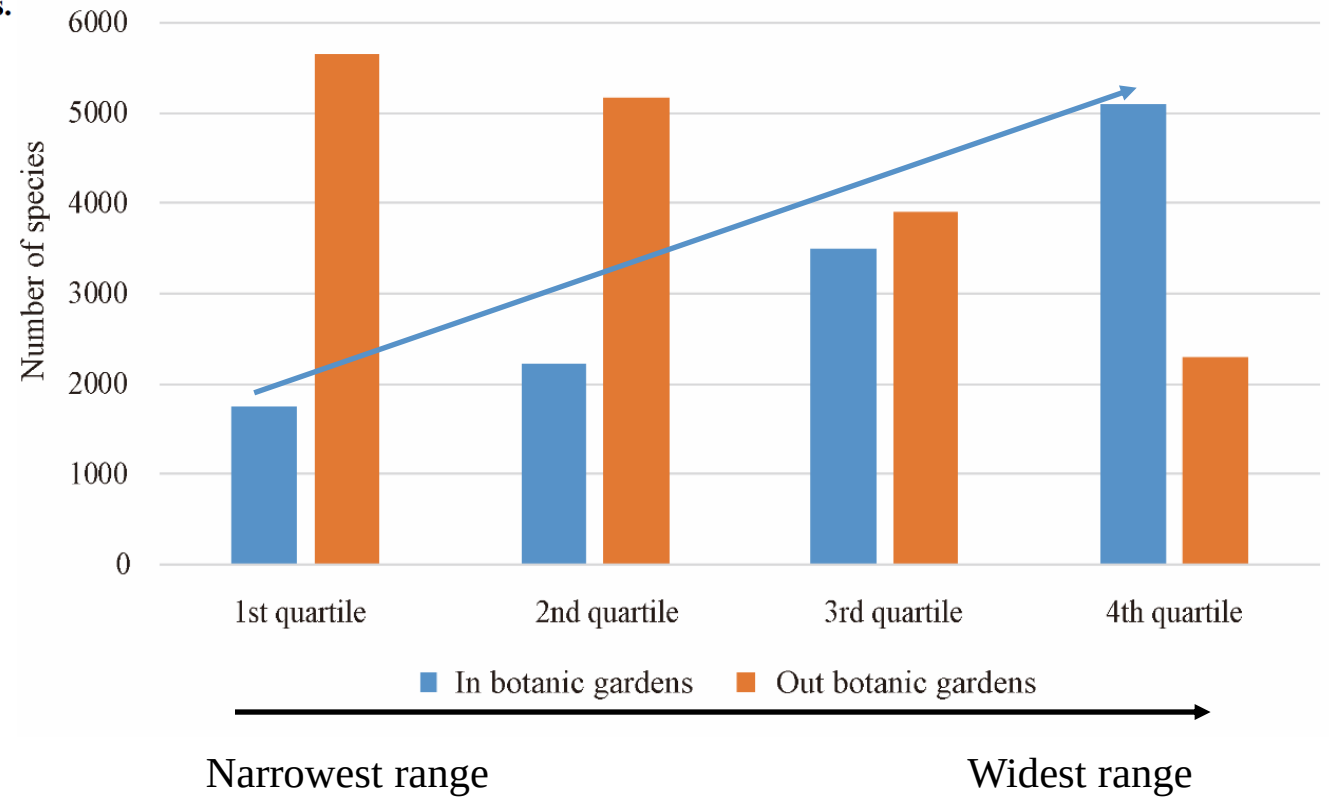
Priority-Group Coverage

National Scale

Table 1 | Summary of *ex situ* conservation in the Chinese botanic gardens.

Plants category	Total	Present	Proportion of present species
All	30,496	12,716	41.70%
Angiosperms	28,178	11,652	41.35%
Gymnosperms	190	147	77.37%
Lycophytes & Ferns	2,128	917	43.09%
Herbaceous species	19,904	6,441	32.36%
Woody species	10,592	6,275	59.24%
Economic species	5,485	4,425	80.67%
Endangered species	3,478	1,715	49.31%
Endemic species	14,827	4,750	32.04%

Present means species with *ex situ* conservation



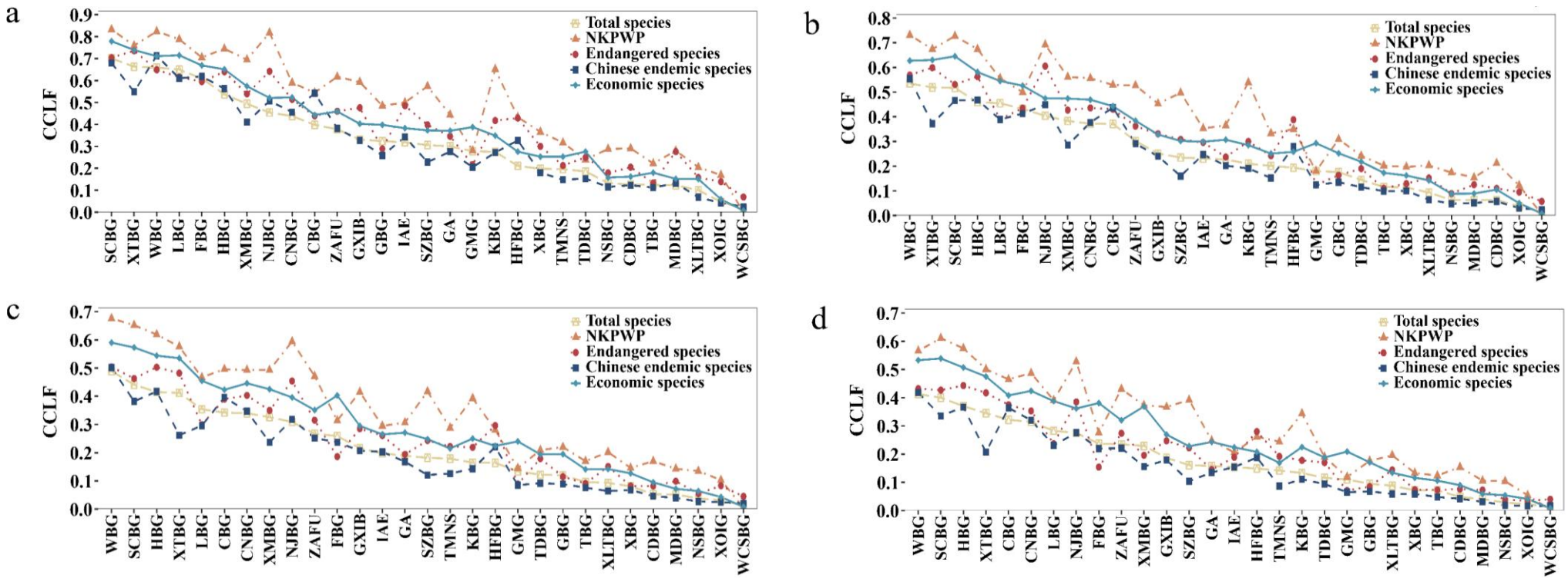
Range-restricted, endemic, threatened, and herbaceous plants remain underrepresented.

Results and Discussion

3E Coverage

Garden Scale

Coverage: economic > endangered > endemic

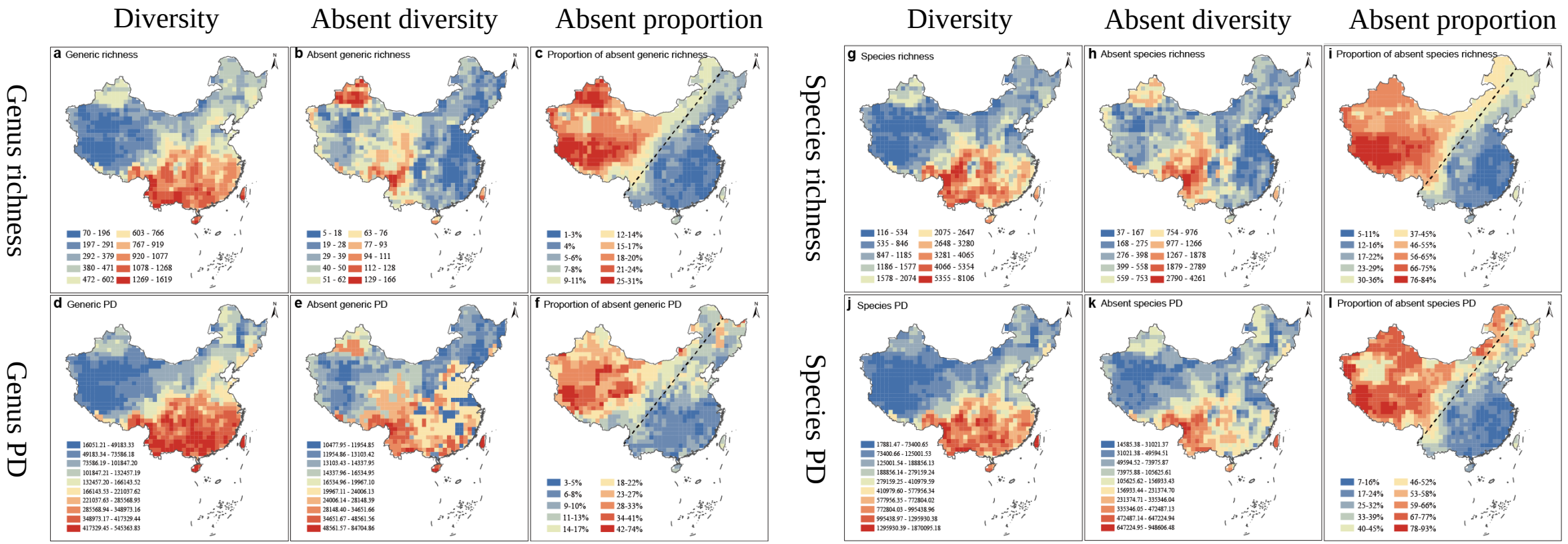


Garden-level results confirm low coverage of endemic and threatened species.

Results and Discussion

Geographic Gaps

National Scale



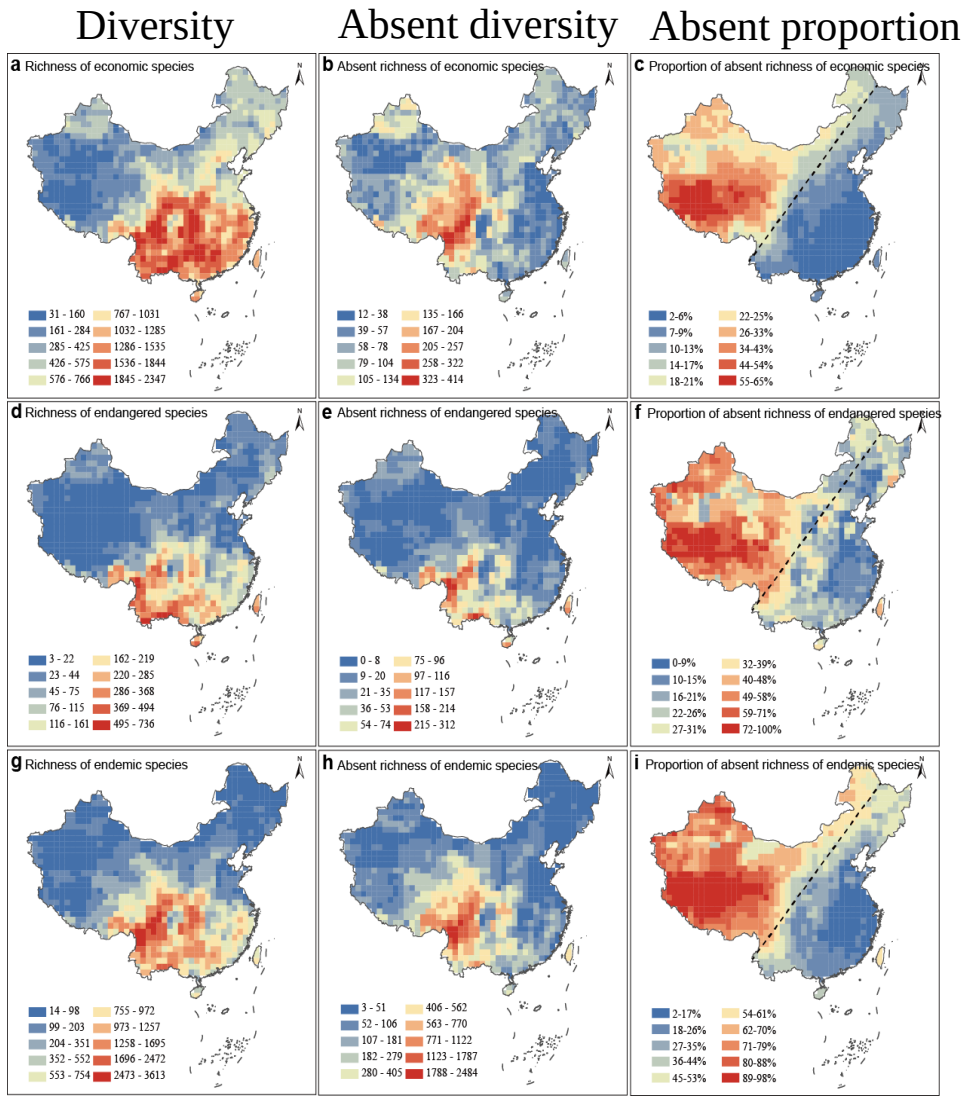
Diversity peaks in southern and southwestern China.

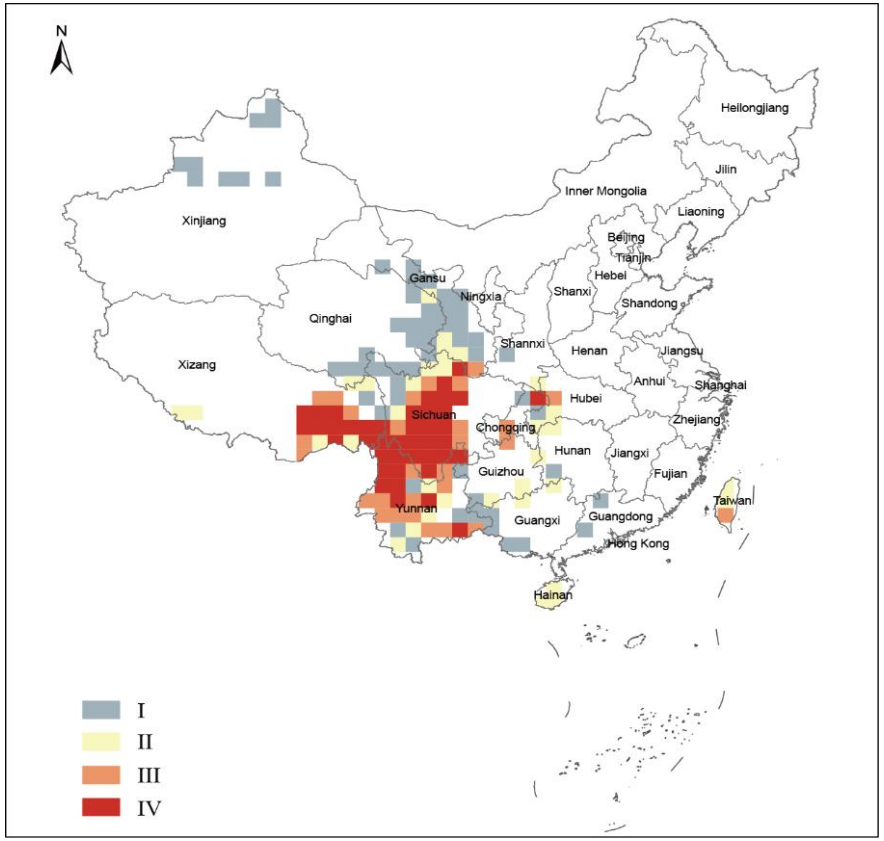
The southwest has most missing species; the northwest has high proportional and phylogenetic gaps.

Results and Discussion

Priority Collection Regions

National Scale





Eastern Himalaya-Hengduan Mountains;

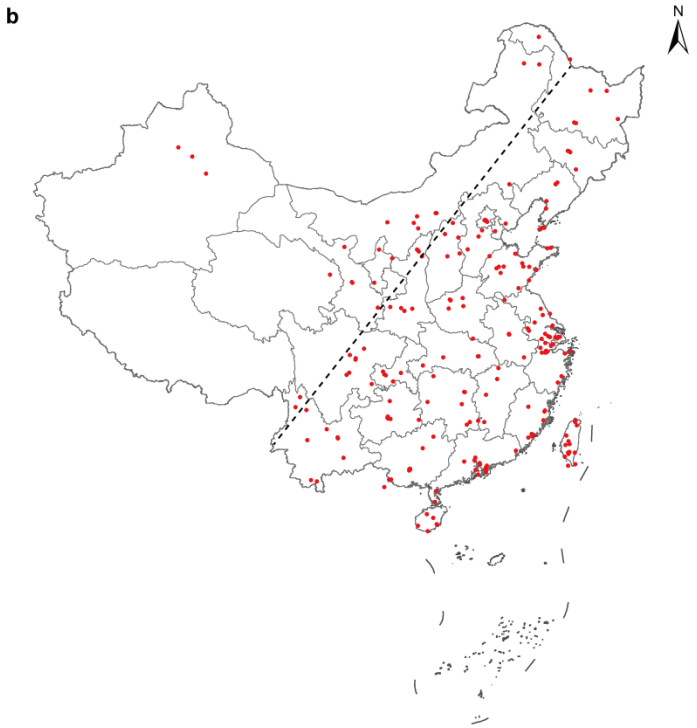
Yunnan-Guizhou-Guangxi;

Chongqing-western Hubei

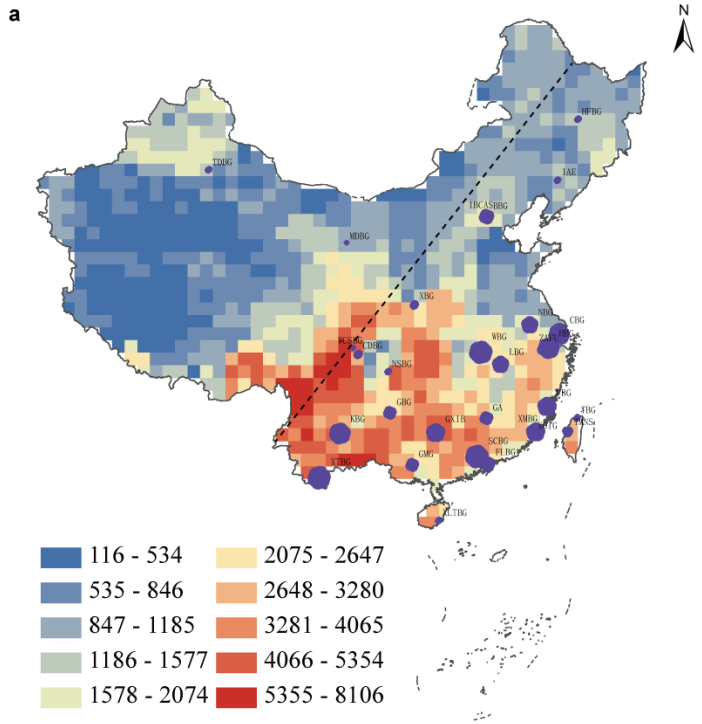
Results and Discussion

Garden Distribution

Garden Scale



Distribution of 229 botanical gardens in China



Species richness in 30 major botanical gardens

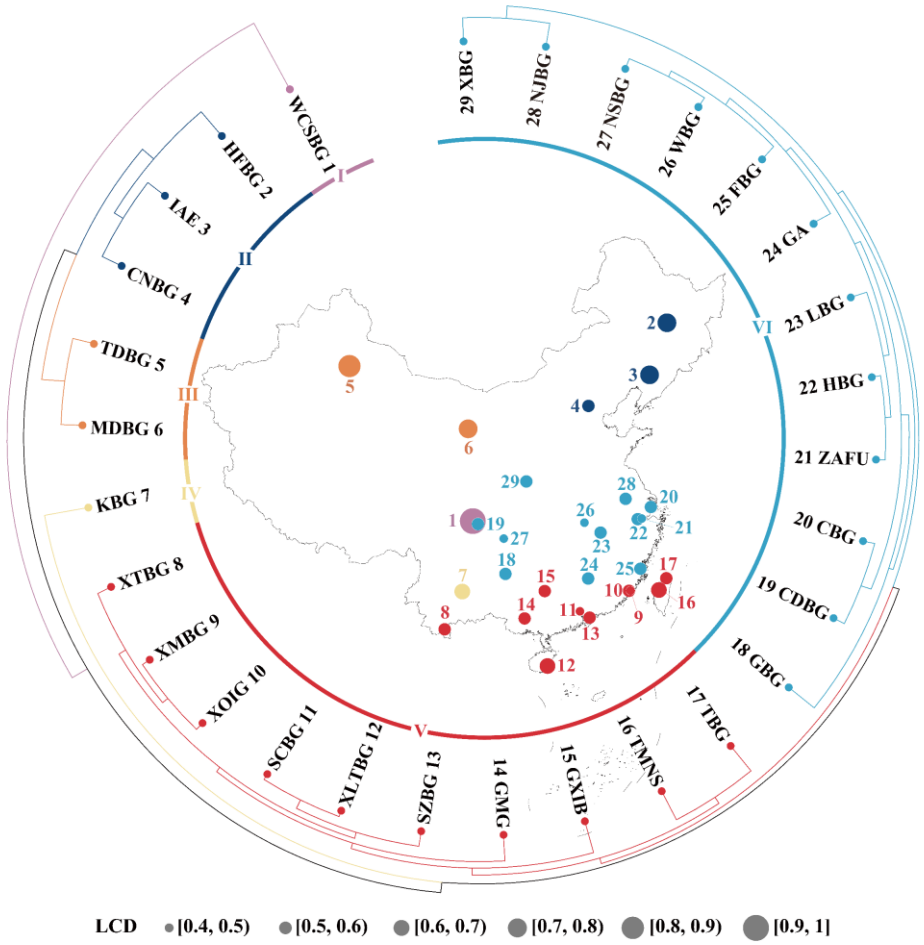
Major gardens are concentrated in eastern and southern China.

Garden distribution does not fully match conservation demand in the southwest and northwest.

Geography Shapes Living Collections

Garden Scale

Collection composition closely reflects geographic location.



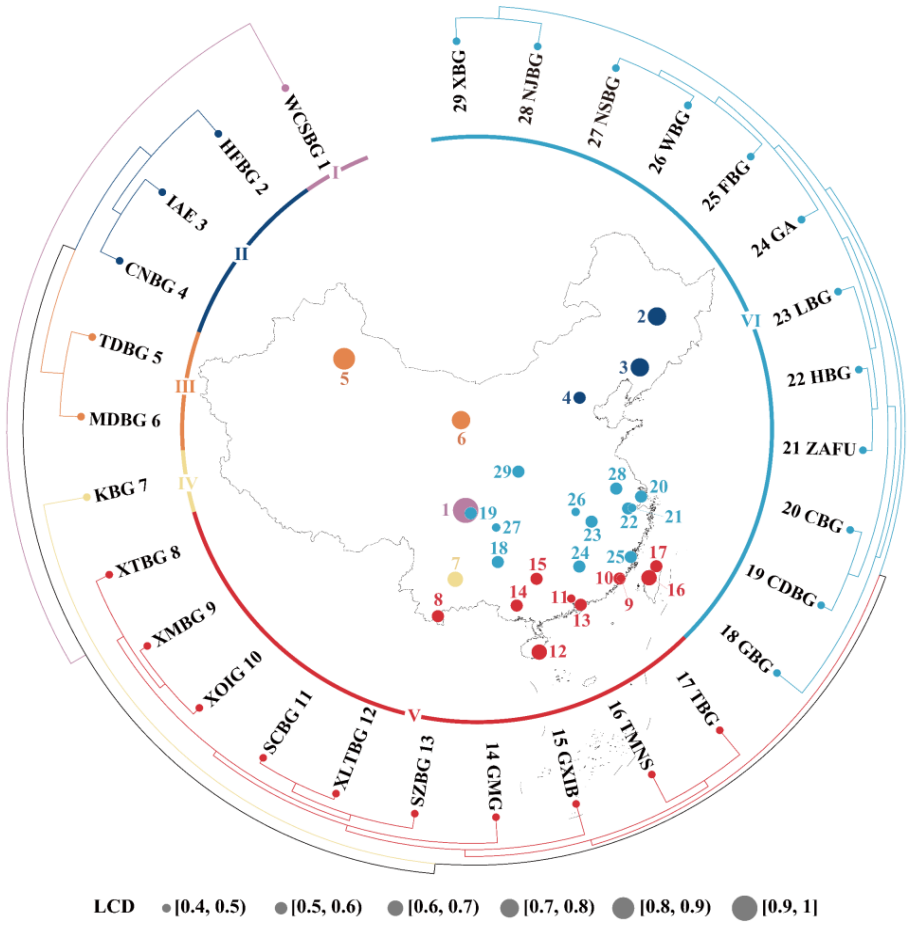
Cluster	Region	Collection focus
Group I	Hengduan Mountains	Rhododendron
Group II	Northeast China	Temperate taxa
Group III	Arid northwest	Drought/salt tolerance
Group IV	Yunnan-Guizhou	Plateau/Hengduan taxa
Group V	South/southwest	Tropical/subtropical taxa
Group VI	East/central China	Subtropical taxa

Results and Discussion

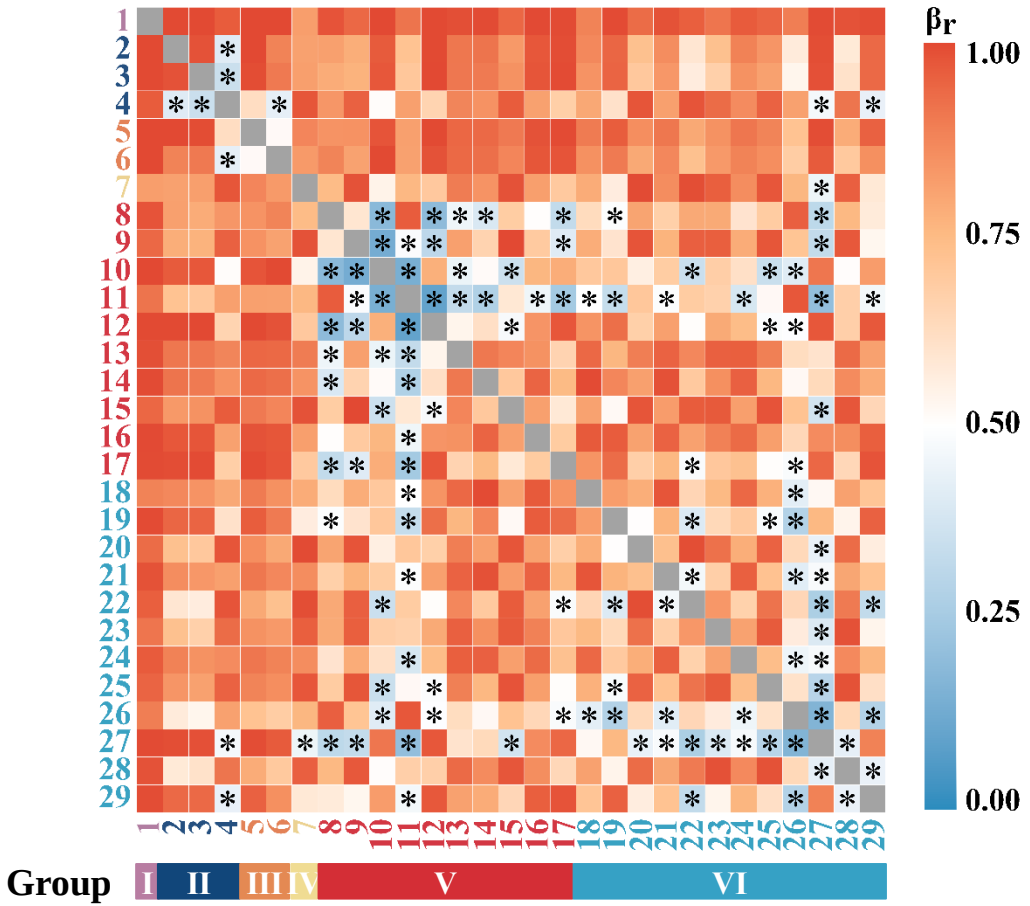
Network Complementarity

Garden Scale

29 botanical gardens → 6 groups



βr < 0.5 indicates similar species composition



Gardens form regional groups, but nested collections reduce the network's marginal gain.

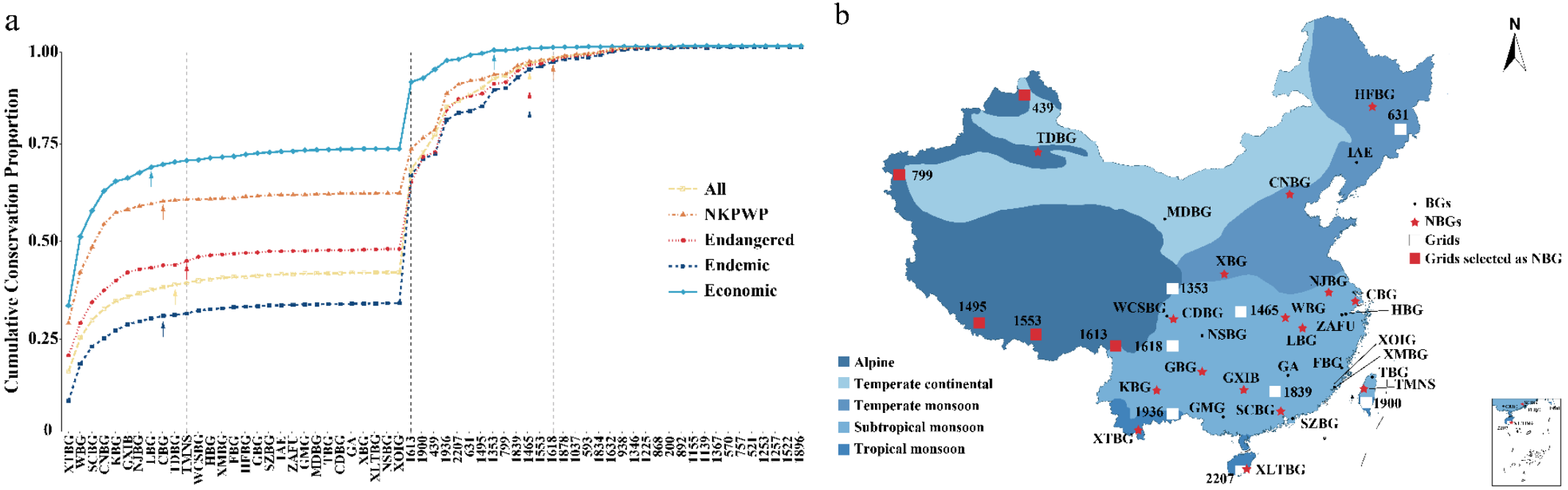
Results and Discussion

Optimized National Network

Proposed “16 + 5” network

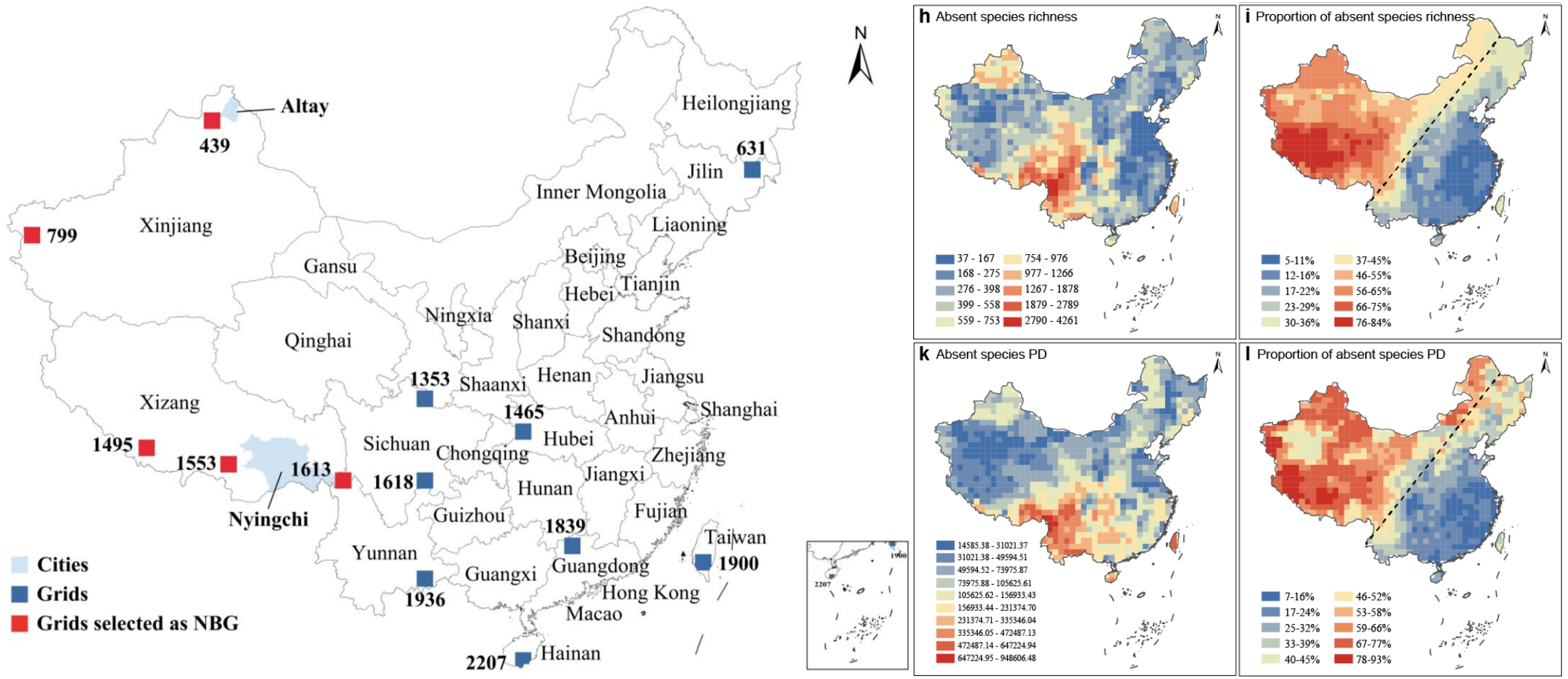
Retain 16 gardens: XTBG, WBG, SCBG, CNBG, KBG, GXIB, NJBG, LBG, CBG, TDBG, TMNS, XLTBG, HFBG, XBG, CDBG, and GBG

Add five priority grids: 1613, 439, 1495, 799, and 1553



Results and Discussion

Priority Grids Fill Major Gaps



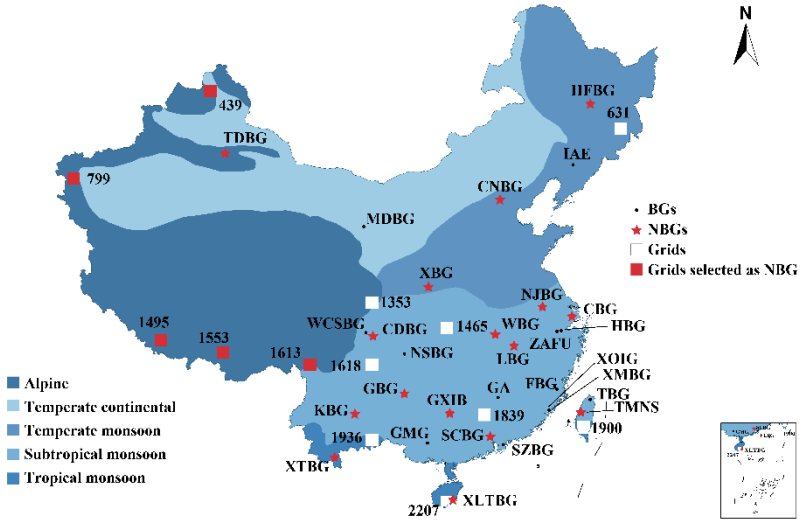
The five priority grids coincide with the strongest concentrations of species missing from *ex situ* collections.

Results and Discussion

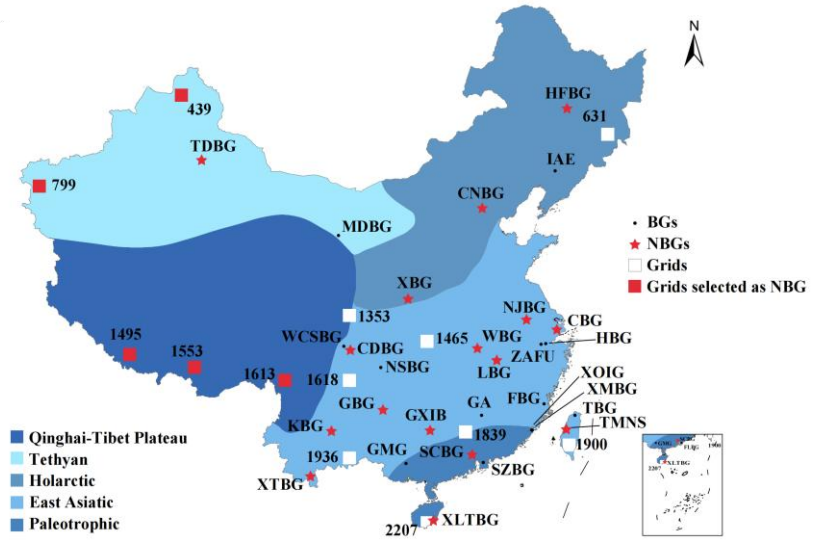
Network Coverage Gains

Potential coverage: 73.2% of China's native vascular plant species

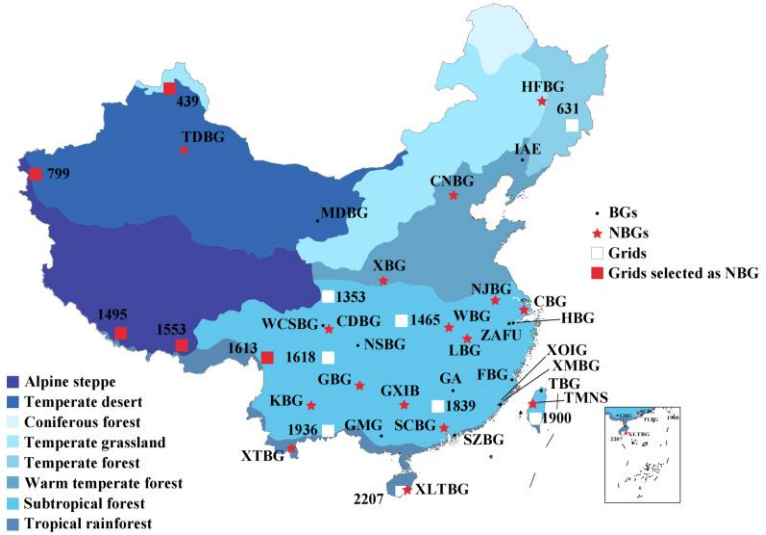
Representation: four major climate zones, all floristic regions, and six vegetation types



Climate zones



Floristic regions



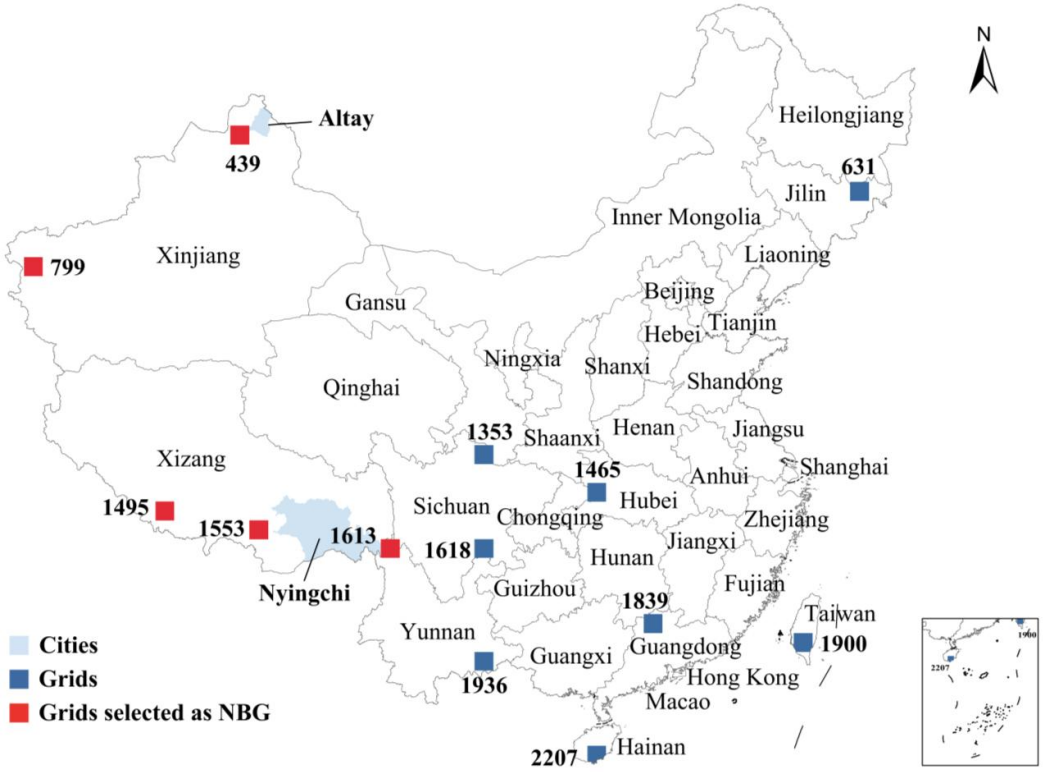
Vegetation types

Results and Discussion A Practical “16 + 1” Strategy

“16 + 5” → “16 + 1”

Nyingchi National Botanical Garden:

A strategic hub for southeastern Tibet, serving the three priority grids (1495, 1553, 1613).





Meconopsis horridula



Primula ninguida



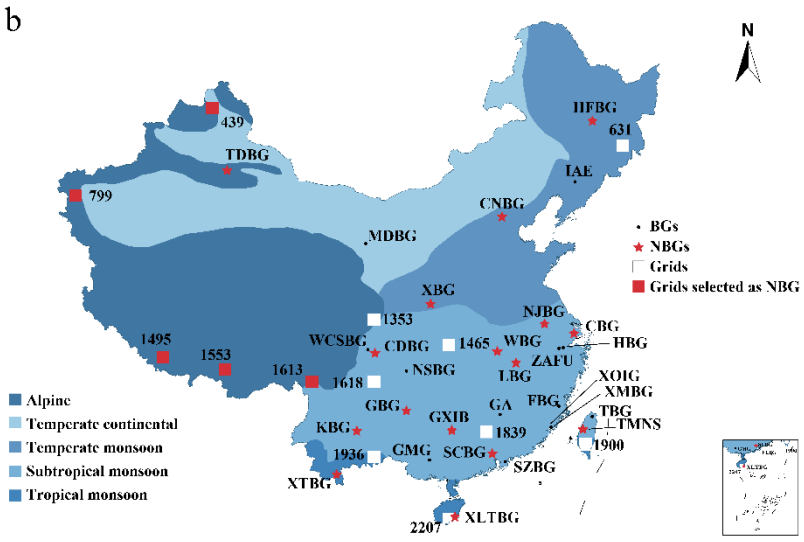
Rhododendron chamaethomsonii

Results and Discussion

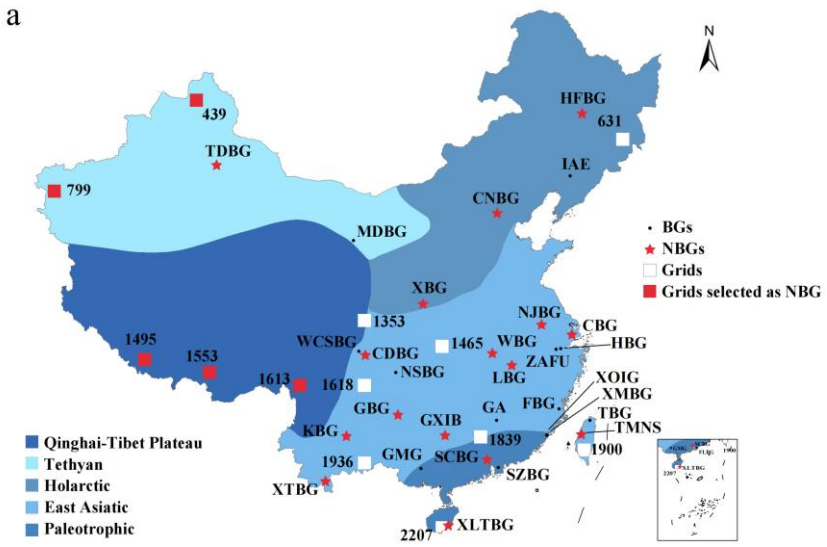
A Practical “16 + 1” Strategy

“16 + 5” → “16 + 1”

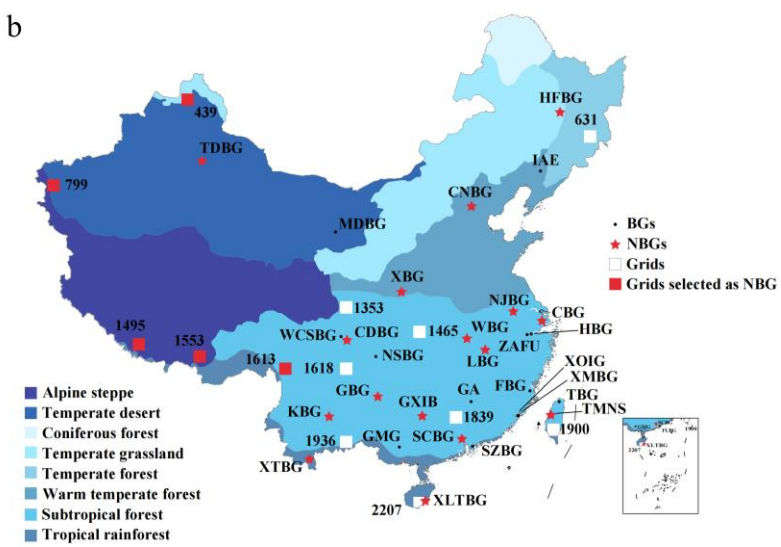
Turpan Desert Botanical Garden can extend its remit to grids 439 and 799, which share similar climate, flora, and vegetation.



Climate zones



Floristic regions



Vegetation types

Conclusions

1. Conservation coverage remains uneven

- About 42% of native vascular plant species and 47% of phylogenetic diversity are represented.
- Threatened, endemic, herbaceous, and range-restricted plants remain underrepresented.
- Major gaps occur in southwestern and northwestern china.

2. Existing botanical gardens form a regional but partly redundant network

- Botanical gardens differ greatly in species richness and local floristic coverage.
- Strong nestedness was detected among several botanical gardens in eastern and southern china.

3. Complementarity can substantially expand national coverage

- 16 core gardens + 5 priority regions.
- Potential coverage increased to 73.2%.

Outlook

1. Close remaining conservation gaps

- Target underrepresented taxa and priority regions, particularly in southwestern and northwestern China.

2. Strengthen coordination among gardens

- Define complementary regional and taxonomic roles, share accession data, and coordinate strategic backup collections.

3. Implement and refine the proposed network

- Evaluate the feasibility, costs, and institutional capacity of the 16+5 framework, followed by pilot implementation and periodic reassessment.

Thank you

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