SCIPOD

ADVANCED MODELLING FOR BETTER CONSERVATION OF NEOTROPICAL CLOUD FORESTS

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Climate change and deforestation threaten many valuable ecosystems across the globe. Of these, Neotropical cloud forests and alpine páramo represent biodiversity hotspots, with many species unique to these areas. Conventional climate models use scales too large to adequately assess potential impacts on cloud forests. Through their research, **Dr Eileen Helmer** from the International Institute of Tropical Forestry in Puerto Rico and her team are overcoming these limitations by producing a robust model that combines relative humidity, frost, and watershed elevation to predict climate change impacts on cloud forests and inform conservation efforts.

The mountains on continents and island chains within tropical latitudes are home to habitats with some of the highest biodiversity on the planet. Clouds form as warm air reaches the higher elevations on the mountains, leaving isolated patches of habitat that are persistently engulfed by fog and mist. Thousands of unique species have evolved in these neotropical cloud forests and páramo, a set of alpine ecosystems occurring in areas above some cloud forests.

Species in the cloud forests and páramos are beautifully adapted to their foggy environment. Cloud forest trees and the mosses, ferns, bromeliads, and lichens which live upon them, are specially adapted to intercept water from the atmosphere. For cloud forests in some drier regions, this equals as much as 75% of the stream water. The grasses and shrubs that dominate páramo habitats are also adapted to intercept water vapour, for example, with a covering of dense hairs, and tolerate the variable temperatures prevalent in the area. Páramo vegetation is critical for the Andean water supply and provides the headwaters for the Amazon River. Additionally, many páramo habitats are geographically isolated, being surrounded by the cloud forests of lower elevations. This isolation means that new plant species are evolving in páramo faster than anywhere else on Earth.

However, despite their value, the cloud forests and páramos are under significant threat from climate change and land-use changes. Warmer ambient air temperatures mean that warm air must travel further up the mountains before clouds form, reducing the areas with the right conditions for cloud forest and páramo species. Reduced humidity may also make these habitats more susceptible to fires, reduce soil moisture, and negatively impact carbon-storage.

Conserving the cloud forests and páramos requires a good understanding of where and how the climate variables that define them will change, but

conventional climate models cannot adequately capture the potential impacts on these relatively small regions.

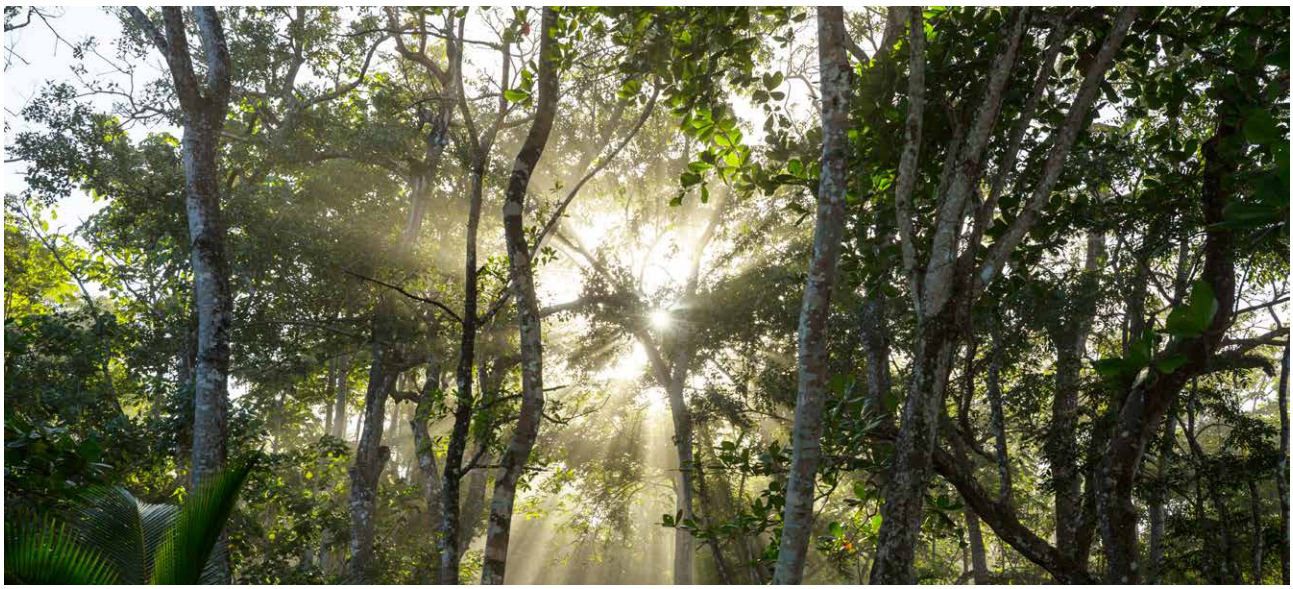
To overcome these limitations, Dr Eileen Helmer from the International Institute of Tropical Forestry in Puerto Rico, USA, and her team of researchers have developed robust new methods to map cloud forests and páramos, and explore how changes in cloud immersion and deforestation might impact these ecosystems in the future. Their research, which was funded by the US Forest Service's International Institute of Tropical Forestry in Puerto Rico, can help to inform conservation management decisions and help to protect these precious habitats.

Cloud forests exist in areas above elevations that have higher relative humidity than the surrounding area, but below elevations where the air becomes too cold or dry for cloud forests. Closer to the equator, a day or two of annual frosts prevent trees from flourishing, and páramo habitats are more likely to occur instead. The minimum elevations where vegetation changes to cloud forest or páramo vary greatly across tropical regions and within mountain chains. Mapping out zones where cloud forests and páramos occur has previously been a difficult endeavour, because factors such as elevation, wind speed, and temperature interact dynamically to produce the conditions suitable for these habitats to occur.

Dr Helmer, along with Scott Baggett and Benjamin Bird from the US Forest Service Rocky Mountain Research Station, Thomas Ruzycki and Shannon Voggesser from Colorado State University, and Elizabeth Gerson from Ecological Research Support, used a new modelling approach to determine cloud forest and páramo zones. Their approach included the effects of mountain size on cloud forest limitations for the first time in any study, allowing the team to detect coastal and isolated cloud forests. By testing their model with data from known cloud forest and páramo habitats, Dr Helmer and her team demonstrated that their model has a sensitivity of 95% in detecting these habitats, in comparison to the 81% achieved previously.

Using their advanced model, the researchers were able to predict cloud forest and páramo zone changes under various climate change scenarios, and at differing levels of deforestation in cloud forest habitats. Although many cloud forests are within protected zones, it was not known whether protected areas incorporate enough of the habitats resistant to the potential effects of climate change.

Between 60 and 90% of neotropical cloud forests are projected to undergo declines in cloud immersion, meaning that clouds are thinner or less frequently engulf the forests, pushing the species that rely on these habitats further up mountains and restricting their ranges. Not only are these effects predicted to be widespread, but they are also likely to be severe in many regions. Alarmingly, severe impacts are predicted to occur within the next 20 years.



Reduced cloud immersion will also have negative consequences for the majority of páramo habitats. Reduced frost levels at higher elevations will likely support the invasion of páramos by tree species from cloud forests, without making up for the area of cloud forests affected by climate change at lower elevations. Dr Helmer and her team suggest that these habitats will likely undergo extensive shrinking, potentially disappearing entirely from some regions. Depending on the climate change scenario and region, these impacts are projected to affect between 70 and 98% of páramo habitats.
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Although their results highlight potentially dire consequences of climate change for these habitats, Dr Helmer and her team note that understanding how the projected changes in cloud forest and páramo habitats overlap with forest cover and protected areas could guide conservation efforts. Their results help reveal where forest protection, monitoring, restoration, or community involvement is most urgently warranted or least costly. Where less severe changes in cloud immersion overlap with unprotected forest, conservation actions may have the greatest benefit.

About 30% of regions containing cloud forest have unprotected habitat where projected climate change is less severe. Extending protection to these areas and to more páramo areas could help to conserve cloud forest and páramo species, despite the impacts of climate change.

Additionally, identifying and protecting areas that also have the greatest amount of intact forest is likely to be the least costly conservation approach. As these habitats are home to many species of birds, mammals and plants found nowhere else on the planet, protecting their home may help to prevent their extinction in the future.

Finally, in some regions, areas of deforestation overlap significantly or entirely with areas exhibiting the least projected climate change impacts. Protecting remaining fragments of cloud forest and restoring deforested areas in these regions is also urgent, to safeguard the habitat in those regions and provide climate sanctuaries for cloud forest species.

Although Dr Helmer and her team's research demonstrates that neotropical cloud forest and páramo habitats can potentially shrink, dry, and in many cases, disappear entirely, focussed conservation efforts based on robust predictive models may help to stem the tide of extinctions. With many unique species found only in these habitats, protecting them is important to help avoid biodiversity declines in these regions.

This SciPod is a summary of the paper 'Neotropical cloud forests and páramo to contract and dry from declines in cloud immersion and frost', from *PLOS One*: https://doi.org/10.1371/journal.pone.0213155

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