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**Borneo : a quantitative analysis of botanical richness,
endemicity and floristic regions based on herbarium
records**

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Borneo

A quantitative analysis of botanical richness,
endemicity and floristic regions
based on herbarium records

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A quantitative analysis
of botanical richness,
endemicity and floristic regions
based on herbarium records

Niels Raes

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Summary

Although it is widely recognized that Borneo harbours one of the world's most important biodiversity hotspots, the spatial patterns of botanical richness, endemism, 'centres of endemism', and Borneo's floristic regions, until now have largely been based on informal expert opinion. Recent digitization of the botanical collections of Borneo, housed at the National Herbarium of the Netherlands, has provided a database that allowed a quantitative, spatial analysis of the components of botanical diversity of Borneo.

The objectives of this study are to develop high-resolution spatial maps of the patterns of botanical richness, -endemism, 'centres of endemism', and the floristic regions of Borneo derived from species distribution models. The resulting maps are related to environmental conditions to explain the patterns of the different components of botanical diversity and the recognized floristic regions. Finally, we assess the extent to which areas of high botanical diversity and the different floristic regions remain forested today to guide conservation efforts of the threatened forests of Borneo.

We used 'Maxent' to develop species distribution models for species treated in 'Flora Malesiana' and represented by at least five records. The 2273 species distribution models were statistically tested with a method we developed for this purpose, resulting in 1439 significant models (63.3%), covering 8577 grid cells (5 arc-minute resolution, ca. 100 km²) of Borneo.

The 1439 significant models were superimposed to generate patterns of botanical richness, -endemism, and 'centres of endemism'. The highest botanical richness is predicted to occur in northern and northwestern Borneo. The northern Crocker Mountains range with Mount Kinabalu, and the high mountains of central East Kalimantan have the highest botanical endemism values. The 'centres of endemism' are found on Mount Kinabalu and the northern Crocker Range Mountains, the southern Müller Mountains, the east side of the Meratus Mountains, and the Sangkulirang peninsula. Areas of high botanical richness and -endemism are characterized by a relatively small range in annual temperature, but with seasonality within that range. Furthermore, these areas are least affected by the El Niño Southern Oscillation drought events. 'Centres of endemism' are characterized by ecological distinctiveness in altitude, edaphic conditions, annual precipitation, or a combination of these factors.

The 11 floristic regions of Borneo were recognized based on a presence/absence matrix derived from the 1439 significant species distribution models. This matrix was analysed using a hierarchical cluster analysis, and the resulting cluster dendrogram was pruned using indicator species analysis (ISA) to partition floristic regions. This method allowed the quantitative confirmation of the floristic distinctiveness and extent of montane rain forest, kerangas, peat swamp, and fresh water swamp forest. The lowland rain forest, previously recognized as one floristic region was divided in at least four (and possibly six) different floristic regions, viz. the lowlands of (i) Sabah and Sarawak, (ii) East Kalimantan, (iii) southern Borneo, and (iv) the 'Wet hill forest of Sarawak'. We could not distinguish, but do recognize, the 'Kinabalu highlands', mangroves, and forests on limestone and ultramafic rock due to the spatial resolution (100 km²) of our analysis.

Correction for the impact of deforestation, forest fire, and land use change on the 11 floristic regions and areas of high botanical diversity revealed that 36% of Borneo's total surface, and 57% of its most diverse areas has already been lost. Especially the most diverse lowland forests have been severely hit by deforestation. Even more worrying is the fact that deforestation has taken its toll in IUCN recognized protected areas. Only 0.6% of Borneo's most diverse areas have an IUCN protected status, of which 33% was already deforested by the year 2000. Most dramatic is the loss of 84% of East Kalimantan's protected lowland rain forests.

To safeguard Borneo's genetic botanical diversity we urge governments and policy makers to award the remaining forested extents of areas with the highest botanical diversity with a protection status, to enforce the protection of recognized protected areas, and to conserve significant parts of each of the 11 floristic regions.

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