Plant Diversity 38 (2016) 10–16

Contents lists available at ScienceDirect

Plant Diversity

journal homepage: http://www.keaipublishing.com/en/journals/plant-diversity/ http://journal.kib.ac.cn

Plant diversity in a changing world: Status, trends, and conservation needs

Richard T. Corlett*

Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Yunnan, 666303, China

ARTICLE INFO

Article history:
Received 22 October 2015
Received in revised form
5 January 2016
Accepted 7 January 2016
Available online 24 May 2016

Keywords:
Land plants
Diversity patterns
Threats
In situ conservation
ex situ conservation

ABSTRACT

The conservation of plants has not generated the sense of urgency—or the funding—that drives the conservation of animals, although plants are far more important for us. There are an estimated 500,000 species of land plants (angiosperms, gymnosperms, ferns, lycophytes, and bryophytes), with diversity strongly concentrated in the humid tropics. Many species are still unknown to science. Perhaps a third of all land plants are at risk of extinction, including many that are undescribed, or are described but otherwise data deficient. There have been few known global extinctions so far, but many additional species have not been recorded recently and may be extinct. Although only a minority of plant species have a specific human use, many more play important roles in natural ecosystems and the services they provide, and rare species are more likely to have unusual traits that could be useful in the future. The major threats to plant diversity include habitat loss, fragmentation, and degradation, overexploitation, invasive species, pollution, and anthropogenic climate change. Conservation of plant diversity is a massive task if viewed globally, but the combination of a well-designed and well-managed protected area system and *ex situ* gap-filling and back-up should work anywhere. The most urgent needs are for the completion of the global botanical inventory and an assessment of the conservation status of the 94% of plant species not yet evaluated, so that both *in* and *ex situ* conservation can be targeted efficiently. Globally, the biggest conservation gap is in the hyperdiverse lowland tropics and this is where attention needs to be focused.

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1. Introduction

The conservation of plant diversity has received considerably less attention than the conservation of animals, perhaps because plants lack the popular appeal of many animal groups (Goettsch et al., 2015). As a result, plant conservation is greatly under-resourced in comparison with animal conservation (Havens et al., 2014). Yet plants are much more important to us. Animals can provide meat, leather, fur and other products, but none of these are necessities for human survival and well-being, while many plant products are essential. Plants provide food for us and our livestock, as well as a huge diversity of other products and services, from timber and fibers to clean water and erosion control. Although most commercial plant products come from a very narrow range of plant species, a life based on only these species would be both unhealthy and dull: even urban dwellers use a wide range of other plant species for various purposes and rural people tend to use many more. Wild plant foods contribute to nutrition and food security, and numerous additional species have roles in traditional medicine. Moreover plants are the basis for all terrestrial ecosystems, providing the three-dimensional structure in which animals live and move, and the food on which a majority feed.

This review focuses on the current status of global land plant diversity, the major threats to its continued persistence, and the priority actions for its conservation. It concentrates on the tropics, where most plant species live but least is known about them.

2. How many plant species are there?

The updated Global Strategy for Plant Conservation (hereafter GSPC) agreed at the CBD meeting in Nagoya in 2010 to include, as its first target for 2020, 'an online flora of all known plants' (www.

* Tel.: +86 18288059408 (mobile); fax: +86 6918715070.
E-mail address: Corlett@xtbg.org.cn.
Peer review under responsibility of Editorial Office of Plant Diversity.

http://dx.doi.org/10.1016/j.pld.2016.01.001
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cbd.int/gspc/targets.shtml). This target is perhaps achievable, but it explicitly omits unknown species, of which there are still many. A recent paper estimated the total number of angiosperm species at around 450,000, of which 10–20% are still unknown to science (Pimm and Joppa, 2015). Recent estimates for gymnosperms (1000 species; Christenhusz et al., 2011), ferns (10,000 species; Ranker and Sundue, 2015), lycophytes (1300 species), mosses (9000 species; Magill, 2010), hornworts (200–250 species; Villarreal et al., 2010), and liverworts (7500; Von Konrat et al., 2010) suggest that the global total for all land plants is around 500,000 species. This compares with around 10,000 bird species and 5400 mammals. Indeed, the only taxonomic groups whose diversities are thought to substantially exceed that of land plants are the largely plant-dependent fungi (1.5–5.1 m; Hawksworth, 2012) and beetles (ca. 1.5 m; Stork et al., 2015).

3. Where are they?

Pimm and Joppa (2015) estimated that two-thirds of all angiosperm species are found within the tropics. Fern diversity is even more highly concentrated in the tropics (Kreft et al., 2010) while, among the bryophytes, liverwort diversity is highest in the tropics but mosses show no clear latitudinal gradient (Geffert et al., 2013; Chen et al., 2015). The distribution of plant species across the tropics is far from uniform, with the highest diversities in the Neotropics and the Asia–Pacific region, and lower diversities in Africa and on oceanic islands. For example, Slik et al. (2015) estimate that there are 40,000–53,000 tree species in the tropics—96% of all the tree species on Earth (Poorter et al., 2015) —with similar numbers (19,000–25,000) in the Neotropics and the Asia–Pacific, but far fewer (4500–6000) in Africa. Although plant diversities are lower on individual islands, endemism is high and around 50,000 species of vascular plants are island endemics (Sharrock et al., 2014). Also, not all concentrations of plant diversity are tropical: regional diversity is also very high in the Mediterranean region and in similar climates elsewhere, as well as in the moist subtropical areas of Asia (Barthlott et al., 2007; Joppa et al., 2013). At higher spatial resolutions, the concentration of plant species is even more marked, with 67% of all plant species confined to, and 81% present in, only 17% of the Earth's land surface (Joppa et al., 2013).

For trees, there is enough data from plot inventories to look at patterns of local diversity on a regional scale. For example, within tropical East Asia (SE Asia plus S China and NE India), the highest diversities (>210 tree species >10 cm diameter in 1 ha of forest) are in lowland rainforests in Borneo and Sumatra, but high diversities (>100 tree species) also occur in lowland rainforests from Sulawesi to southern China (Corlett, 2014a). Plots at higher altitudes (>1200 m), on extreme soil types, and in areas with a long dry season have lower tree diversities, as do all sites north of the tropics. The contrast between tropical and temperate zone tree diversity is highlighted by the fact that just 52 ha of lowland rainforest at Lambir in Borneo supports as many tree species (1175) as all the temperate forests in the northern hemisphere together: Asia, Europe and North America (Wright, 2002). Similar diversity patterns occur in other tropical regions, with land plant diversity best predicted by the number of wet days per year (Kreft and Jetz, 2007).

4. Do we need them all?

The conservation of all plant species can be justified on a range of aesthetic, scientific and ethical grounds - it is simply good stewardship - but these arguments seem to have been used more effectively in support of animal conservation. Unlike butterflies or frogs, plants are expected to be useful. In low-diversity ecosystems, most plant species do have specific human uses that justify their protection, but this is not true in the hyperdiverse tropical forests, where local people appear to know only a subset of the flora (personal observations in Papua New Guinea and SE Asia). The use of relatives of species with specific human uses in plant breeding programs considerably extends the list of 'useful' plant species. For example, a recent study in China identified 871 species of wild relatives of major crops (Kell et al., 2015), although this is still a relatively small proportion of China's total angiosperm flora of around 30,000 species (Wang et al., 2015). All wild plant species, however, are parts of natural ecosystems which, in turn, provide services for human populations. Are they all necessary for ecosystems to function?

High local plant diversities in tropical forests have been explained in multiple ways, with most of these depending on differences between species, in their resource use (water, nutrients, light) and/or in their pests and diseases (Wright, 2002; Corlett, 2014a). Neutral theory, in contrast, suggests that coexistence depends on the ecological equivalence of species rather than their differences (Rosindell et al., 2012). The available evidence strongly supports the idea that coexistence depends on differences (Corlett, 2014a), but this does not necessarily imply that these differences are important to the maintenance of ecosystem functioning. In the most species-rich forests, most species are rare and the common species are likely to dominate ecosystem functions. For example, a remarkably few, common, large tree species (1.5% of the total tree flora in both the Amazon Basin and Central Africa) contribute disproportionately to carbon storage and fluxes in tropical forests (Fauset et al., 2015; Bastin et al., 2015). However, a recent study showed that the rare species in high diversity ecosystems support the most distinctive and vulnerable functions, and that these species make a disproportionate contribution to the potential range of functions that can be provided by the ecosystem (Mouillot et al., 2013). In an era of rapid global change, this functional redundancy is likely to be a useful insurance policy against unpredictable threats.

5. How many species are threatened?

Target 2 of the GSPC is assessing the conservation status of all known plants by 2020, but we are still a long way from achieving this. Fewer than 20,000 plant species have been formally assessed so far at the global level using the IUCN Red List criteria, so the proportion of land plants that are threatened is not accurately known. Pimm and Joppa (2015) suggest that a third of all angiosperms are at risk of extinction, including most of those that have not yet been described, since these are likely to have small ranges and be locally rare. Brummitt et al. (2015) assessed the status of a random sample of 7000 plant species against the Red List criteria, including bryophytes, ferns, gymnosperms and angiosperms (represented by monocots and the well-studied legumes) and concluded that 22% were threatened (IUCN categories Vulnerable, Endangered, or Critically Endangered) and 30% threatened or near-threatened. For the major groups assessed, the percentage threatened ranged from 11% for legumes to 40% for gymnosperms. Compared with other groups assessed in the same way, plants are more threatened than birds, similar to mammals, and less threatened than amphibians.

Note, however, that this sampling approach necessarily excludes the species still unknown to science and thus almost certainly underestimates the overall threat levels. Moreover, Data Deficient species were assumed to be threatened in the same proportions as those with enough information, while it is more likely that data deficiency most often reflects rarity and thus higher vulnerability. The habitat with most threatened species was overwhelmingly tropical rainforest in both the above studies. A recent model-based assessment of the conservation status of 15,200 Amazonian tree

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