Met Office

Factsheet 4 of 6
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Risk management of climate thresholds and irreversible change:
Tropical forests

What is the nature of the threshold?

Various processes can cause thresholds and irreversible change in tropical forests[1]. In the fire-vegetation feedback, loss of forest allows fire to spread more easily, driving more forest loss, and making some of the loss irreversible[2, 3]. A climate-vegetation feedback also occurs. Trees release a significant amount of rainwater back into the air, allowing further rainfall. Forest loss reduces this recycling of rainwater, reducing rainfall[4], and driving more forest loss. Again, this can make some forest loss irreversible. Large-scale forest loss is known as dieback.

There is no single threshold of change that could drive large-scale forest loss. This is partly because forests can be affected by human activity in various ways[1]. These include deforestation and fire, climate change, and change in atmospheric CO_2. Also, different parts of tropical forests have different thresholds. For example, the south-southeastern Amazon is at higher risk because of its drier climate and proximity to human activity[5]. However, even the wettest regions are still sensitive to droughts, as they may be adapted to live with high amounts of rainfall. Also, as tree loss can reduce rainfall and raise temperatures in other parts of the forest, loss of tree cover in one area can spread to other parts of the forest.

The risk of large-scale tropical forest loss may be reduced by reducing greenhouse gas emissions and by controlling regional land use[6]. The latter includes encouraging fire-free land use as well as reducing deforestation[6,7] (Fig. 1) and increased tree planting. The pattern of deforestation is important. In recent years, fragmentation of the forest edge has exposed a larger number of trees to fires started by human activity[8].

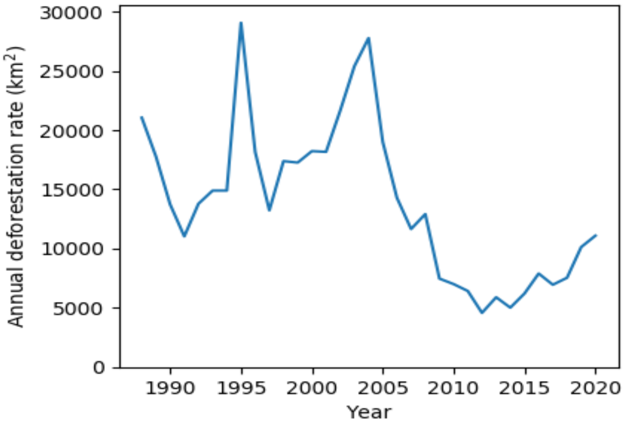

Figure 1. Deforestation rates in the Brazilian Amazon region from 1988 to 2020 (data from PRODES-INPE).[1]

What impacts might be expected if a threshold were crossed?

Some regions could see loss of forests, whilst other may see a change in forest composition (e.g. towards smaller, lower-carbon species[9]). Tropical forests provide a number of ecosystem services, including: supporting millions of species; absorbing large amounts of carbon dioxide (they provide about half of the current global land carbon uptake[3]); influencing and regulating regional water cycles, by recycling rainfall. Reduction in tropical forest carbon uptake would drive further global warming. As well as loss of biodiversity, regional impacts of forest loss would include reductions in hydropower generation, and rainfall over agricultural regions. The regional impacts could be large but may be reduced via a range of adaptation options[6].

If a threshold is crossed, are the changes irreversible?

Some forest loss would be irreversible, due to fire-vegetation and climate-vegetation feedbacks. It is possible that these positive feedbacks are strong enough that most forest loss would be irreversible[2,3], but more research is needed to quantify this[10].

There is some temporary resilience to tropical forest dieback, so it would be possible to overshoot a threshold for some period without dieback occurring. If the climate changes to a point where much of a forest is unsustainable, the forest will not be lost immediately, but over a period of years. This is because forest loss from climate change is expected primarily during extreme drought years[11,12], which place additional stress on trees. Forest dieback would be most likely to occur through a series of extreme droughts spread over a number of years. This temporary period is inherently uncertain as it arises from natural climate variability. However, it would be shorter in a warmer climate, as severe droughts would be more frequent.

How likely is such a threshold to be crossed?

The likelihood of large-scale forest dieback is hard to quantify. There are various thresholds that, if crossed, could lead to large scale forest loss. A threshold could be crossed through either deforestation, or climate change[1], but the greatest risk is from a combination of both.

Some experts have suggested that if around 25-40% of the Amazon forest is lost, this could mean large-scale transition to savanna over the southern and eastern Amazon[1]. At present, around 20% of the Amazon has been deforested.

Current models suggest that if deforestation was halted or reversed, it is unlikely that large-scale dieback would occur during the current century from climate change alone. This is even found[13] in a set of alternative versions of the older Hadley Centre model that had originally[14] projected 21st century Amazon dieback. However, improved understanding of processes such as nutrient limitation and fire, could increase forest loss in future model projections. The combined effect of deforestation and climate change could lead to much greater forest loss.

What are the prospects for early warning and what long-term observing systems need to be maintained?

Any early warning system requires long-term maintenance of consistent observations. Various elements of an early warning system exist, but further research is required to understand the proximity of thresholds. Monitoring of land use is routine, but some deforesters may be adapting to avoid detection[15]. New Met Office work[16] has shown potential for seasonal forecasting of severe drought, which could feed into efforts to encourage fire-free land-use in drought years. Monitoring during[17] and after[18, 19, 20] large droughts is key to help understand forest resilience. The RAINFOR project directly monitors growth and mortality of trees[21] in many plots across the Amazon, giving key information about forest sustainability. A key missing observation is widespread monitoring of plant hydraulic systems: needed to help understand drought threshold proximity. Satellite monitoring of vegetation indices give a global view of forest health[22], while burnt area tracks forest loss from fire. Long-term in-situ drought[9] and fire[12] experiments are providing greater information about forest susceptibility to future changes. The proposed international Amazon Free Air Carbon Enrichment experiment would, if fully funded, provide key understanding about response to future CO_2 increases.

What future research is planned at the Met Office Hadley Centre?

Hadley Centre model improvements are including key new ecosystem processes (nutrient limitations, fire, and vegetation demographics), and their consequences for projections will be explored. Other work may include high-resolution simulations of the effects of forest loss on regional rainfall, and further analysis of seasonal forecast capability.

References – Met Office papers in **bold**

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