Amazon: the beginning of the end?

No way out. Life-lines to remote communities dried completely. Alter do Chao, Brazil.

As global temperatures rise, climate models predict the Amazon will dry out: the rainforest recently suffered its worst drought in living memory. **John Gash** and **Peter Cox** assess the causes and discuss how the forest responded.

South-west Amazonia's dry season normally starts in August and finishes early September. In 2005 it began in May and continued into October. Virtually no rain fell over large areas of the Brazilian states of Acre and Rondônia, nor in the neighbouring regions of Bolivia and Peru. Rivers, which were already unusually low at the start of the dry season, dried up and remote communities which rely on river transport lost access to supplies of food, as well as schools and hospitals.

At the same time a series of hurricanes, most famously 'Katrina' which destroyed New Orleans, battered the Caribbean and the southern coast of the United Sates.

Climatologists were asked for explanations. Were these events connected? Was this climate change in action? Will the rainforest survive?

While it is not possible to unequivocally attribute a given drought to either global warming or deforestation, it is clear that unlike most of the previous droughts in Amazonia, the 2005 drought was not caused by El Niño conditions in the Pacific Ocean. Climatologist José Marengo of the Brazilian climate centre analysed the meteorological and ocean conditions in 2005. He concluded that the drought was associated with the unusual conditions in the Atlantic. José said, 'The warm sea surface temperature in the tropical north Atlantic created a weather pattern which reinforced the subsiding air over south-west Amazonia giving drought conditions – this same warm sea surface temperature can also be linked to the enhanced hurricane activity in the Caribbean.'

> Were hurricane Katrina and the Amazon drought connected?

Phil Harris of the Centre for Ecology & Hydrology has been looking at how the rainfall in Amazonia may change in response to global warming. Phil has analysed output from the Hadley Centre global climate model looking at how future changes in sea surface temperature could alter weather patterns and rainfall over Amazonia. He found that warm temperatures in the eastern Pacific Ocean tend to result in less rain in Amazonia in the wet season, but in contrast warm temperatures in the Atlantic produce drier dry seasons. Because trees have mechanisms to survive short droughts (see 'Creating artificial drought conditions') the rainforest could probably survive either of these, but if they occur together, or if there is a series of droughts, the future for the forest looks precarious. As

Daniel Beltra/Greenpeace

Phil says, 'You would need them all to happen at once, but if all the things that the model says could happen, do happen – then forest die-back could become a reality.'

The consequences of Amazonian forest die-back would be serious. Apart from the loss of the world's greatest store of biodiversity, there is the possibility that this vast area, which is now a sink of carbon, would become a carbon source (soil and decaying plants can release carbon to the atmosphere). This would result in a positive feedback amplifying global warming.

The next scientific challenge is to apply the new knowledge we have on how forests react to drought to make more reliable predictions of the impacts of global warming. The questions are far-reaching: will global warming increase the severity and frequency of Amazonian droughts? How resilient is the Amazon rainforest to drought? How did the rainforest respond to the 2005 drought? Under what conditions will the Amazon rainforest die back? Is there a critical 'dangerous' carbon dioxide level at which this will occur?

NERC is supporting projects that address many of these questions, including the QUEST-QUERCC* project which is improving models of how plants respond to drought conditions; NERC's CLASSIC** Earth Observation Centre which is using satellite-data to detect changes in land-cover and to model how these feedback on climate; and a consortium project which is studying the conditions under which tropical forests will convert to savannah. These projects are part of a growing worldwide effort to understand the sensitivity of the planet's most diverse forest ecosystem to the combined pressures of deforestation and climate change. The results of these studies are urgently needed to inform policies designed to deal with climate change and biodiversity conservation.

Creating artificial drought conditions

A controlled, manipulative experiment is a good way to discover how well the rainforest trees will survive future droughts. Patrick Meir and Rosie Fisher from Edinburgh University have been working in the eastern Amazon, with scientists from the Brazilian Federal University of Para and the Museu Goeldi in Belém. They created an artificial drought by excluding half of the rainfall from a 100-metre-square plot of forest. Plastic sheeting intercepted rainwater dripping off the canopy and piped it away before it could reach the soil; a one-metre deep trench around the edge of the plot prevented water flowing in from outside.

Measurements of the sap flowing up the tree trunks and out through the leaves showed that as the soil dries out, evaporation reduces. The drought-stressed trees closed their stomata – the small holes in their leaves – and used only a quarter of the water used by the trees in the control plot. Rosie Fisher believes that this is a survival mechanism to maintain the capillary action which keeps the canopy leaves supplied with life-giving water. 'As the soil becomes drier it becomes progressively more difficult to extract water from it and the leaves have to exert a greater suction. If the suction were to become too great the narrow threads of water in the sap wood would break, the water supply would fail and the trees would die' explained Rosie.

Rosie Fisher measuring how a drought-stressed tree restricts its water use.

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* QUEST-QUERCC: Quantifying and Understanding the Earth System - Quantifying ecosystem roles in the carbon cycle
** CLASSIC: Climate and Land-Surface Systems Interaction Centre

Marked rise in forest fires

South-west Amazonia has a relatively low rainfall and is close to the natural edge of the rainforest zone. During the 2005 drought the undergrowth of the forest became tinder dry, causing widespread forest fires with satellite images revealing vast plumes of smoke covering the region.

NERC provided an urgency grant to a team from Leeds and Oxford universities, led by Oliver Phillips, to assess the damage to the forest ecosystem caused by the drought. Members of the team, Yadvinder Malhi, Luiz Aragão and colleagues analysed the satellite images and discovered that in 2005, the total number of forest fires in the region increased by 280 percent compared to 2004. Luiz said, 'Fires are likely to be the major agent of forest transformation, and if droughts become more frequent south-western Amazonia looks especially vulnerable.'

Scientists measuring the impact of the drought from the change in tree girth of 30,000 trees across Amazonia.