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Plant biodiversity: Environmental impact and future threats

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Abstract
For many years researchers have investigated the effects of climate change on the future of plant biodiversity and predicting its response to environmental impact has become an extremely active field of research. Although there is relatively limited evidence of current extinctions caused by environmental impact due to climate change, studies suggest that it could surpass habitat destruction as the greatest global threat to biodiversity over the next few decades. However, the multiplicity of approaches and the resulting variability in projections make it difficult to get a clear picture of the future of biodiversity under different scenarios of global environmental impact. Hence, there is an urgent need to review our current understanding of the effects of climate change on biodiversity and our capacity to project future impacts using models. To this end, this review presents both the possible impacts of climate change and the different responses for change in biodiversity.

Keywords: plant biodiversity, environmental, scenarios, global

Introduction

Biodiversity is fundamental as it ensures natural sustainability of all life on earth not only for the current population but also for the future generations. However, plant biodiversity continues to be threatened and in consequence, it affects the survival of humans (Ibanez, 2006) [3]. Various concerns have been raised by environmental advocates and agencies such as the UNEP, WWF, GreenFacts Foundation, and EPA with regards to the threats posed on many of the world's ecosystems which are increasingly deteriorating in state by becoming unhealthy and unbalanced (Brook, 2009; Bellard, 2012) [4].

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, 2015) [2]. As a result, plant conservation is greatly under-resourced in comparison with animal conservation, 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. There are an estimated 500,000 species of land plants (angiosperms, gymnosperms, ferns, lycophytes, and bryophytes), with diversity strongly concentrated in the humid tropics (Pimm and Joppa, 2015) [1].

Major Threats

Habitat loss and deforestation: Habitat loss and associated fragmentation is the biggest single threat to plant diversity, particularly in the tropics (ter Steege *et al*., 2015) [6], where conversion of tropical forests to pastures and commercial crop monocultures (oil palm, rubber, soy etc.) has replaced small-scale cultivation by poor farmers as the major driver of forest loss. Few forest-adapted plant species survive complete deforestation, and even if a substantial fraction of the original forest cover remains, fragmentation drives changes that tend to reduce plant diversity. Large areas of the remaining forest, whether fragmented or not, are degraded by logging, fire, and other impacts, including fuelwood harvesting in densely populated areas (Specht *et al*., 2015) [7]. Non-forest habitats, from savannas and grasslands to deserts, are similarly threatened by agricultural development.

Environmental Pollution: Every plant on Earth today is exposed to an atmosphere that differs significantly in composition from any that its ancestors would have experienced. Changes in the concentration of the major greenhouse gases (CO2, CH4, N2O) are considered separately below, but other air-borne pollutants can also impact plant diversity. Major source of air pollution is the burning of fossil fuels and the most important primary pollutants are sulphur dioxide and nitrogen oxides. Ozone, which is produced from hydrocarbons and nitrogen oxides in the presence of sunlight, is the most important secondary pollutant. Particulates (or aerosols: solid and liquid particles suspended in the air) are derived from a variety of primary and secondary sources. Air pollution is declining in Europe and other developed regions, but increasing in much of Asia. Wet and dry deposition of nitrogen compounds not only acidifies the soils but can also dramatically change nutrient cycles, as has happened over much of southern China, with a largely unknown impact on plant diversity (Zhu *et al*., 2015) [8]. Indeed, for tropical forests in particular, our current understanding of the impacts of air pollution and nitrogen deposition on plant diversity is very limited.

Climate Change: The impacts of climate change are also complex and unpredictable, and even more pervasive. After around 1 °C of global warming so far, many temperate zone plants are leafing and flowering earlier in spring and-less consistently-delaying leaf fall in autumn. Some species have extended their ranges towards the poles and/or to higher altitudes, although other species have not done so. Growth rates have generally increased where temperature is limiting and decreased where water is. Although no global plant extinctions have yet been attributed to anthropogenic climate change, there is evidence that local extinctions have occurred at the climatic margins of species ranges (Buse *et al*., 2015) [9]. When changes in the local climate exceed the range of natural variation, plant populations can either acclimate (i.e. adjust physiologically within the lifetime of an individual), adapt (by evolutionary changes over multiple generations), move to somewhere with a more suitable climate, or die. There is very little information available on either acclimation capacity or evolutionary potential for all but a few model plant species (Corlett, 2015) [10]. Studies suggest that most plant species will find it difficult or impossible to track the expected rate of climate change, except in steep topography where climatic gradients are equally steep.

The multiple components of climate change are anticipated to affect all the levels of biodiversity, from organism to biome levels. They primarily concern various strengths and forms of fitness decrease, which are expressed at different levels, and have effects on individuals, populations, species, ecological networks and ecosystems. At the most basic levels of biodiversity, climate change is able to decrease genetic diversity of populations due to directional selection and rapid migration, which could in turn affect ecosystem functioning and resilience (Botkin *et al*. 2007) [11]. However, most studies are centered on impacts at higher organizational levels, and genetic effects of climate change have been explored only for a very small number of plant species.

At a higher level of biodiversity, climate can induce changes in vegetation communities that are predicted to be large enough to affect biome integrity. The Millenium Ecosystem Assessment forecasts shifts for 5 to 20% of Earth's terrestrial ecosystems, in particular cool conifer forests, tundra, scrubland, savannahs, and boreal forest (Sala *et al*. 2005) [12].

A previous analysis of potential future biome distributions in tropical South America suggests that large portions of Amazonian rainforest could be replaced by tropical savannahs (Lapola *et al*. 2009) [13]. At higher altitudes and latitudes, alpine and boreal forests are expected to expand northwards and shift their tree lines upwards at the expense of low stature tundra and alpine communities (Alo & Wang 2008) [14]. Increased temperature and decreased rainfall mean that some lakes, especially in Africa, might dry out (Campbell *et al*. 2009) [15]. The implications of climate change for genetic and specific diversity have potentially strong implications for ecosystem services. The most extreme and irreversible form of fitness decrease is obviously species extinction.

Assessing the future of global biodiversity

Our understanding of the effects of global environmental impact on plant biodiversity and its different levels of response is still insufficiently developed. Yet, it is enough to raise serious concern for the future of plant biodiversity. The most pressing issue is to quantitatively assess the prospects for biological diversity in the face of global environmental impact. Although several methods exist to draw inferences, starting with existing paleontological or recent data, experiments, observations, and meta-analyses (e.g., Lepetz *et al*. 2009) [16], ecological modelling is the most commonly used tool for predictive studies. Progress in this field is characterized by both an extremely high pace and a plurality of approaches. In particular, there are three main approaches to projecting species loss, concentrating either on future changes in species range or species extinction or changes in species abundance. However, all three modelling approaches have so far largely focused on one axis of response (change in space), largely overlooking the importance of the other aspects. In addition, they seldom account for the mechanisms of these responses (plasticity and evolution). We briefly discuss here the basic principles and the weakness of the models that are the most widely used at global or at large regional scales in this context, focusing on representative examples of recent work.

Biodiversity range model components

Studies modelling species' range shifts are generally based on the assumption that species niches are defined by a small set of environmental variables, defines the suitable climatic habitat for that particular species. These Bioclimatic Envelope Models, or BEMs, relate current species ranges to multiple environmental variables and thereby define the climatic niche (envelope) for each species. It is then possible to project this niche for different future climate scenarios in order to determine the potential redistribution of the suitable climate space of the species. The extinction risks can then be calculated in different ways using species-area relationships (Thomas *et al*. 2004) [17] or IUCN status (Thuiller *et al*. 2005) [18].

Shifts in distinct vegetation types, often referred to as biome or habitat shifts, are often simulated with Dynamic Vegetation Models (DVM). These models forecast shifts in vegetation and associated biogeochemical and hydrological cycles in response to climate change. DVMs use time series of climate data (e.g., temperature, precipitation, humidity, sunshine days) and take into account constraints of topography and soil characteristics in order to simulate monthly or daily dynamics of ecosystem processes. Plant species are represented as groups with similar physiological and structural properties, termed Plant Functional Types (PFTs), which are designed to represent all major types of plants (Sitch *et al*. 2008) [19]. PFT distributions can then be used to estimate changes in biome or habitat ranges. Currently, DVMs are of limited use for projecting responses in biodiversity directly (i.e., the absence of animals and the limitation to ca. 10 PFTs exclude direct utilization). However, coupled with extinction models, they allow extinction risk for species to be estimated at the regional or global scale (e.g., van Vuuren *et al*. 2006) [20].

Projections of species loss

The field of climate change biology has thus followed several distinct and independent lines of model development and that is potentially advantageous, as the convergent predictions can be regarded as an indication of robustness. In essence, the results show that local species extinctions cover an extremely large range, with some areas experiencing virtually no losses and others facing nearly complete loss of current species. Nevertheless, even these global estimates suggest major losses of biodiversity due to global environmental impact due to climate change that are generally higher than current rates of loss and far higher than rates of species extinctions documented in the fossil record (Barnosky *et al*. 2011) [21]. Regarding the vulnerability of 25 major plant biodiversity hotspots, Malcolm and colleagues suggested that the extinctions of endemic species could reach 39-43% under in worst-case scenarios, representing the potential loss of 56,000 endemic plant species and 3,700 endemic vertebrate species (Malcolm *et al*. 2006) [22].

Limitations of predictive tools

Each of the modelling approaches has some limitations that constrain their predictive power. In general, models do not take into account the multiple responses of species to climate change, but rather focus mainly on one axis, spatial shifts of potential habitat (McMahon *et al*. 2011) [23]. The temporal and the physiological responses are generally overlooked, as are the genetic and plastic capacity of species. In addition, species are commonly considered as static and independent entities, although their dynamics and their role in ecological networks are both known to be essential. However a new generation of models is emerging that focuses on more realistic biological hypotheses and meets some of the challenges posed by each limitation (Brook *et al*. 2009) [4].

Conclusion

The combination of a well-designed predictable tools, well-monitored, and well-managed system of protected areas, with ex situ conservation in seed banks and, where necessary, living collections and cryogenic storage, should be enough to protect all land plant species through the next few decades of rapid global environmental change. The major barriers to this goal of zero global plant extinctions are: the many undescribed plant taxa, which cannot receive targeted protection; the low percentage of known taxa whose status has been assessed, so we cannot efficiently assign protection; the uneven global coverage of protected areas, particularly in the hyperdiverse humid tropics, and the lack of plant inventories within them; the massive underrepresentation of tropical taxa in ex situ collections; and the apparent absence of any sense of urgency among everyone from plant biologists to government officials, conservation NGOs, and the general public. None of these problems are inherently intractable and all the gaps could be filled.

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