The installation of 3000 clear plastic panels simulates an El Niño drought in 4000 m^2 of Daintree rainforest.

A Raincoat for a Rainforest

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How do you study the effects of drought in a rainforest? Try covering one in plastic.

I have been working in the tropics for more than two decades, and I still find that the wet season has to be experienced to be believed. Hot, humid days harken an early darkening sky and often-thunderous downpours. Under the rainforest canopy, one sees, hears and smells the rain minutes before one feels it. The massive trees, vines and epiphytes above need to become saturated before the rain reaches the understorey, giving one a few moments to scurry for shelter or at least a raincoat.

Rainforests are wet places, and have been so for millions of years, but will this always be the case? While most people think about global climate change as the gradual rise of atmospheric carbon dioxide and of temperature, in the short term it's the increasing likelihood of extreme events such as droughts and heat waves that most worries ecologists like myself.

Severe droughts, such as those associated with El Niño or rising sea-surface temperatures, have affected vast areas of tropical rainforest already, including much of the Amazon, Borneo and New Guinea. Leading computer models predict that droughts may become more frequent in the future.

Tree death is one of the most important consequences of drought and, if widespread, can provoke changes in forest composition, carbon storage and flammability.

The problem with extreme events like droughts is that they are inherently unpredictable. We don't know when or where the next drought will occur, making it very difficult to study them or predict their impacts.

Experiments can overcome this. One way to explore the impacts of drought in tropical rainforests is through large-scale water-exclusion experiments – essentially creating an artificial drought.

Globally, large-scale drought experiments in rainforests have only been attempted twice, both in the Amazon. I am leading a third attempt at the Daintree Drought Experiment in northern Queensland. Combining the efforts of plant physiologists, ecologists, soil experts, climatologists and hydrologists, our ambitious goal is to assess the varying responses of plants to drought, from their roots to the highest pinnacles of the forest. Others will study how smaller animals such as insects respond to drought.

The Amazonian drought experiments revealed that trees initially shed their leaves to reduce their water demands. Then, after 3 years of drought, the trees began to die. Larger trees were at a higher risk than smaller trees, which was surprising given that larger trees have deeper roots and hence have access to more soil water. Woody lianas were also more vulnerable to death than many understorey plants. An increase in woody debris on the forest floor was thought to increase the risk of fire significantly in these normally fire-resistant habitats.

The Daintree study employs a 47-metre-tall canopy crane to examine forest functioning at all vertical levels.

Our experiment will greatly extend this knowledge. We will first determine whether Australian rainforests respond similarly to those in the Amazon to determine whether such responses are universal to rainforests. Then, using a 47-metre-tall canopy crane, we will closely observe forest functioning at all vertical levels to help identify the drivers of plant stress and demise.

An estimated 80–90% of all plant species live in tropical forests. It would be impossible to study all of these species, but we can try to understand whether there are general features of plants, such as their leaf or wood anatomy, that make certain species more vulnerable to drought than others. This is another key goal of our study.

Our study is based at the Daintree Rainforest Observatory, a research station operated by James Cook University in the spectacular Daintree region. My colleagues, students and I have just finished installing

Caption? Credit?

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more than 3000 clear plastic panels covering more than 4000 m^2 of rainforest. Prior to this, we spent 2 years monitoring the growth and survival of 700 large trees and 1000 lianas in a 1-ha site that is fully accessible by the canopy crane. In addition, we measured how the rainforest functioned by monitoring the movement of carbon dioxide and soil water in the forest, as well as the rates of sap flow in trees and the primary productivity of the rainforest canopy.

The main goal of our ambitious experiment is to simulate an El Niño drought by increasing the length and severity of the dry season. The typical 4-month-long dry season will be extended to 6 months in duration, and 80–90% of the rain that drips down onto the forest floor will be removed by the plastic sheets and gutters. In the future, we might also dig trenches around our experiment to stop water infiltrating laterally, but this would involve cutting through the roots of a lot of plants, so we won't do this unless it seems essential to the experiment.

We want to study the mechanisms by which droughts create a cascade of fatal stresses. Air bubbles could form in a tree's water vessels because of inadequate water flow, blocking water movement to its leaves. Widespread blockages in a plant could cause immediate death, whereas small blockages could halt photosynthesis, causing the tree to starve to death. In addition, a food- or water-stressed tree might become more vulnerable to attack from insects, pathogens or parasitic plants such as climbing vines.

Such mechanisms might act alone or together, and the particular attributes of plants might influence their vulnerability to different causes of death. For example, trees with higher wood density may be more drought-tolerant because they better resist air bubbles forming in their water-carrying vessels. This resistance may be a consequence of their narrower water vessels.

Among trees, further drought-resistance strategies could include having succulent stems that store lots of water, having deciduous leaves that are shed during dry periods to conserve water, or having strong control over the tiny leaf-pores, called stomata, that a plant opens to take in carbon dioxide for photosynthesis (for every molecule of CO_2 that diffuses into a leaf, a plant typically loses around 140 molecules of water to the atmosphere).

We are hoping to study not just trees but also the myriad other plants in the rainforest – including vines, shrubs and epiphytes – whose responses to drought remain almost entirely unknown.

Our study has faced many logistical challenges – setting up a big experiment like this is never easy – but it attempts to address head-on one of the most potentially serious future threats to tropical rainforests. We know that severe droughts can impact the biodiversity, dynamics, structure and carbon storage of rainforests. Droughts can also have major impacts on atmospheric carbon emissions, evapotranspiration and cloud formation, with both local and global ramifications.

After a lot of hard slogging, our experiment is now underway, and it is an exciting time. We know this research is an important endeavour, because in many different ways rainforests affect us all.

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