Ecology

Inventory hints at the future of African forests

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An analysis of six million trees reveals spatial patterns in the vulnerability of Central African rainforests to climate change and human activities. The maps generated could be used to guide targeted actions across national boundaries. See p.90

Preserving the biodiversity of rainforests, and limiting the effects of climate change on them, are global challenges that are recognized in international policy agreements and commitments[1]. The Central African rainforests are the second largest area of continuous rainforest in the world, after the Amazon rainforest. They store more carbon per hectare than does the Amazon and, on average, have a higher density of large trees[2] than does any other continent – a feature attributed to the effects of big herbivores, particularly elephants, on the competition between trees for light, water and space[3]. Human activities, notably logging and over-hunting, facilitated by an expanding road network[4], pose a serious threat to Central African rainforests and their value for society[5].

How important is climate change, when acting on top of these existing human-generated pressures, for the future of these rainforests? Réjou-Méchain *et al.*[6] provide an answer on page 90, and show that expected changes in climate in the region pose serious risks to the rainforests. Some forests in locations that have so far been relatively undisturbed by humans are more vulnerable to climate change than are those in areas already affected. For those areas already affected, the lower tree diversity as a consequence of human intervention reduces the capacity of forests to respond to climate change.

The authors had access to an impressive commercial forest-inventory data set from 105 logging concessions (designated areas in which commercial operators are allowed to harvest timber), across five Central African countries. Analysing the abundance distribution of 6.1 million trees across 185,665 plots, the authors generate maps of floristically unique forest types – forests characterized by distinct sets of tree species. The spatial extent of these forest types is predominantly shaped by climate gradients, with further effects arising from human-induced pressures and variation in soil type.

Previous research into links between species distribution and environmental variation used approaches such as ecological niche models, which are mechanistic or correlative models that relate field observations of species with environmental variables to predict habitat suitability. But the resulting predictions of how various species will be affected by climate change have been highly uncertain. This is mainly because of sampling bias, challenges such as spatial autocorrelation (locations closer together in space tend to be more similar to each other than do locations farther apart)[7], and high variation in the responses of individual species to environmental drivers of distribution, including human-induced factors.

Réjou-Méchain *et al.* instead applied a modelling approach called supervised component generalized linear regression, which can identify the main predictive factors from an array of possibilities. This enabled them to detect distribution patterns at the scale of species assemblages (the set of species in a community), rather than focusing on individual species, and to model species and assemblage distribution in response to predictive variables, such as those of climate and human pressures, that potentially show linear dependencies on each other (collinearity). Collinearity is a challenge in niche models, and commonly occurs between climate variables, producing results that are unreliable and difficult to interpret.

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By combining their approach with a method called cluster analysis, Réjou-Méchain and colleagues show that the Central African rainforests are not a single bloc of forests, but instead encompass at least ten distinct forest types. This includes climate-driven types of forest such as the Atlantic coastal evergreen forest in Gabon, which harbours tree species that prefer cool, dark areas for the dry season. Another grouping, semi-deciduous forest, is found along the northern margin of the Central African region studied, and is characterized by species that can tolerate higher rates of water loss to the atmosphere (evapotranspiration).

Such spatial variability in the species composition of Central African rainforests has many implications. For example, it will affect forest vulnerability to climate change, how warming might interact with human pressures to change biodiversity, and how it might affect the potential of these forests to mitigate the rise in atmospheric carbon. Global warming is projected to result in a drier, hotter environment in Central Africa, and previous research has suggested potentially dangerous implications for the fate of the rainforests there[8]. They might respond to limited water availability by opening canopies and becoming more prone to fires and less carbon dense. Using climate-model projections for the year 2085, Réjou-Méchain and colleagues conclude that the current climate niches associated with the ten forest types they have identified might disappear, or move to locations that would be difficult for the forests to reach through dispersal of tree seeds (by means such as wind and animals), and would hence become inaccessible.

What do these findings mean for the future, and how can we manage the forests to minimize the threat from climate change? To provide an answer, Réjou-Méchain *et al.* looked at three components that characterize the vulnerability of forest communities to warming: their sensitivity, exposure and adaptive capacity. The authors conclude that some areas are more sensitive than others, which means that the dominant tree species in some forest types will be less able to tolerate environmental change than will those in other areas – for example, species in the northern and southwestern edge of the rainforest. Some areas, particularly those in the east, are expected to be more exposed to climate change than others. And some, especially areas under pressure from human activities, have lower local biodiversity, and might thus have less capacity to adapt compared with areas of greater biodiversity.

Réjou-Méchain *et al.* report that the areas most vulnerable to climate change and predicted to be highly vulnerable to future human-induced pressures include forests in coastal Gabon, the Democratic Republic of the Congo (Fig. 1) and the northern margin of the domain studied. This finding suggests priority regions for targeted actions to protect forests from environmental changes. One such region under human pressure is in Cameroon

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Figure 1 | Kahuzi-Biéga National Park, Democratic Republic of the Congo. The road marks the boundary of this forest, which is one of the few remaining forest habitats for the eastern lowland gorilla (*Gorilla beringei graueri*). Rainforests are under threat from human-induced pressures, such as the deforestation visible outside this park. Réjou-Méchain *et al.*[6] present maps of Central African rainforests that could aid conservation work.

and contains a forest group called degraded semi-deciduous forest. Protecting this type of forest offers a fast way of generating a carbon sink that will operate over a long time frame[9]. This is because it features long-lived 'pioneer' taxa, which colonize areas after a disturbance — whether natural or human induced. Such species frequently have a high requirement for light, and in this region have the potential to reach great heights in the absence of further disturbance.

As for elsewhere in sub-Saharan Africa, climate-change predictions for 2085 are uncertain for Central Africa. Réjou-Méchain and colleagues' projections for the effects of human pressures for that year are probably underestimates, especially considering that road expansions are likely to continue to push the frontier of wilderness deeper into remote forest areas. Nevertheless, the research offers convincing evidence enabling land users and managers to take decisive actions. This could include efforts to protect the areas most vulnerable to climate change from human pressures, for example by setting up protection schemes, and actions that could include boosting forest connectivity in areas that have already experienced high levels of human pressure. To ensure the effectiveness of any interventions, it will be imperative to engage with local people in developing management solutions. Conservation and the sustainable management of rainforest carbon stocks have key roles in the reduction of carbon emissions.

Perhaps most crucially, rainforests in Central Africa and the ecosystem services they provide are intertwined with people's livelihoods and food security. Developing sustainable management plans that recognize the diversity of the ways in which people interact with and depend on these forests will be a huge challenge. It will require concerted cross-disciplinary and cross-sectoral efforts that move beyond national boundaries.

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