

Institution: University of Exeter
Unit of Assessment: Earth Systems and Environmental Sciences (UoA7)
Title of case study: Amazon Rainforest and Climate Change
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Research at the University of Exeter on the links between the Amazon rainforest and climate change has influenced international climate policy, has directly assisted Brazilian environmental policymakers, and has received international media coverage. The underpinning research spans the vulnerability of the rainforest to anthropogenic climate change and the mechanisms behind the Amazonian droughts of 2005 and 2010. Impact has been achieved by stimulating public debate through the media, by contribution to science-into-policy documents produced by the World Bank and for the United Nations Framework Convention on Climate Change (UNFCCC), and by direct face-to-face interaction with UK and Brazilian policymakers.</p>
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>The Amazon basin is a key component of the Earth System providing about a fifth of all of the freshwater inputs to the global oceans. It is a hotspot for biodiversity that houses about 10% of all species on Earth, and it is home to 25 million people. The Amazon rainforest also stores 120 billion tonnes of carbon, and exchanges about 10 billion tonnes of carbon per year with the atmosphere. The future of the Amazon rainforest is therefore of critical importance for the climate system, for the global carbon cycle and biodiversity, and therefore for the well-being of humanity.</p> <p>The Amazon rainforest is however currently suffering from multiple pressures associated with direct deforestation and from changes in mean climate and climatic extremes. Research carried-out by University of Exeter researchers has led to concerns that the Amazon rainforest could “dieback” in the 21st century, releasing carbon to the atmosphere and accelerating climate change, as well as damaging the ecosystem services that the forest currently provides. This notion of “Amazon forest dieback” emerged from climate-carbon cycle projections carried out by University of Exeter researchers Peter Cox and Richard Betts when they were both full-time at the Met Office-Hadley Centre. Underpinning the impact here is subsequent research, all carried out since Cox moved to the University of Exeter in 2006, which has developed a deeper understanding of the mechanisms and risk of Amazon dieback.</p> <p>A key paper in 2008 identified an unexpected link between changes in air quality and the risk of 2005-like droughts in Amazonia [1]. It showed that reducing anthropogenic aerosol pollution in the Northern Hemisphere, associated primarily with reduced sulphur dioxide emissions from burning sulphurous coal, has allowed the tropical north Atlantic to warm relative to the south, prompting the Inter-tropical Convergence Zone (ITCZ) to move northwards and delaying the onset of the rainy season in the south and west of Amazonia.</p> <p>This research helped motivate a special issue of <i>New Phytologist</i> in 2010, in which Cox, Jupp and their collaborators on a World Bank funded project (see section 4) estimated the risk of future drying in key regions of Amazonia based on projections from 23 climate models [2]. In 2010, Luiz Aragao of the University of Exeter also published an influential paper which suggested that some of the additional carbon storage arising from avoided deforestation would be offset by increases in the frequency of forest fires [3].</p> <p>Recent research by Cox, Friedlingstein and collaborators, published in 2013 [4], has identified an “emergent constraint” on the loss of tropical land carbon as a result of climate change, which arises from the observed inter-annual variability in the atmospheric CO₂ concentration. As such it significantly reduced the uncertainties concerning the risk of Amazon forest dieback [5], and identified the extent of the CO₂ fertilization of tropical forest growth as the remaining key uncertainty.</p>

Impact case study (REF3b)

3. References to the research (indicative maximum of six references)

Key references to research that underpins the impact described in this case study (*University of Exeter researchers in italics*):

- 1) Cox, P.M., Harris, P., Huntingford C., Betts, R.A., Collins, M., Jones, C.D., Jupp, T.E., Marengo J., Nobre, C., 2008. Increasing risk of Amazonian drought due to decreasing aerosol pollution. *Nature*, 453, 212-216. #
- 2) Jupp, T.E., Cox P.M., Rammig, A., Thonicke, K., Lucht, W., Cramer, W., 2010. Development of probability density functions for future Amazonian rainfall. *New Phytologist*, 18, 682-693.
- 3) Aragao, L.E.O.C., Shimabukuro, Y.E., 2010. The incidence of fire in Amazonian forests with implications for REDD. *Science*, 328, 1275-1278. #
- 4) Cox, P.M., Pearson, D., Booth, B.B.B., Friedlingstein, P., Huntingford, C., Jones, C.D., Luke, C.M., 2013. Sensitivity of tropical carbon to climate change constrained by carbon dioxide variability. *Nature*, doi:10.1038/nature11882. #
- 5) Huntingford, C. et al (includes Cox, P.M.), 2013. Simulated resilience of tropical rainforest to CO₂-induced climate change. *Nature Geoscience*, doi: 10.1038/geo1741.

References that best indicate the quality of the underpinning research.

Grant support related to this research:

- World Bank Project on Amazon Dieback, Exeter PI: Peter Cox, Sponsor: World Bank, Period: 2008-2009, Value: £125,000.
- NERC Emergency Grant on Amazon 2010 drought, Exeter PI: Luiz Aragao, Sponsor: NERC, Period: 2010-2012, Value: £52,566.
- NERC International Opportunities Fund: PULSE-Brasil project, Exeter PI: Peter Cox, Sponsor: NERC, Period: 2012-2015, Value: £240,803.

4. Details of the impact (indicative maximum 750 words)

Our close engagement with key stakeholders has led to impacts on international policy and Brazilian environmental policy. Extensive media coverage has stimulated widespread public debate.

Informing International Policy

The intact Amazon rainforest is currently absorbing about 1 billion tonnes of carbon per year (i.e. more than 10% of annual anthropogenic CO₂ emissions), but this has been almost completely offset by the carbon dioxide emissions due to deforestation over the last few decades. Largely in response to widespread tropical deforestation, the UNFCCC introduced the mechanism *Reducing Emissions from Deforestation and Forest Degradation* (REDD) in 1995. REDD is a set of steps designed to use market and financial incentives to reduce the emissions of greenhouse gases from deforestation and forest degradation. Exeter's research concerning changing fire frequency in Amazonia and the implications for REDD policy [3] is referenced in UNEP and FAO documents [a,b].

More general concerns over the risk and impact of Amazonian forest dieback led the World Bank to fund a project in 2008 with the goal "to assist in understanding the risk of a potential reduction in biomass density in the Amazon basin induced by climate change impacts (Amazon dieback) and its implications". Cox and Jupp of the University of Exeter were contracted members of the World Bank's project team along with collaborators from Brazil, Japan and Germany. Interim reports from the project were presented to the UNFCCC "Subsidiary Body for Scientific and Technical Advice (SBSTA)", and the project outcomes continue to feed into public debate [c] and UNFCCC policy discussions concerning the "permanence" or otherwise of tropical carbon stores [d]. The project published its full report in 2010 [e], concluding that *fertilization effects of elevated atmospheric*

Impact case study (REF3b)

carbon dioxide levels on forest ecosystems like the Amazon have proven to be a key unknown”, and that “Amazon dieback should be considered a threshold for dangerous climate change”. Both of these conclusions derive in large part from work carried-out by researchers at the University of Exeter (see Section 2).

Our most recent research findings, which constrains the loss of tropical land carbon under climate change, were reported by the *International Geosphere-Biosphere Programme (IGBP)* to the *United Nations Framework Convention on Climate Change (UNFCCC)* “Subsidiary Body for Scientific and Technical Advice (SBSTA)”, at its meeting in Bonn in June 2013 [f]. The results of this research have also been made available to UK policymakers through Cox’s position on the Scientific Advisory Group of the *Department of Energy and Climate Change (DECC)*, where they have contributed to the UK’s more positive attitude towards avoided deforestation within the UNFCCC negotiations.

Brazilian Environmental Policy

Our research in this field has also had a very direct impact on environmental policymakers in Brazil. After the publication of his paper in 2010 [3], Luiz Aragao met with policymakers from the Acre regional government of Brazil to discuss the policy implications. Out of that meeting grew a long-term collaboration between the University of Exeter, the *Brazilian National Institute for Space Research (INPE)*, and the *Brazilian State Government of Acre*, which culminated in the funding of a joint project called “PULSE-Brazil”, which Cox leads. This project is developing a Geographical Information System (GIS) to display and analyse data on the changing environmental conditions in Brazilian Amazonia, so as to inform policy concerning responses to environmental change in the State of Acre and other vulnerable States of Brazil [g]. PULSE-Brazil has enabled very direct interaction with the Environmental Secretary of Acre (Vera Reis) who has attended all of the project meetings, and has been aided by the hiring of a Portuguese speaking project manager (Duarte Costa) who is spending extended periods working alongside the Acre officials in Brazil to facilitate effective knowledge exchange.

Informing Public Debate through the Media

The iconic nature of the Amazonian rainforest and its importance for the Earth System, make our research of great interest to the public and the media. Research from the University of Exeter has contributed significantly to public debate, appearing in newspapers and television programmes. For example, the Amazonian drought of 2010 and its mechanisms were discussed extensively by the BBC [h], and the “Amazon Dieback Scenario” was covered by the New York Times in 2011 [i]. Amazon dieback was also described in the BBC1 Horizon “Hot Planet” episode that aired in 2009 and 2010, and on which Cox appeared and was the scientific consultant [j]. In 2012, Cox spent 2 weeks in Amazonia making a TV programme, which aired in the US in October 2013 (<http://www.thetippingpoints.com/>).

5. Sources to corroborate the impact (indicative maximum of 10 references)

- a) A safer bet for REDD+: review of the evidence on the relationship between biodiversity and the resilience of forest carbon stocks (2010). <http://www.unep-wcmc.org/medialibrary/2011/08/30/5cd5ebd7/A%20safer%20bet%20for%20REDDplus%20Resilience%20review.pdf>
- b) UN Food and Agriculture Organization publication on: REDD-plus and biodiversity: opportunities and challenges <http://www.fao.org/docrep/013/i1758e/i1758e14.pdf>
- c) World Bank Report on Amazon Dieback (2010) <http://www.bicusa.org/en/Article.11756.aspx>
- d) Amazon Dieback and the 21st Century (2011). http://pib.socioambiental.org/anexos/19928_20110517_110041.pdf
- e) Submission to the UNFCCC AWG-LCA (2012). <http://unfccc.int/resource/docs/2012/smsn/ngo/204.pdf>
- f) UNFCCC Subsidiary Body for Scientific and Technical Advice, Bonn, June 2013.

Impact case study (REF3b)

<http://unfccc.int/resource/docs/2013/sbsta/eng/misc05a01.pdf>

- g) PULSE-Brazil website and GIS tool. http://www.pulse-brasil.org/?page_id=76
- h) BBC1 New article on 2010 Amazon Drought (2010). <http://www.bbc.co.uk/news/science-environment-12362111> .
- i) New York Times (2011), "The Amazon Dieback Scenario". http://green.blogs.nytimes.com/2011/10/07/the-amazon-dieback-scenario/?_r=1
- j) BBC1 Horizon Documentary, "Hot Planet" (2009). <http://www.bbc.co.uk/programmes/b00jf6md#clips>