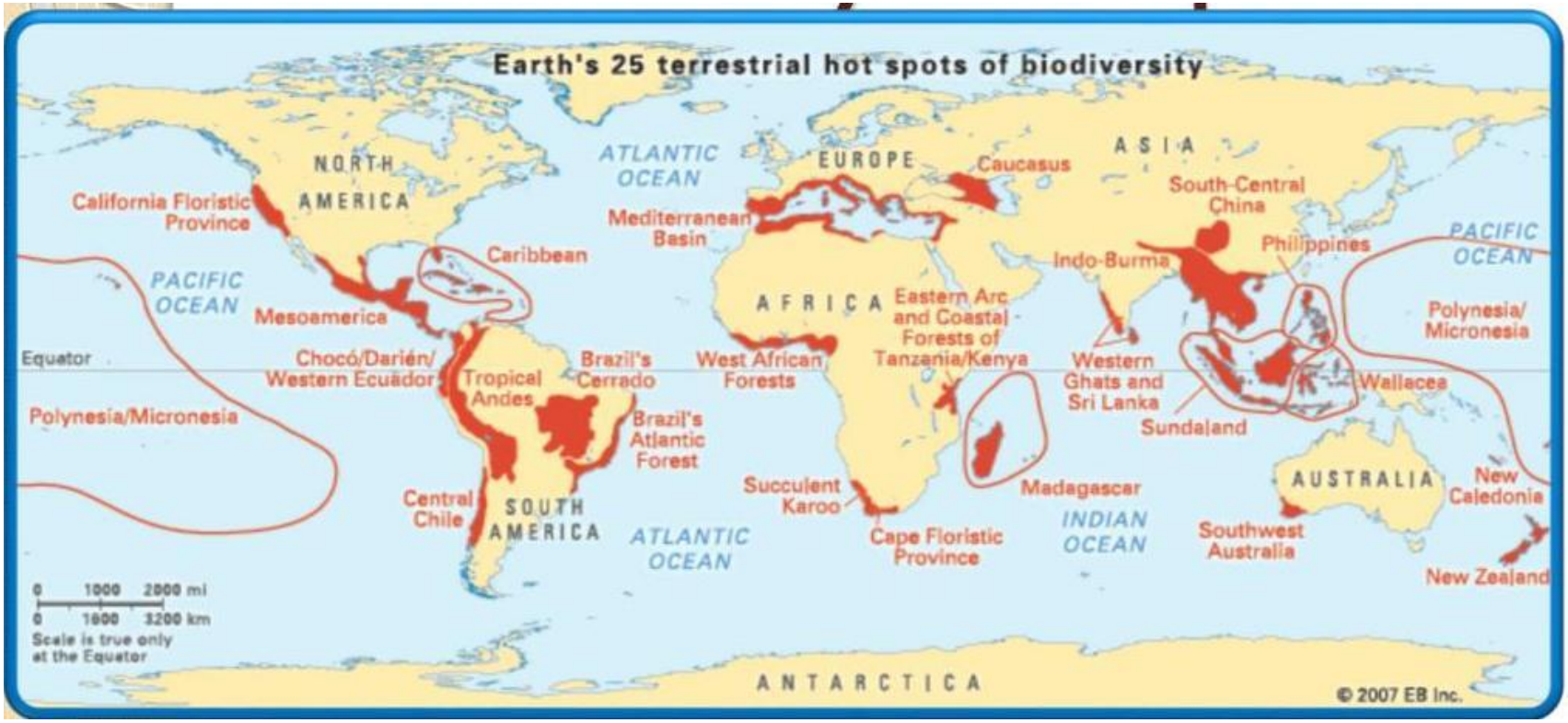
Mapping patterns of species richness and endemism to understand evolution of particular groups

Sergei Volis

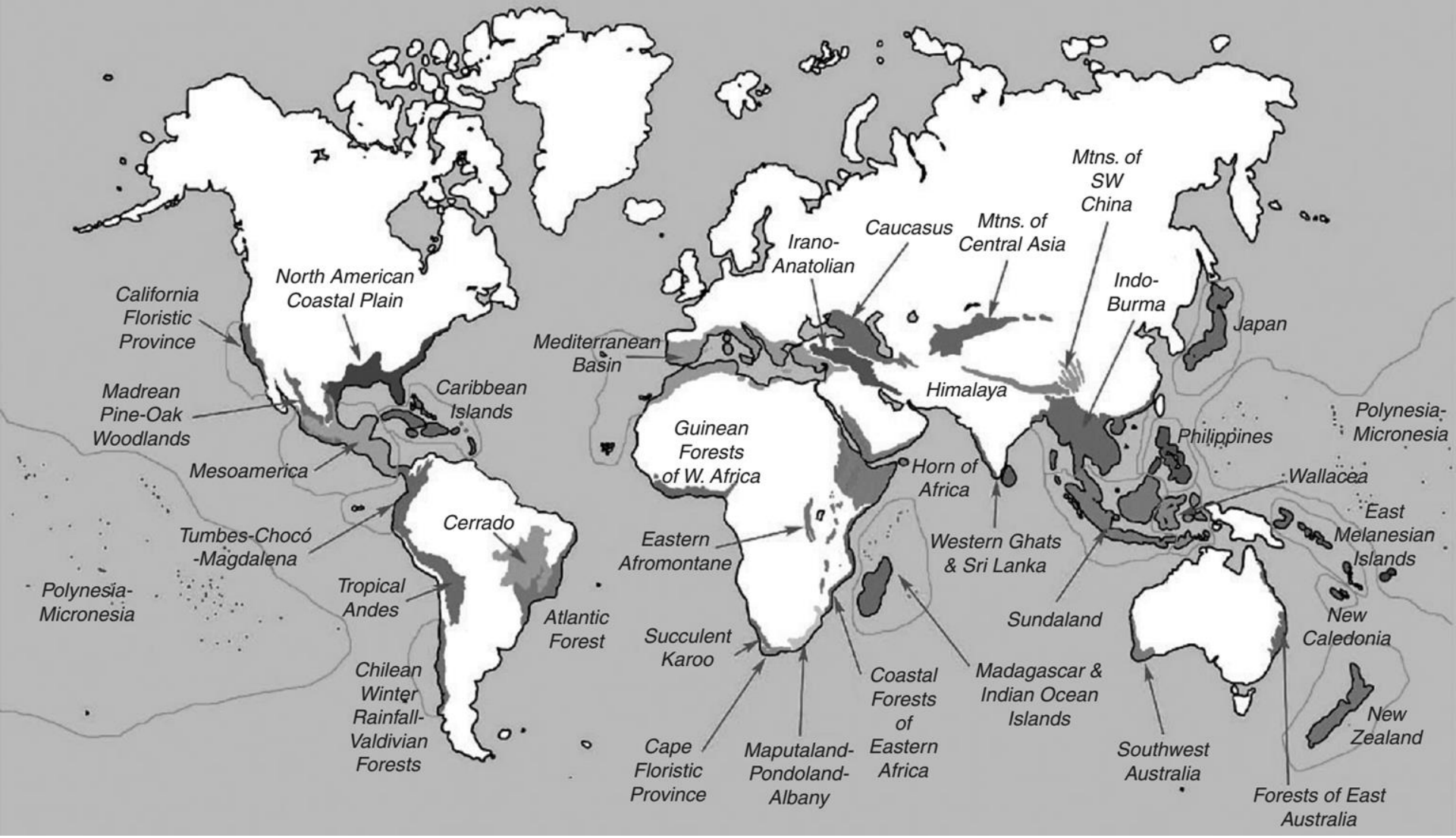
Why patterns of species richness and endemism are important?

- for conservation concerns

narrow endemics are usually rare and therefore potentially threatened

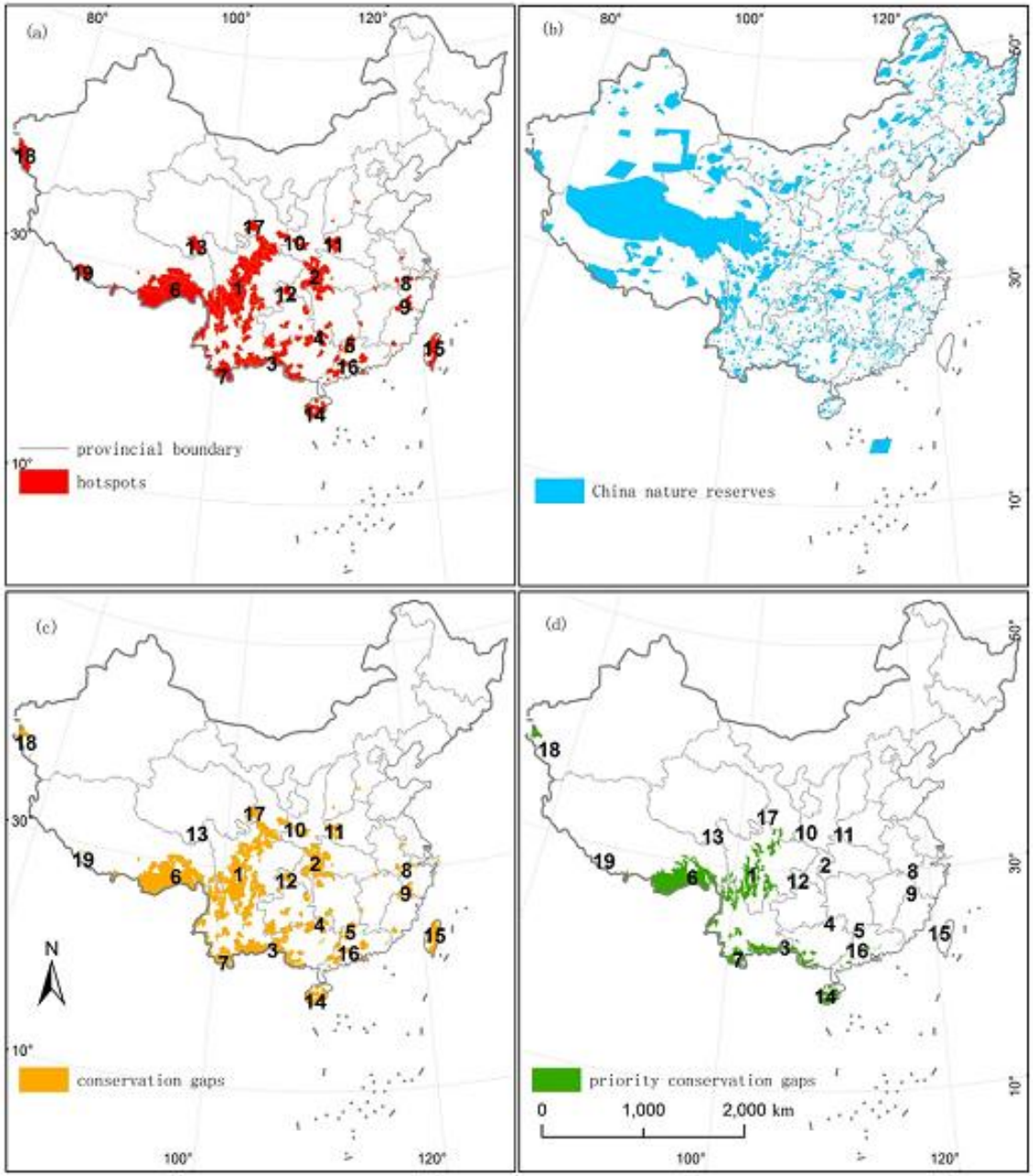


Myers et al. *Nature* 2000

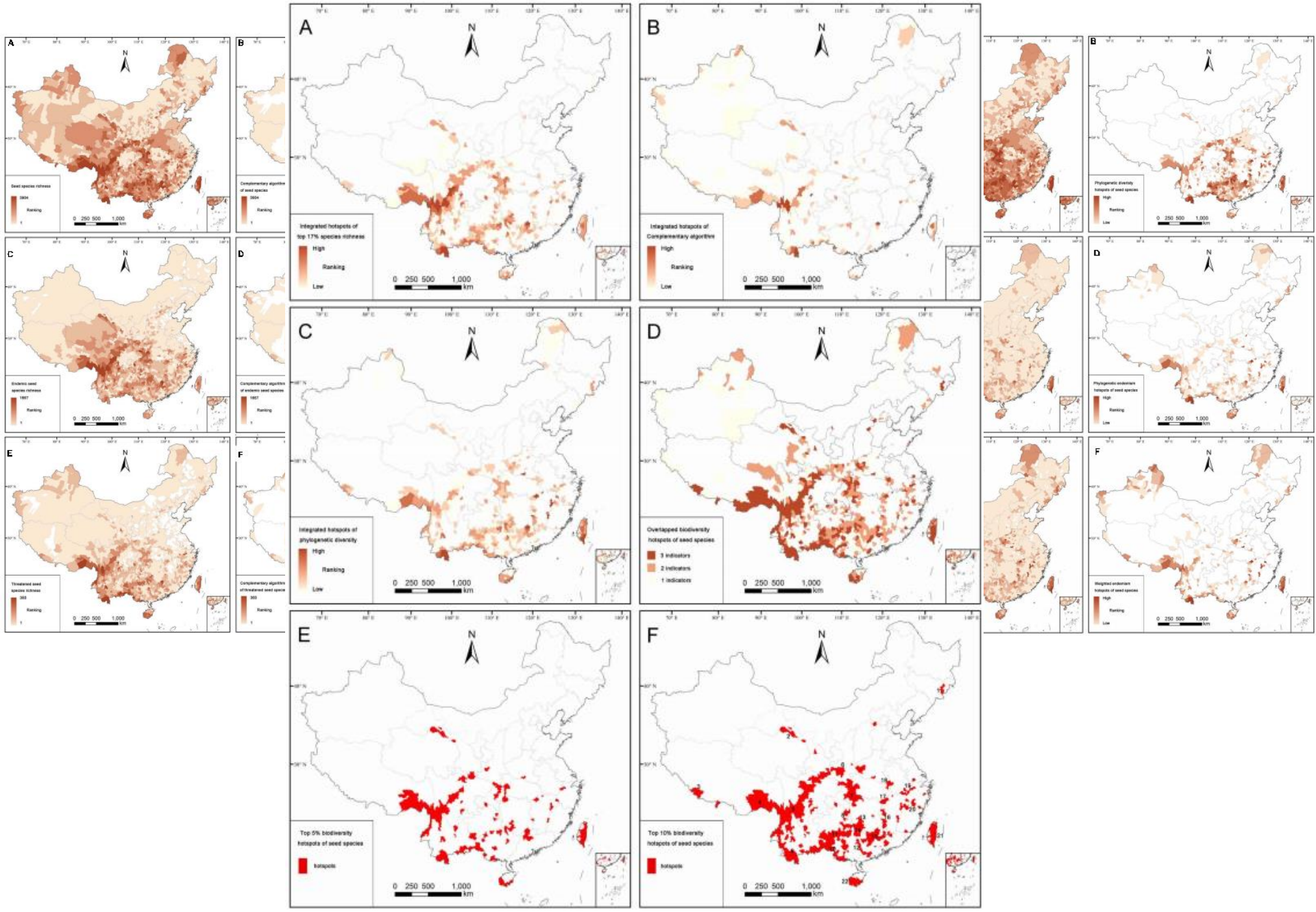


Currently recognized global hotspots of plant endemism, which are defined as having >1500 endemic plant species

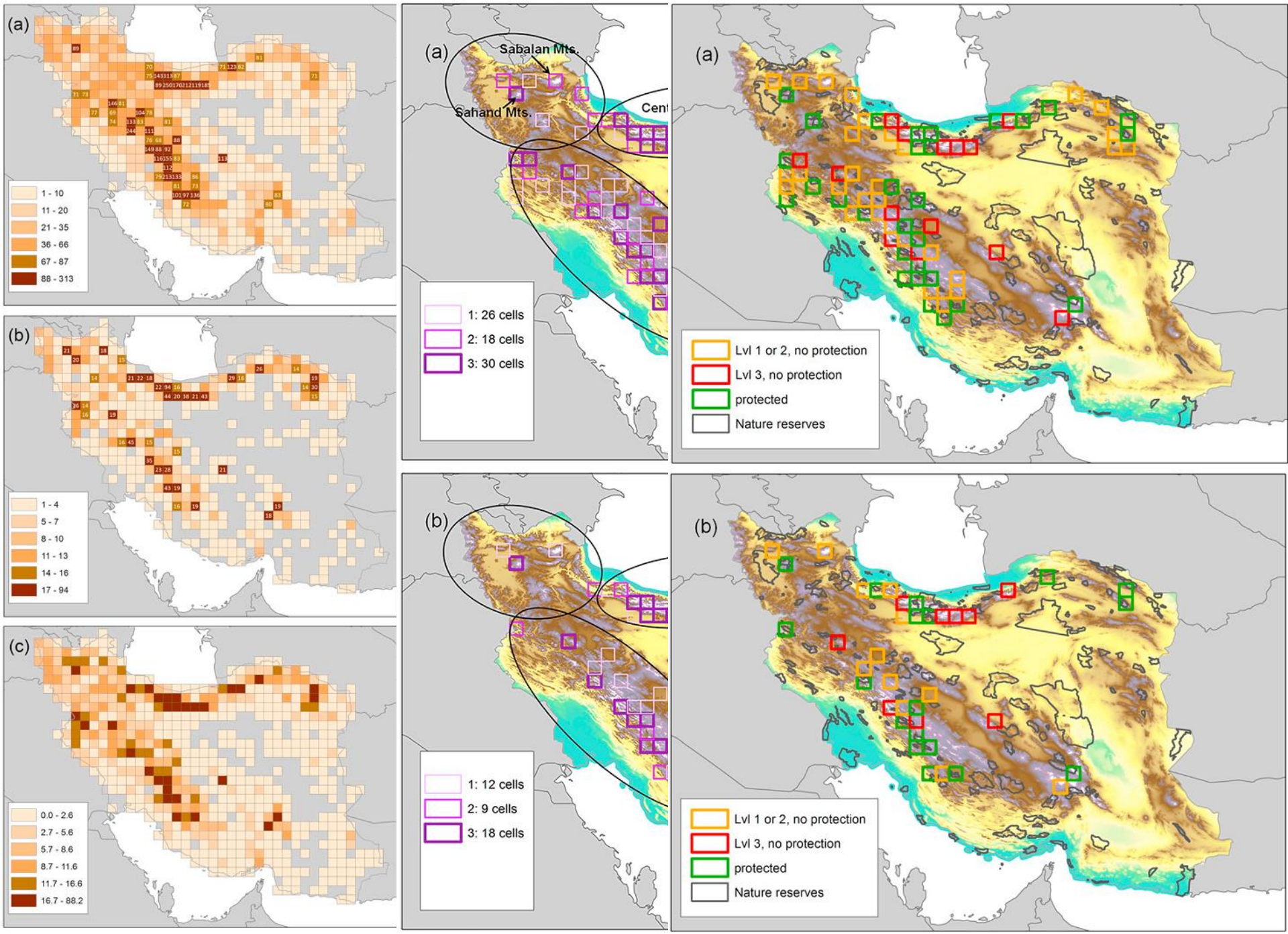
Harrison & Noss 2017



Huang et al. *Biol. Cons.* 2016

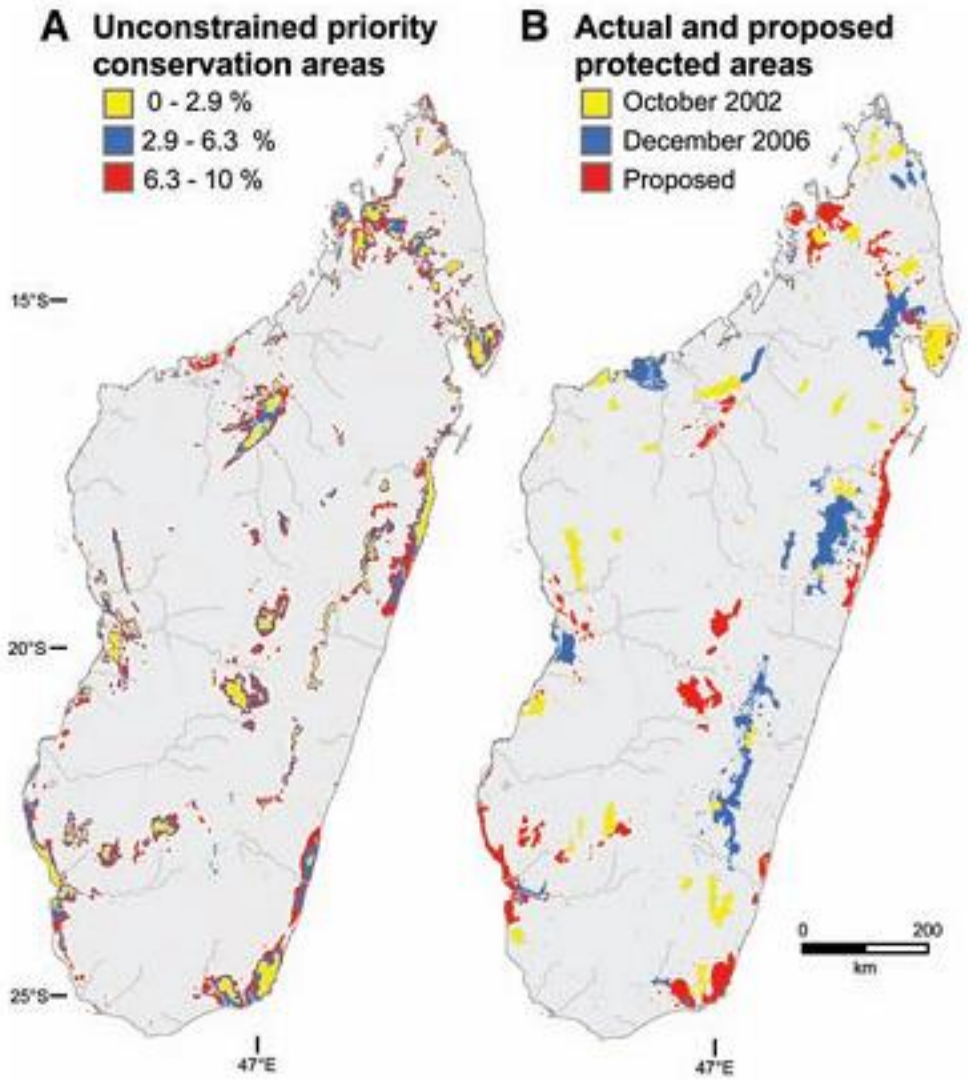


Huang et al. *Front. Pl Sc.* 2022



Noroozi et al. Biol. Cons. 2019

Conservation priority zones in Madagascar



Kremen et al. *Science* 2008

Why patterns of species richness and endemism are important?

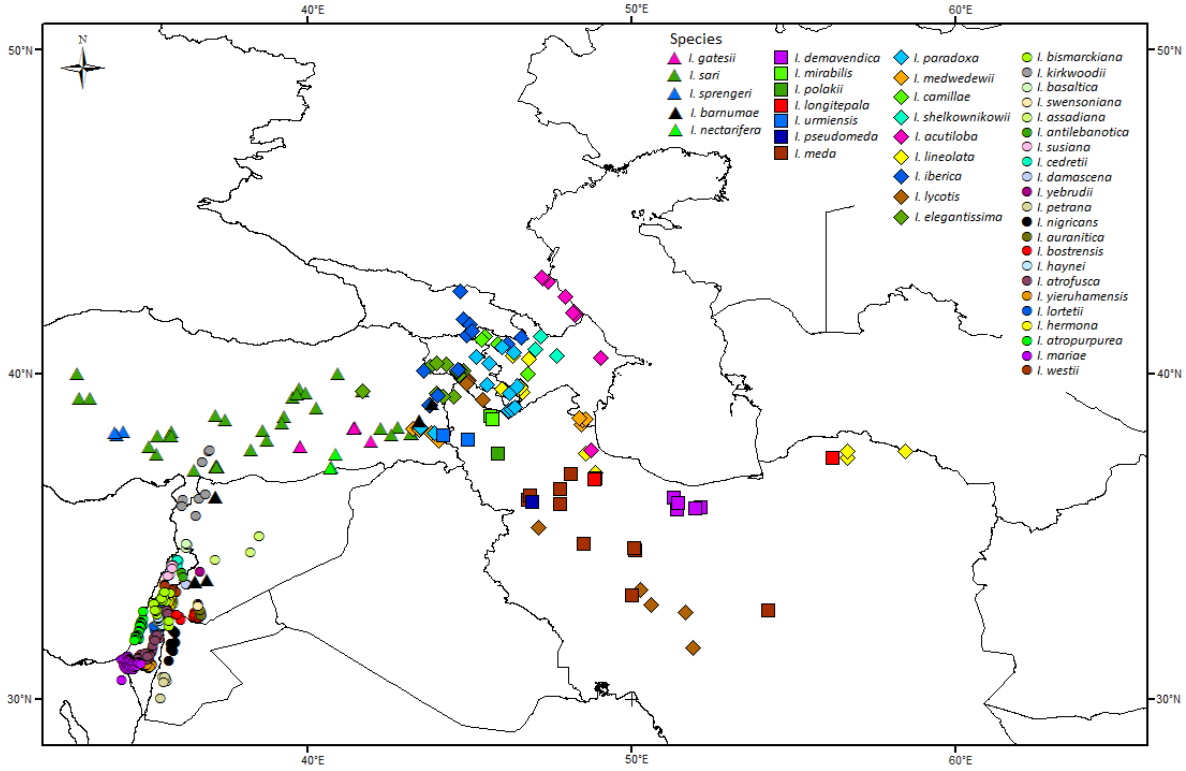
- for understanding groups' evolution

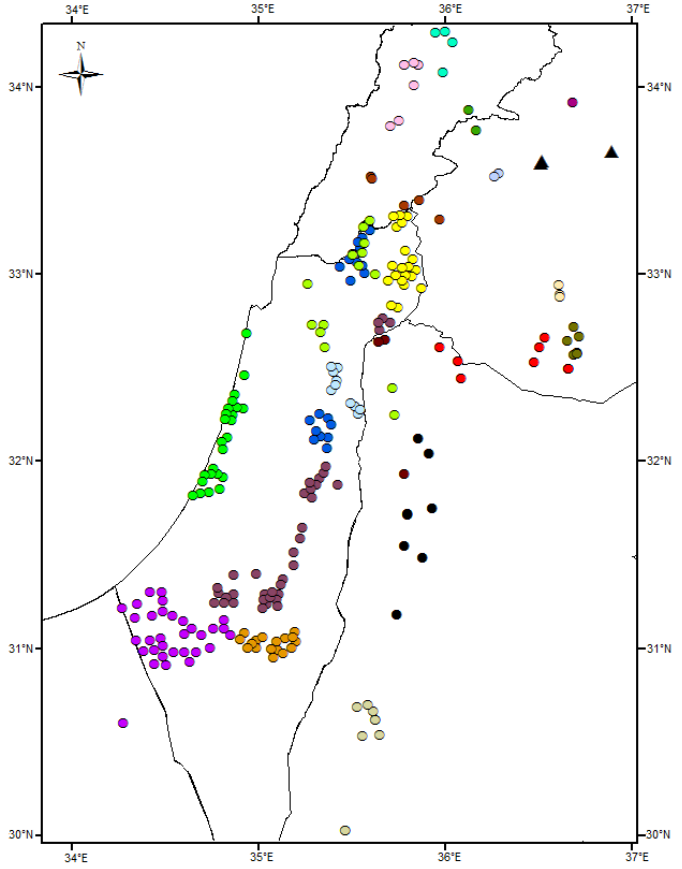
Centers of species richness and endemism can help to identify the areas of origin, intensive speciation or refugia

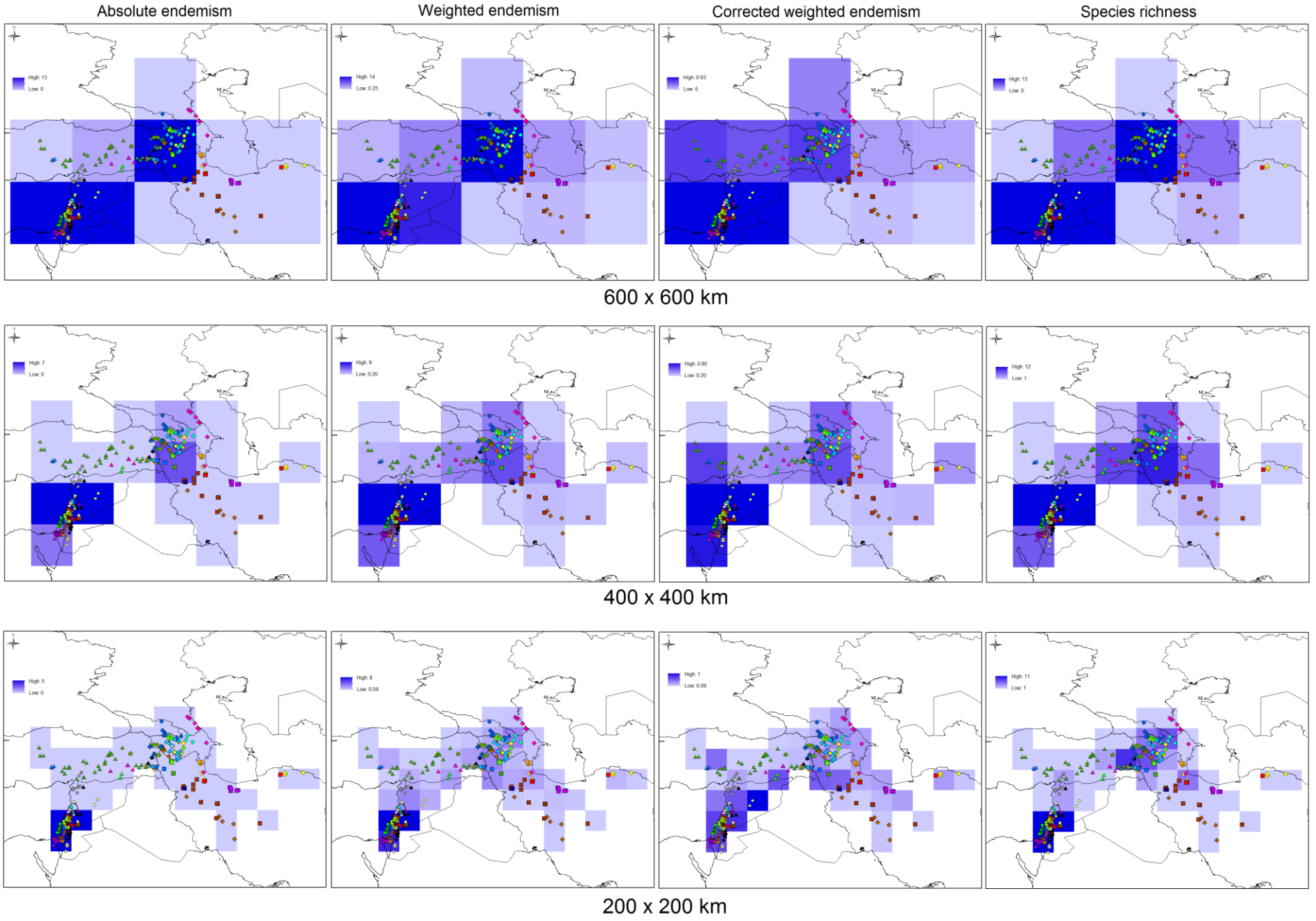
Metrics

- Species Richness (SR), defined as the number of species present in each grid cell,
- Absolute endemism (number of species endemic to a cell),
- Weighted Endemism (WE; Crisp *et al.*, 2001), defined as a species richness inversely weighted by species ranges,
- Corrected Weighted Endemism (CWE; Crisp *et al.*, 2001) which is WE divided by the total species count in a grid cell to partially account for high species richness
- Phylogenetic Diversity (PD; Faith, 1992) is the sum of branch lengths connecting the root of the phylogenetic tree to all species within each grid cell
- Phylogenetic endemism (PE; Rosauer *et al.*, 2009) measures the degree to which branches found in a grid cell are restricted to this location

Iris sect. *Oncocyclus* - 47 species


Species
I. gatesii
I. sari
I. sprengeri
I. barnumae
I. nectarifera
I. demavendica
I. mirabilis
I. polakii
I. longitepala
I. urmiensis
I. pseudomeda
I. meda
I. paradoxa
I. medwedewii
I. camillae
I. shelkownikowii
I. acutiloba
I. lineolata
I. iberica
I. lycotis
I. elegantissima
I. bismarckiana
I. kirkwoodii
I. basaltica
I. swensoniana
I. assadiana
I. antilebanotica
I. susiana
I. cedretii
I. damascena
I. yebrudii
I. petrana
I. nigricans
I. auranitica
I. bostrensis
I. haynei
I. atrofusca
I. yieruhamensis
I. lortetii
I. hermona
I. atropurpurea
I. mariae
I. westii
N
40°E
50°E
60°E
50°N
40°N
30°N

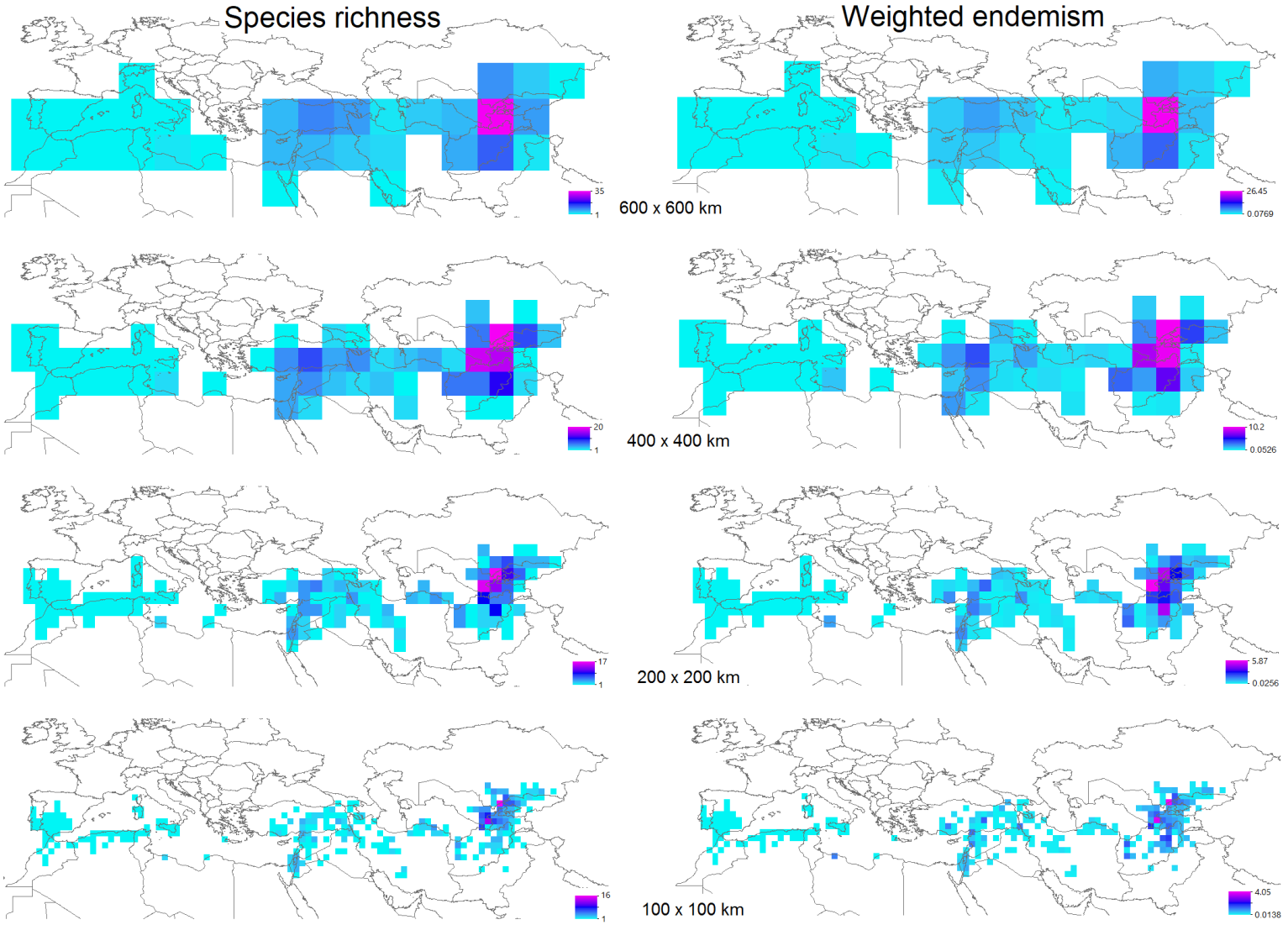

N
34°E
35°E
36°E
37°E
34°N
33°N
32°N
31°N
30°N


Absolute endemism
Weighted endemism
Corrected weighted endemism
Species richness
High: 13
Low: 0
High: 14
Low: 0.25
High: 0.93
Low: 0
High: 15
Low: 0
600 x 600 km
High: 7
Low: 0
High: 9
Low: 0.20
High: 0.80
Low: 0.20
High: 12
Low: 1
400 x 400 km
High: 5
Low: 0
High: 8
Low: 0.09
High: 1
Low: 0.09
High: 11
Low: 1
200 x 200 km

Results

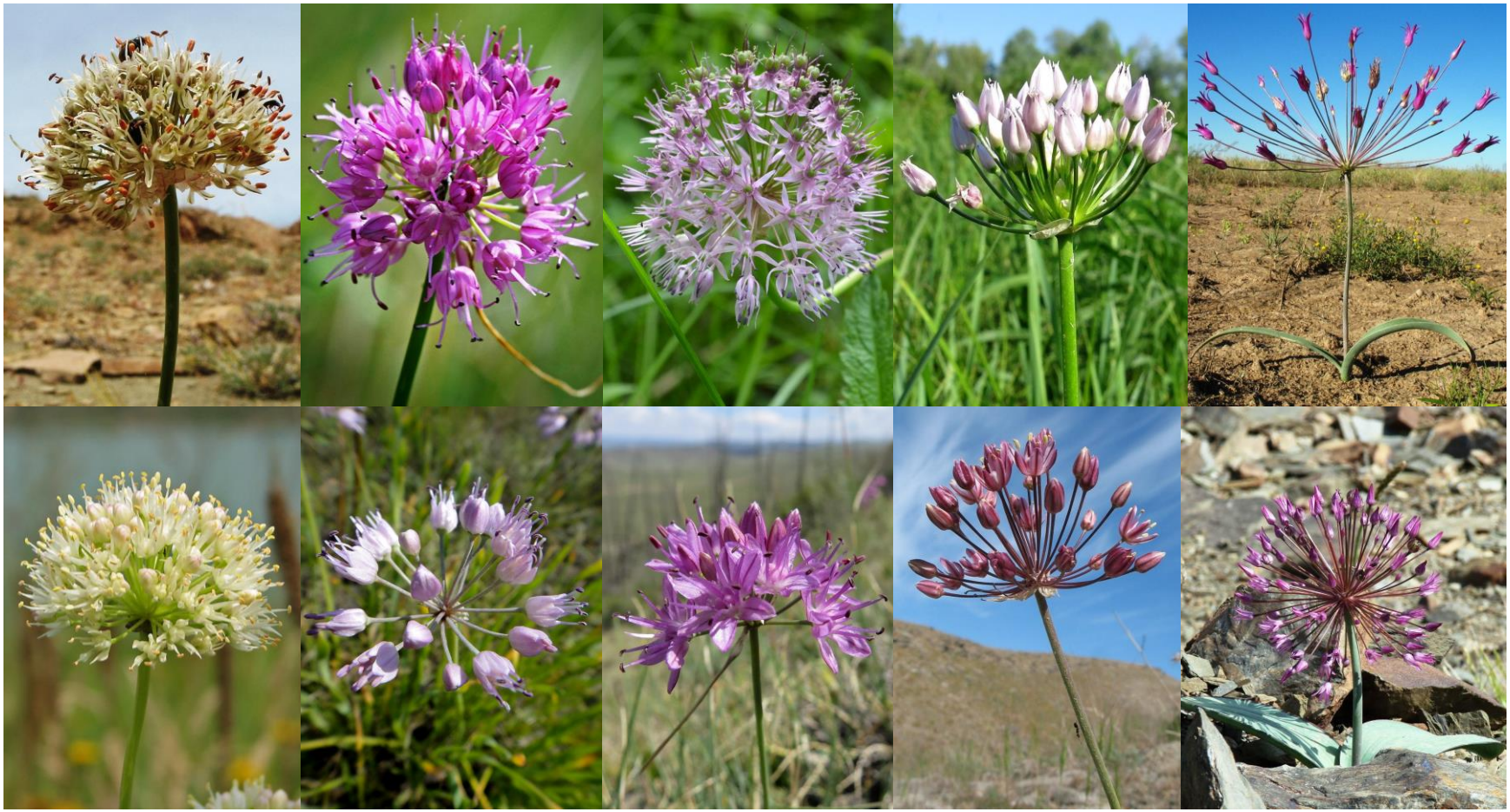
- The highest species richness in Levant and Transcaucasia
- The highest endemism under resolution of 200 × 200 km in Levant, and under resolution of 400 × 400 and 600 × 600 km in Levant, the Caucasus, northeastern Turkey and northwestern Iran
- Together with the results of phylogenetic and biogeographic analyses these results helped to reconstruct evolution of the group

Iris sect. *Scorpiris* - 74 species

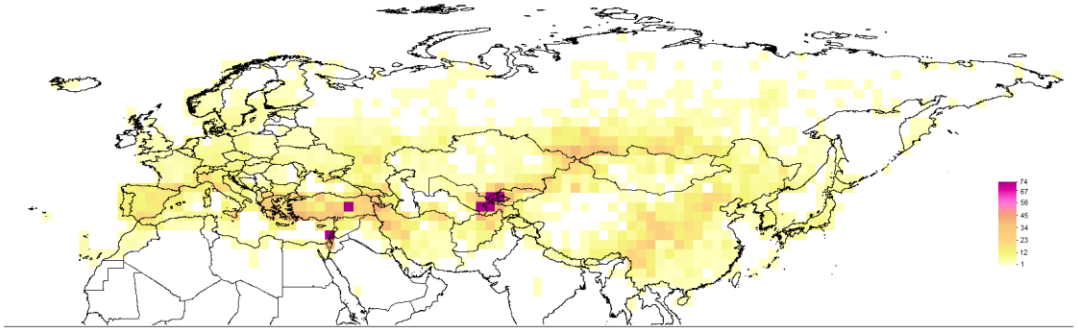


- A major center of species richness and endemism in Central Asia/Afghanistan, a secondary one in Turkey/Levant, and a third one in the Caucasus/western Iran
- The highest by far species richness and endemism are in the mountainous area embracing Tien Shan, Pamir-Alay and Hindu Kush chains.

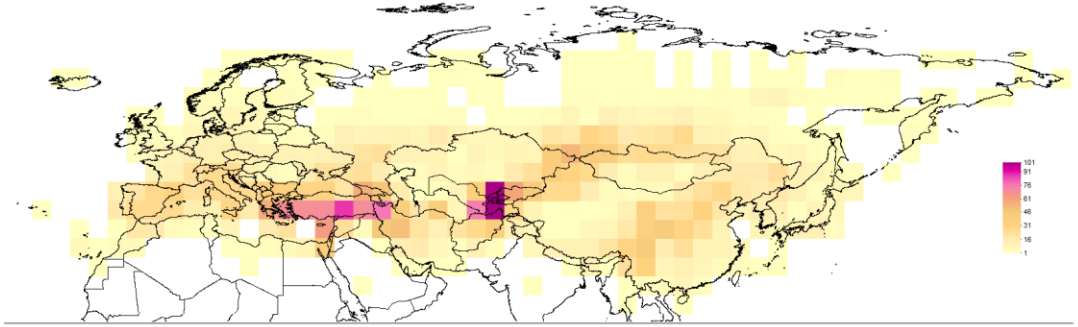
Allium - 901 species



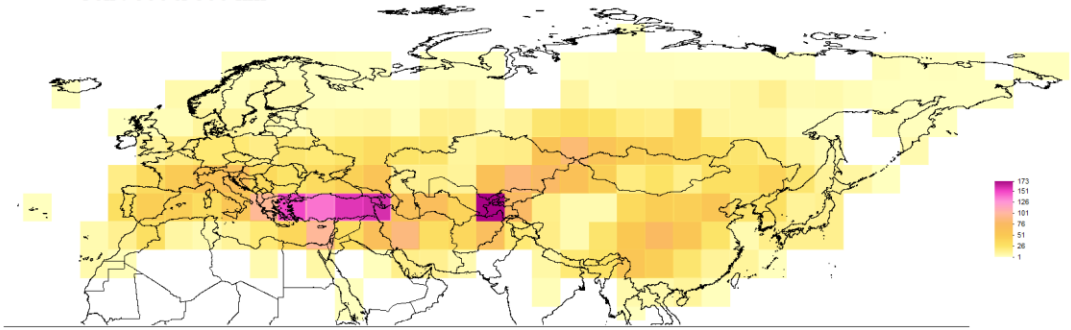
Cell: 200 x 200 km



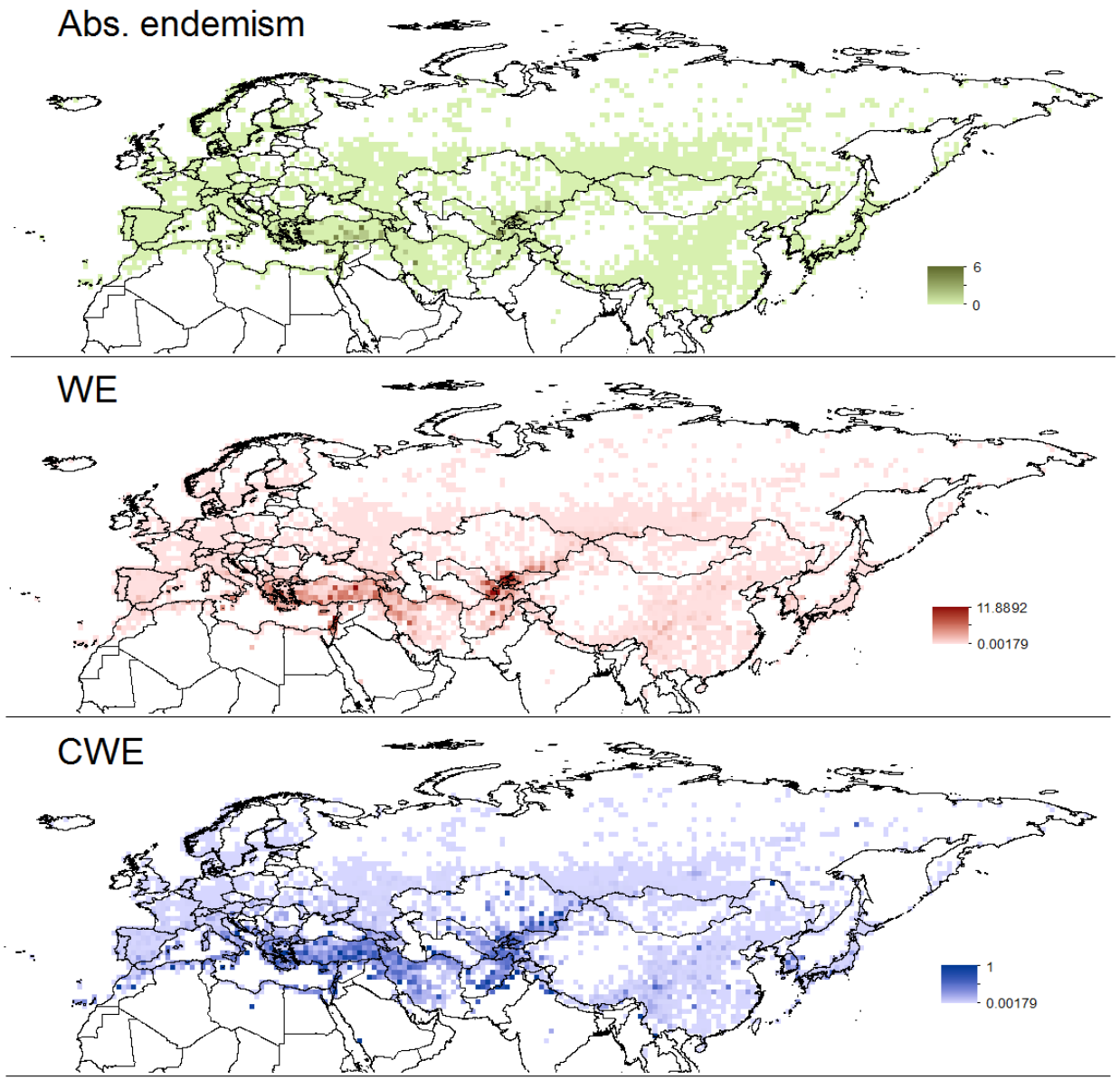
Cell: 400 x 400 km



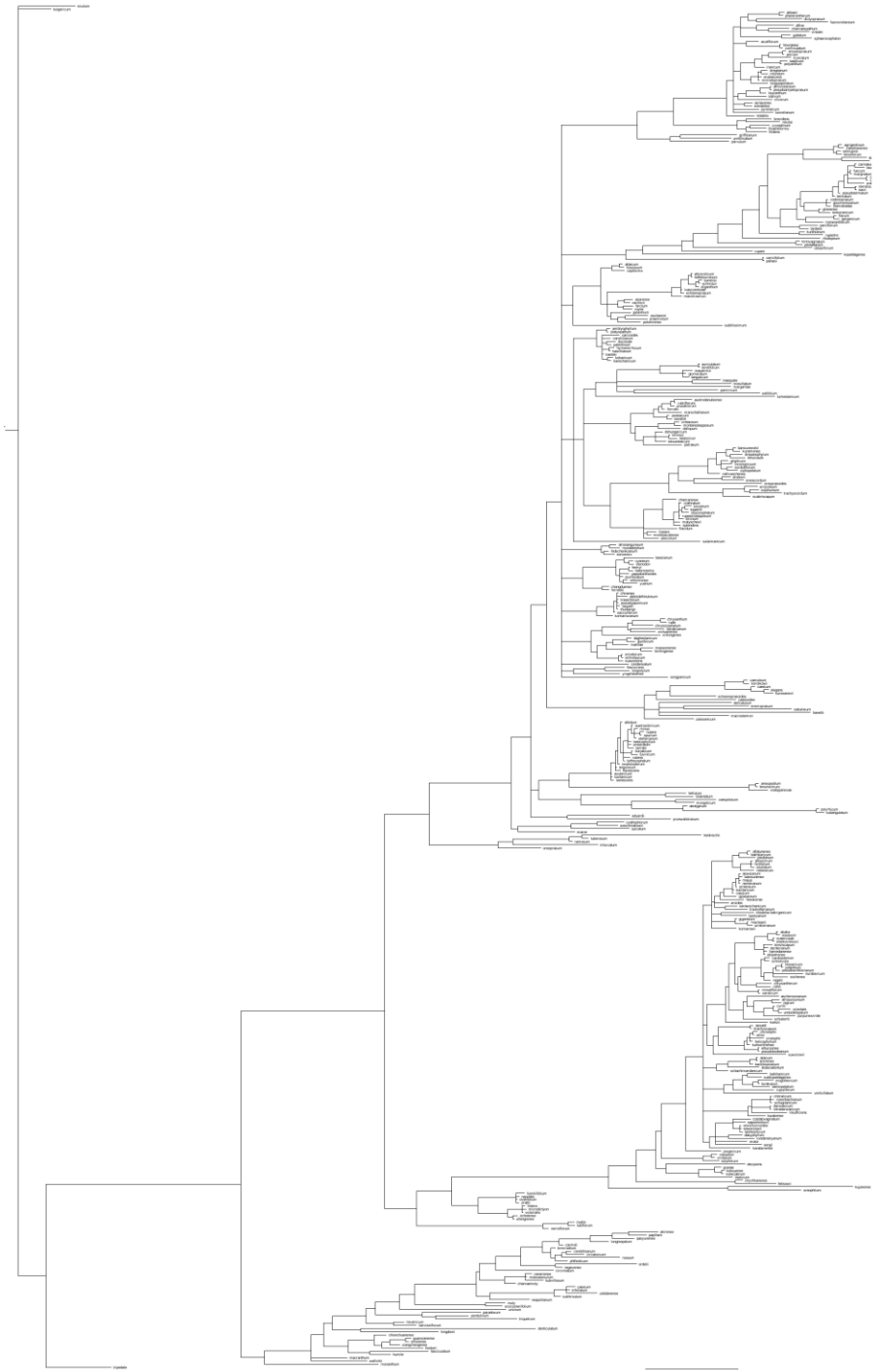
Cell : 600 x 600 km

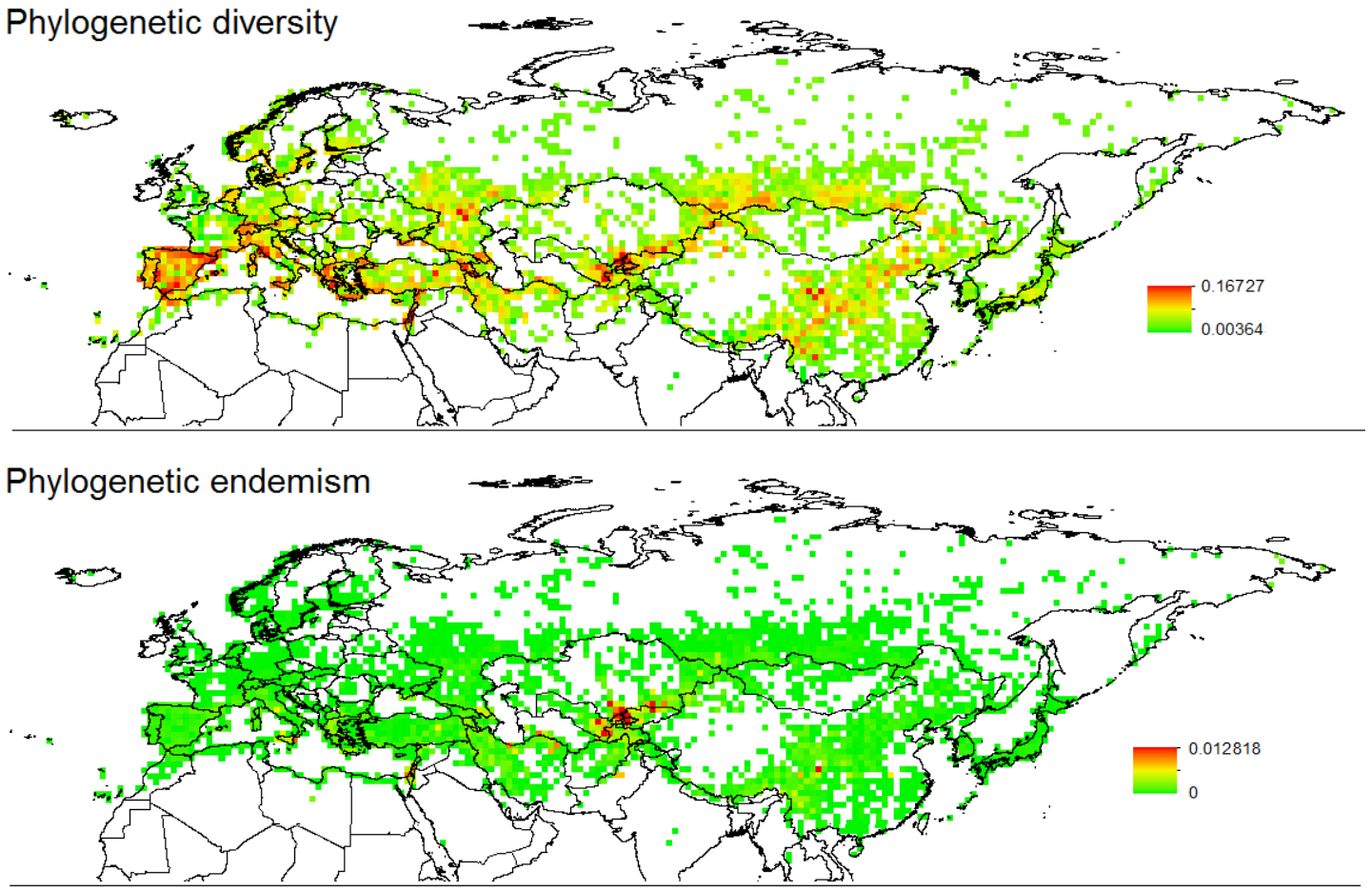


The areas of exceptional species richness are Tian Shan and Pamiro-Alay mountains of Central Asia and Transcaucasia, including eastern Turkey and north-western Iran, Levant, central and western Turkey, and Greece



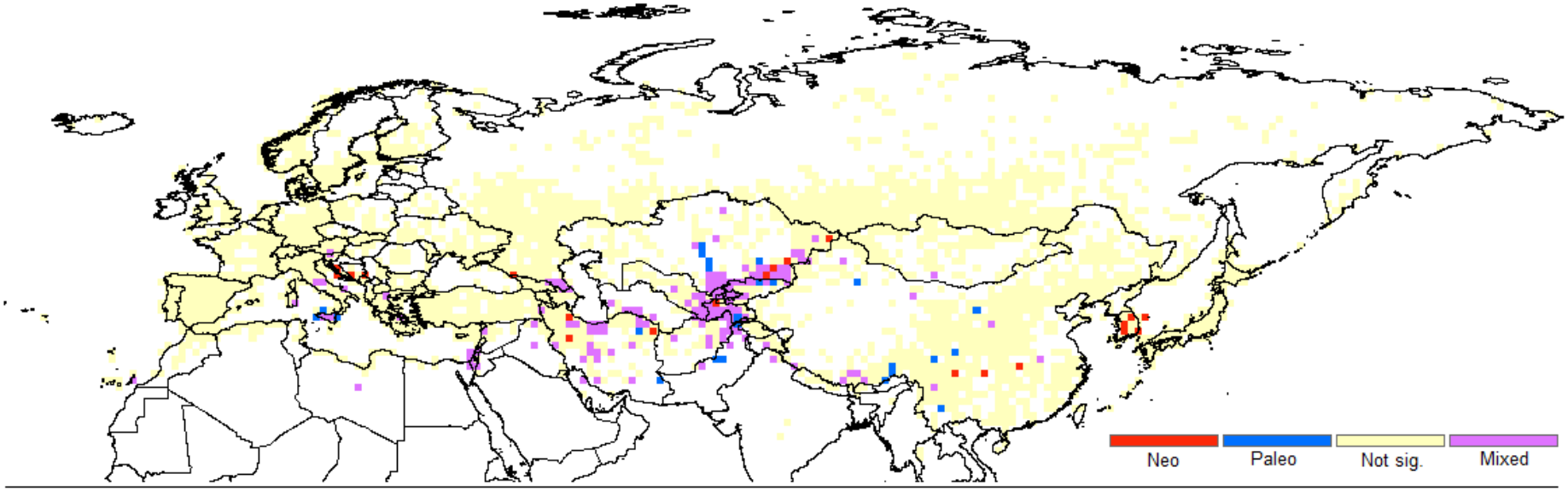
Locations harbouring many endemic *Allium* species are mainly in Turkey, Greece, Levant, western Iran and an area embracing northern Afghanistan and mountainous Central Asia


0.09



Phylogenetic diversity (PD) is high in European Mediterranean, Turkey, Levant, the Crimea, the Caucasus and the area of Russia north of it, Central Asia, southern Siberia and China

High phylogenetic endemism (PE) was restricted almost exclusively to Central Asia, with a few points scattered in Iran, Pakistan, Turkey, Israel and China



The centres of paleo-endemism, i.e. areas with an over-representation of long branches, are scattered across a belt stretching from Italy to Korea; particularly rich in the grid cells dominated by paleo-endemism are Sicily and Kazakhstan.

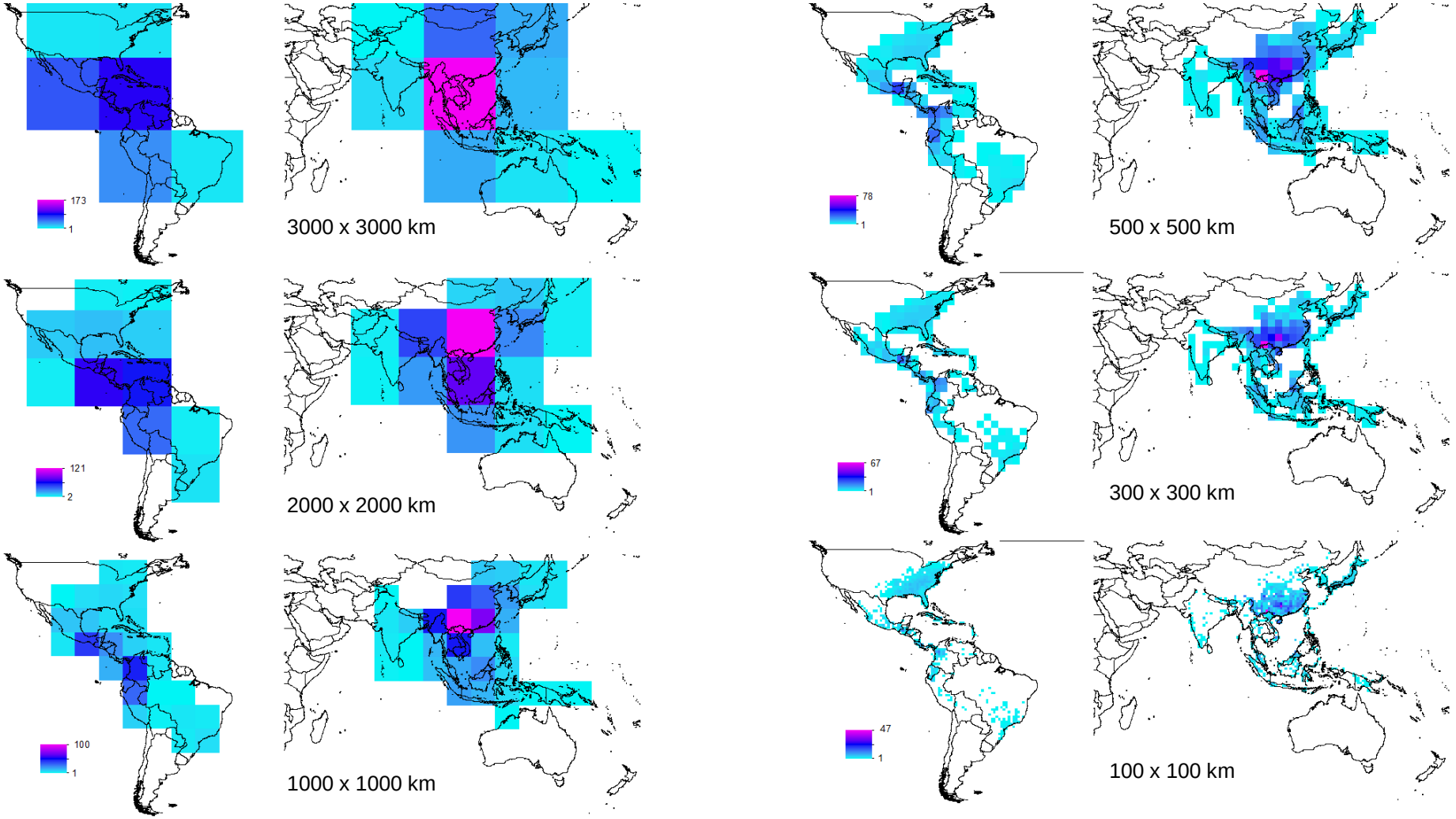
The centres of neo-endemism, i.e. areas with an over-representation of short branches, are scattered in the same belt; particularly rich in grid cells dominated by neo-endemism are the Balkans, Iran and Korea.

Areas of mixed endemism are mainly in Central Asia, Iran and the Levant, with some areas also in the European Mediterranean, the Caucasus, and China.

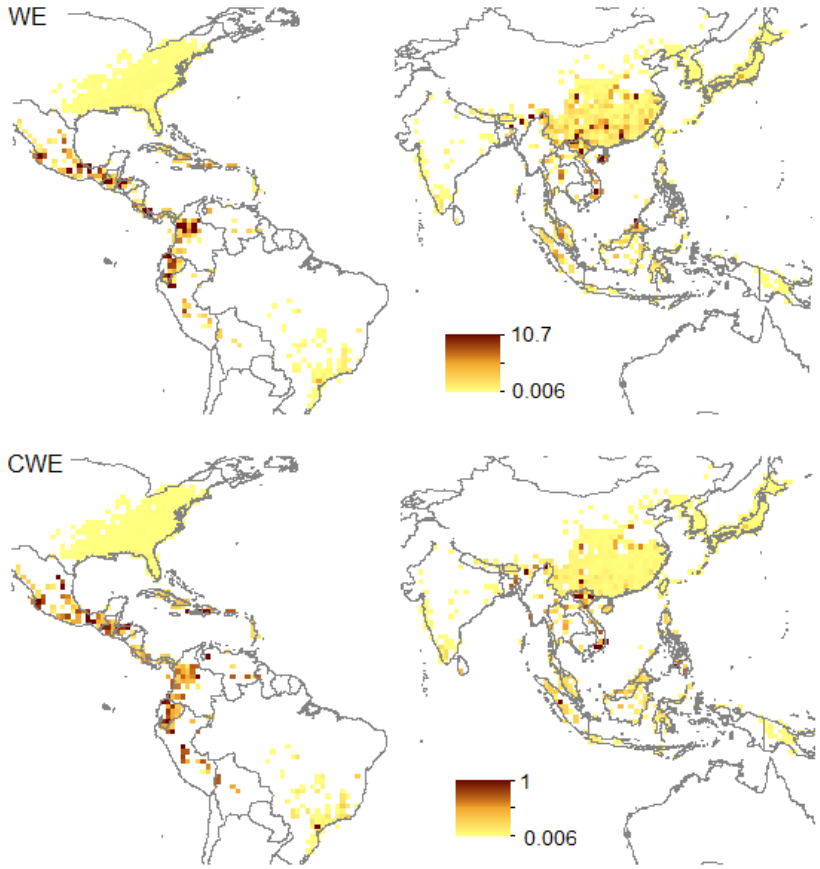
Conclusions

• This pattern of species richness and endemism suggests that areas with rough terrain and complex topography, on the one hand, and open and dry landscapes, on the other hand, were the major areas of *Allium* evolution and diversification.
• Although the vast majority of *Allium* species are distributed outside the Qinghai-Tibet Plateau (QTP), in each evolutionary lineage we find taxa that are distributed in the QTP, and might have evolved in connection with the geological development of the QTP and topographic and climate changes that occurred in the areas surrounding QTP from the early Oligocene to the late Miocene.
• The rapid diversification of *Allium* taxa we observe west of QTP in mountainous areas embracing the Iranian plateau, Zagros, Alburz, Kopet-Dag, Tien Shan, Pamiro-Alai, Karakorum and Hindu Kush mountain chains.
• The latter area supported rapid speciation and also apparently acted as the area of many local refugia during the climatic oscillations since the Miocene, as evident by high paleo- and neo-endemism that we detected.

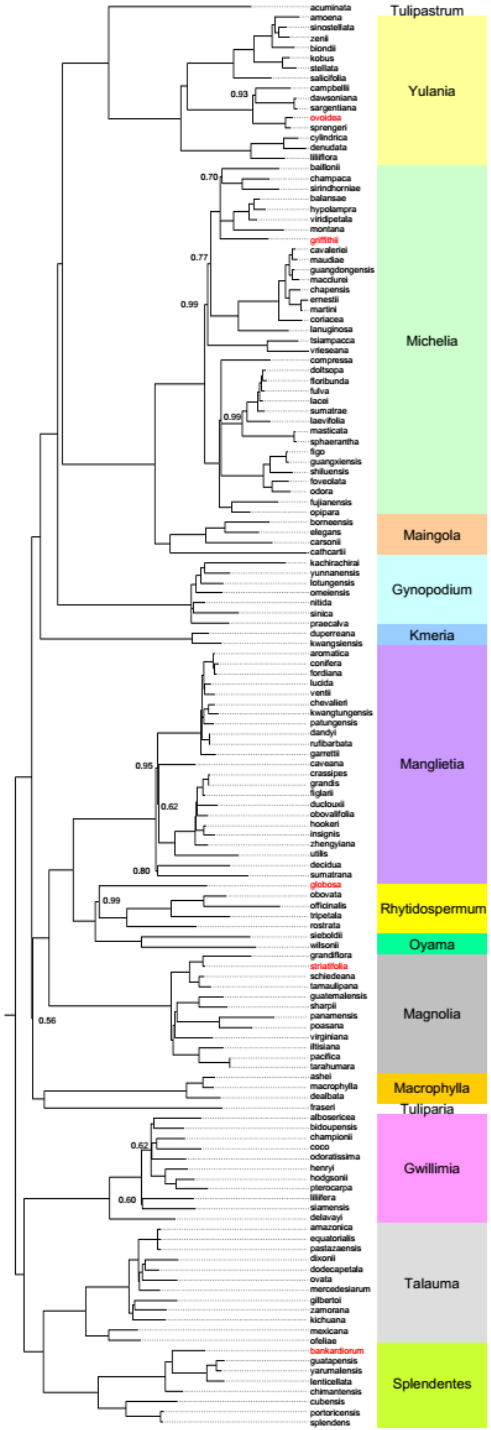
Magnolia - 371 species

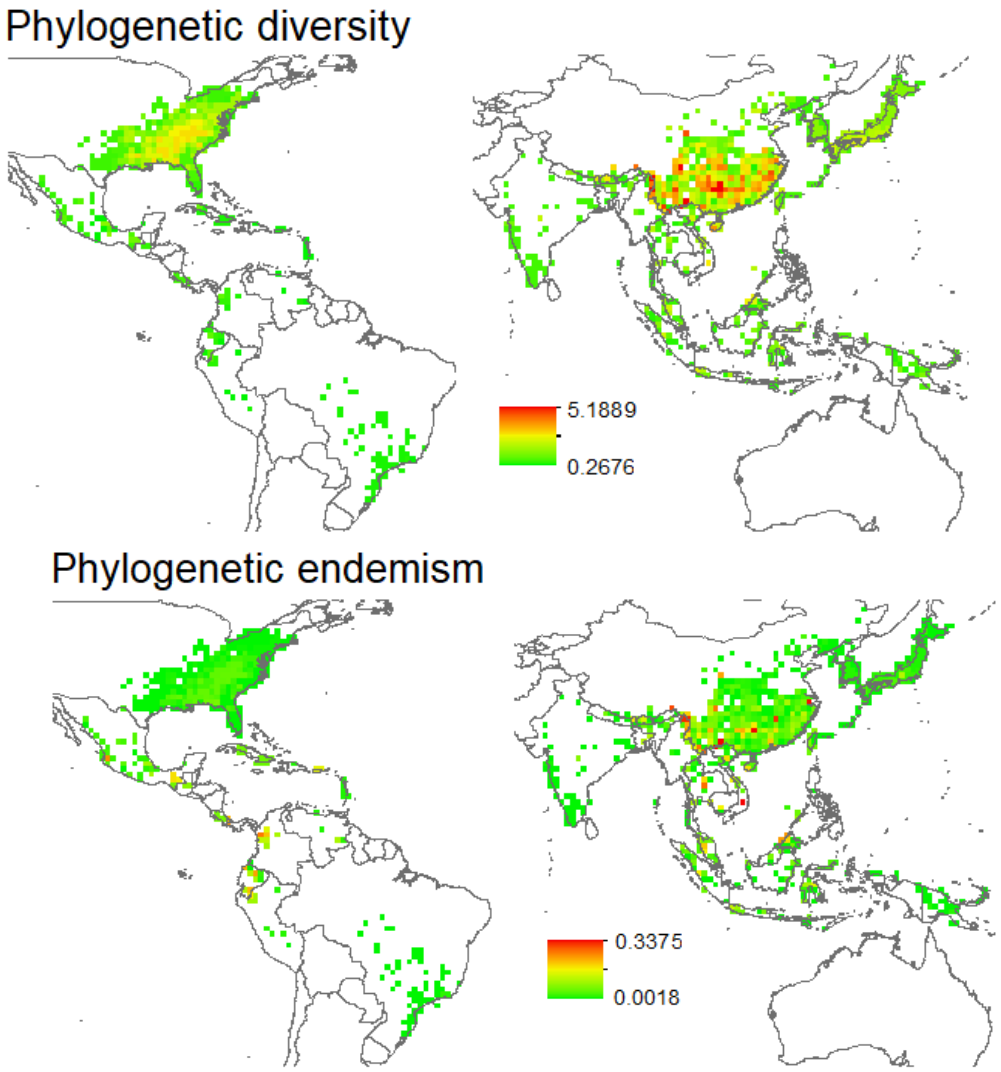


The areas of exceptionally high species richness are in southern China and Indochina in the Eastern Hemisphere, and southern Mexico, Central America, Colombia and Ecuador in the Western Hemisphere



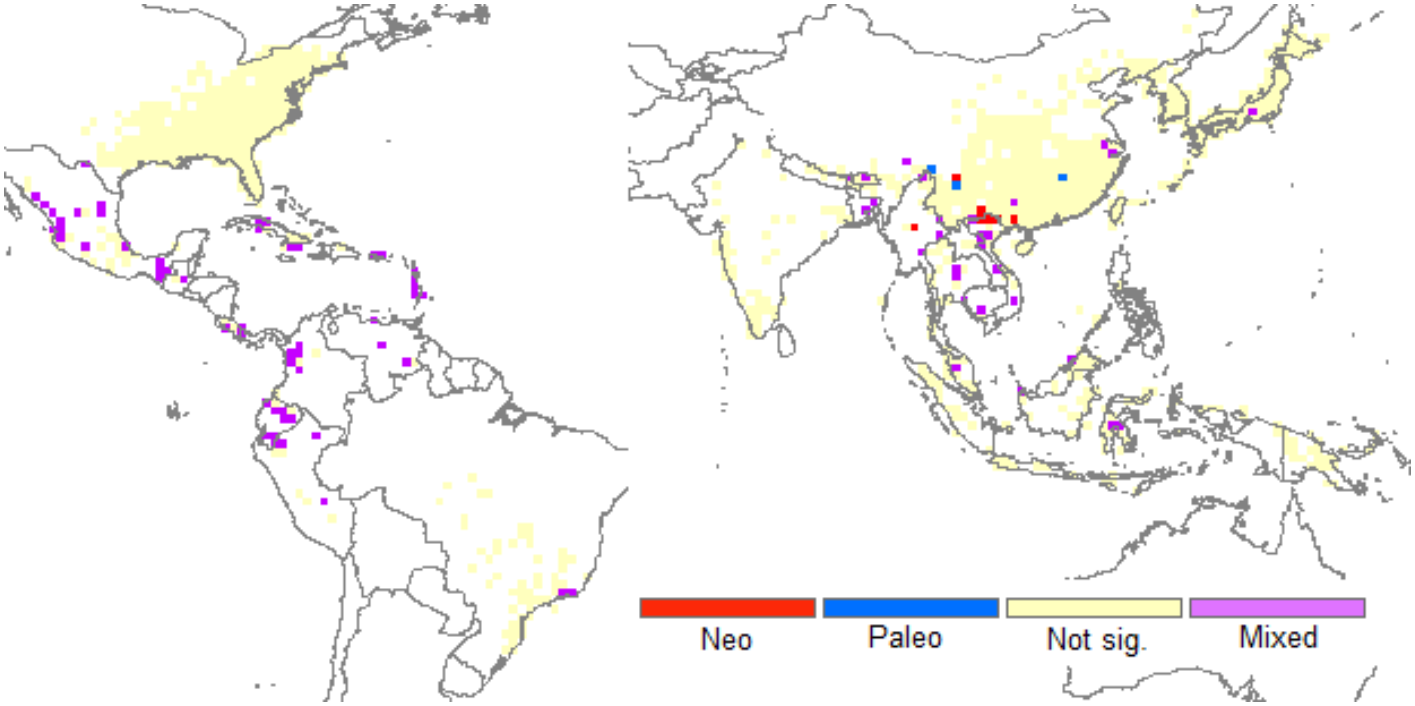
There are more cells with exceptionally high WE and these cells are more densely distributed in the Western Hemisphere than in the Eastern Hemisphere


Tulipastrum
Yulania
Michelia
Maingola
Gynopodium
Kmeria
Manglietia
Rhytidospermum
Oyama
Magnolia
Macrophylla
Tuliparia
Gwillimia
Talauma
Splendentes
0.93
0.70
0.77
0.99
0.99
0.95
0.62
0.80
0.99
0.56
0.62
0.60



Phylogenetic diversity (PD) was found to be much higher in the Eastern Hemisphere than in the Western Hemisphere, and the areas with high PD were almost exclusively in China

The areas with high phylogenetic endemism (PE) were detected in both Eastern Hemisphere and the Western Hemisphere, but in the former the number of such locations was higher. In the Western Hemisphere such locations were restricted to Mexico, Central America, Colombia and Ecuador, and in the Eastern Hemisphere they were mostly in China, Assam and Indochina



• Only three cells were identified as centers of paleo-endemism, i.e. areas with an over-representation of long branches that are rare across the landscape, all in China.
• Five cells were identified as the centers of neo-endemism, i.e. areas with an over-representation of short branches that are rare in the landscape: three in China, one in Vietnam and one in Myanmar.
• However, there were many areas of mixed endemism in both Western and eastern Hemisphere

Conclusions

- The results of CANAPE analysis suggest that the Western Hemisphere and the Eastern Hemisphere are both “cradles” and “museums” for *Magnolia*
- Despite a common belief that *Magnolia* is a conservative genus, the large number of species in this genus, and the pattern of phylogenetic endemism revealed in this study, as well as a known wide breadth of magnolias ecological niche challenge this view and suggest that many species not only survived in the most favorable locations during climatic fluctuations, but also acquired some adaptations to specific environmental conditions

Major conclusion

- Mapping patterns of species richness and endemism can provide vital information for understanding plant evolution, especially if combined with phylogeographic and biogeographic analyses