Institution: University of Exeter

Unit of Assessment: 17a (Geography & Environmental Studies)

Title of case study: Developing Evidence-Based Policies for Tropical Forest Management and Carbon Emission Reductions

1. Summary of the impact (indicative maximum 100 words)

Dr Luiz Aragão in Geography at Exeter has, since 2008, led research focused on quantifying the impacts of environmental change on fire risk and carbon dynamics in Amazonian forests. This has had a number of impacts. First, research into drought frequency and intensity and fire occurrence has directly informed the **design and implementation of environmental policy and regulation** in relation to a 'zero fire' policy by the State of Acre in Brazil. Second, the research has led to the development of **new monitoring tools to assist policy makers** in understanding the interactions between climate, ecosystems, and human health in Amazonia. Third, research into carbon emissions has **influenced methodological development** within the United Nations REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) programme in Colombia. Finally, Dr Aragão's research has been widely disseminated in media outlets, thus **increasing awareness of the general public and policy makers** on drought and fire issues in Amazonia.

2. Underpinning research (indicative maximum 500 words)

Around 1.3 billion tonnes of carbon is emitted to the atmosphere annually as a result of land cover change – and this is mostly occurring in the tropics (Le Quere et al., 2009). As a result, there has been a marked increase in interest, from a policy perspective, in curbing carbon emissions that occur due to tropical deforestation and forest degradation. This is particularly evident through the United Nation's REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) programme. However, the ability to develop and implement more effective policy approaches has necessitated a much greater scientific knowledge around the vulnerability of carbon stocks in tropical rainforests – especially within the context of climate change-induced droughts, increased fire risk, and increased human activity. This case study describes research on these issues conducted by Dr Aragão, which has examined two specific aspects of this problem: (1) the relationships between drought, fire, and human activity; and (2) tropical forest-based carbon dynamics. This research has had a direct impact on regional environmental policy and practice.

NERC-funded research by Dr Aragão initially focused on the relationships between drought, fire, and human activity, and used datasets from the 2005 regional drought as a proxy for modelling future climate conditions in Amazonia. This research demonstrated that 48% of the Amazon basin experienced severe water deficits, resulting in a 33% increase in fires in comparison to long-term averages (Aragão et al., 2007). In addition, research by Dr Aragão and colleagues into tropical forest biomass dynamics demonstrated that the 2005 drought had the effect of reducing total carbon biomass by 1.2-1.6 billion tonnes of carbon due to tree mortality and reduction in forest productivity (Phillips, Aragão et al., 2009, Phillips et al., 2010). Moreover, before the drought Amazonia was a sink of 400 Mt of carbon, but during the 2005 drought this ecosystem became a source of 900 Mt of carbon to the atmosphere (Phillips, Aragão et al., 2009). Aragão then used similar methods to quantify the potential of carbon assimilation in undisturbed Amazonian forests (Aragão et al., 2009), demonstrating how above- and below-ground net primary productivity of undisturbed Amazonian forests correlated with soil properties, including phosphorus.

Since 2009, Dr Aragão's research on the relevance of fire to efficient implementation of REDD programs has become especially critical. This research, which used statistical techniques to analyse satellite-derived data on active fires and deforestation in Amazonia, showed that because of the combined effects of human activity, droughts and forest fragmentation, that the incidence of fires was likely to increase even when rates of deforestation were declining, potentially affecting carbon savings through REDD programs (Aragão & Shimabukuro, 2010). A major outcome of this work was that Dr Aragão became increasingly involved in collaborative research with the Brazilian Acre State Government (the epicentre of the 2005 drought) to assess fire mitigation options,

research that became particularly important when the Amazonia area was severely affected by a second major drought in 2010. This included research to develop the PULSE tool (Platform for Understanding Long-term Sustainability of Ecosystems) that was jointly funded in 2012 by NERC and Sao Paulo State Research Council in Brazil, and is aimed at understanding interactions between climate, ecosystems, and human health in Amazonia.

Key researcher
Dr Luiz Aragão, Senior Lecturer in Geography (2008 to present), University of Exeter.

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

Evidence of the quality of the research that underpins this case study is provided through the following peer-reviewed publications and grants secured through competitive funding sources.

Aragão, L., Malhi, Y., Barbier, N., Lima, A., Shimabukuro, Y., Anderson, L., Saatchi, S. 2008. Interactions between rainfall, deforestation and fires during recent years in the Brazilian Amazonia. *Philosophical Transactions of the Royal Society* B 363, 1779-1785.

Aragão, L., Malhi, Y., Metcalfe, D., Silva-Espejo, J. et al. 2009. Above- and below-ground net primary productivity across ten Amazonian forests on contrasting soils. *Biogeosciences* 6 (12), 2759-2778.

Aragão, L., Malhi, Y., Roman-Cuesta, R., Saatchi, S., Anderson, L., Shimabukuro, Y.E. 2007. Spatial pattern and fire response of recent Amazonian droughts. *Geophysical Research Letters* 34, doi: 10.1029/2006GL028946.

Aragão, L. and Shimabukuro, Y. 2010. The incidence of fire in Amazonian forests with implications for REDD. *Science* 328, 1275-1278.

Phillips, O., Aragão, L., Lewis, S., Fisher, J. et al. 2009. Drought sensitivity of the Amazon rainforest. *Science* 323, 1344-1347.

Phillips, O., van der Heijden, G., Lewis, S., López-González, G., Aragão, L. et al. 2010. Drought-mortality relationships for tropical forests. *New Phytologist* 187 (3), 631-646.

Grants underpinning research:
- Impacts of Climate Extremes on Ecosystem and Human Health in Brazil: PULSE-Brazil. NERC International Opportunity Fund (NE/J016276/1), Co-Investigator, £250,000, 2012-2015
- Immediate responses of forests to understorey fires during the 2010 Amazonian drought. NERC Urgency Grant (NE/I018123/1), Principal Investigator, £65,000, 2011-2012.
- Mapping and quantifying post-fire carbon budget in Amazonia. NERC Fellowship (NE/F015356/1). Principal Investigator, £292,000, 2008-2012.
- Assessing the impacts of the recent Amazon drought, NERC Urgency Grant (NE/D01025X/1), £150,000, 2006-2008.

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

Dr Aragão's research has had impact at global (United Nations), national (Colombia), and state (Acre - Brazil) levels, informing the **design and implementation of environmental policy** to regulate fire usage in Amazonia, underpinning the development of **new monitoring tools to assist policy makers** in the region, and has **influencing methodological developments** within the United Nations REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) programme in Colombia.

In Amazonia, fire has been routinely used to clear primary rainforest, but has major ecosystem, carbon cycle and land management implications. Research undertaken by Dr Aragão has strongly influenced the design and implementation of **new 'zero fire' policies and regulation** within the State of Acre, Acre being one of the 9 Brazilian Legal Amazonia States, and covers an area of ~164,000 km^2 (larger than England and Wales together). Since 2008, the Brazilian Public Ministry has been working to eradicate fire usage for land management, a campaign that ultimately led to a

Civil Action in April 2011 to curb the use of fire in land clearance by 2011. Aragão's research was used to support this legal action by the Brazilian National Public Ministry and the Public Ministry of Acre State against the State of Acre Municipalities and relevant environmental bodies. Dr Aragão was the only UK-based academic quoted in the legal action, and evidence is provided both in the Legal Action document listed in Section 5 (evidence **item #1**), which is also publically available at the official website of the Brazilian Public Ministry (http://www.prac.mpf.gov), and in a letter from the Attorney of the Republic at Acre State (evidence **item #2**). This action has led directly to improved management of fire risk in this region, with recent data from the Brazilian National Institute of Space Research's fire monitoring system showing that the Civil Action has been responsible for a reduction of 49% in fire occurrence in Acre State in 2011 and 2012 in relation to the decadal mean (2001-2010).

This positive result then allowed Aragão to secure (in Dec 2011) the support of Acre's government Institute for Climate Change (see evidence **item #3**), for the development of the PULSE tool (Platform for Understanding Long-term Sustainability of Ecosystems) in a collaborative project funded by the NERC and Sao Paulo State Research Council in Brazil. This project is specifically aimed at **supporting policy makers** to analyse, visualise, and understand the interactions between climate, ecosystems, and human health in Amazonia. The knowledge gained through the body of research is being integrated into a web-based platform by scientists and government agents in a participative effort to facilitate decision-making processes and long-term environmental planning, and to directly **improve public awareness** on the impacts of fire and drought on carbon emissions in the Amazon by making the tool publically available.

Aragão's work (Aragão & Shimabukuro, 2010) has also **changed awareness of policy makers** on the critical importance of considering fires in relation to the international REDD policy framework. Aragão's scientific findings have, since 2011, been used as scientific reference in reports by the United Nations (UN) Ecosystem Program and the United Nations Food and Agriculture Program **to help design the REDD+ environmental policy** within the UN- REDD program (see evidence **items** #**4, 5, 6**). This has global implications for strategies to mitigate climate change impacts by reducing carbon emissions from land use change and for safeguarding tropical biodiversity. Based on Aragão's findings, REDD authorities are now aware that reducing deforestation in tropical nations alone does not warranty the permanence of carbon stocks. Rather, the success of REDD concepts depends upon redesigning policies to accommodate mitigation of fire occurrence. In this context, Aragão has contributed as a Scientific Advisor (since 2009) to the development of Colombian **government policy** on reducing carbon emissions. In particular, research on methodologies to measure carbon changes in forest biomass (see Section 3) was fundamental to influencing the Colombian REDD+ pilot program's standards and guidelines for quantifying and monitoring carbon stocks in Colombian forests. Aragão's participation as the only UK scientific advisor (Oct 2009) at the meeting *Technical and Scientific Capacity to Support REDD projects in Colombia* directly assisted the implementation of the Colombian's REDD+ methodological framework, leading to impact on policy development for a national government and United Nations REDD+ program (see evidence **item #7**). The output of this action was the creation of the Colombian REDD+ policy protocol coordinated by the Colombian's National Institute of Hydrology, Meteorology, and Environmental Studies and the Ministry of Environment. This protocol was subsequently presented by representatives of the Colombian Official Committee at the Conference of the Parties 17 to the United Nations Framework Convention on Climate Change (UNFCCC), in Durban on the 2nd of December 2011 (see **item #8**).

Finally, through attention from the Brazilian and international media that has disseminated Aragão's research findings widely, the body of research outlined in Section 2 has **increased the awareness of the general public and policy makers** on drought and fire issues in Amazonia. This has occurred through quotes in several broadly disseminated News channels, including the BBC. Aragão has also been interviewed by renowned Brazilian newspapers to comment on fire problems in Brazil and featured on BBC News at 10 commenting on the 2010 drought impacts in Amazonia (see **items #9**). In addition, Aragão's work on carbon assimilation has been cited in the Brazilian Government Panel on Climate Change report (see **item #10**), which is a major vector to inform public and policy makers on climate change impacts, mitigation and adaptation in Brazil.

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

#1. Legal action by the Public Ministry of National Government against Acre state to curb fire (in Portuguese) – (http://www.prac.mpf.gov.br/atos-dompf/acp/acp%20queimadas.PDF/view).

#2. Letter from Anselmo Lopes – Attorney of the Republic, Lead author of the Public Civil Action to prohibit fire usage in the State of Acre, Brazil.

#3. Letter from Eufran do Amaral President of Climate Change Institute and Environmental Services Regulation of Acre State - IMC

#4. Miles, L., Dunning, E., Doswald, N., Osti, M. 2010. A safer bet for REDD+: Review of the evidence on the relationship between biodiversity and the resilience of forest carbon stocks. Working Paper v2. Multiple Benefits Series 10. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK (http://www.unep-wcmc.org/medialibrary/2011/08/30/5cd5ebd7/A%20safer%20bet%20for%20REDDplus%20Resilience%20review.pdf)

#5. Miles, L., Dunning, E., Doswald, N. 2010. Safeguarding and enhancing the ecosystem-derived benefits of REDD+. Multiple Benefits Series 2. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge, UK (http://www.unep-wcmc.org/multiple-benefits-series-2_629.html)

#6. Miles, L. And Dickson, B. 2010. REDD-plus and biodiversity: opportunities and challenges. Forests, people and wildlife, Unasylva No. 236, Vol. 61, 2010/3, Food and Agriculture Organization of the United Nations, Rome. (http://www.fao.org/docrep/013/i1758e/i1758e14.pdf)

#7. Letter from Ministry of Environment and Sustainable Development, Government of Colombia, confirming Dr Aragão's role as an expert witness and in designing the environmental monitoring for the REDD+ program in Columbia.

#8. National Institute of Hydrology, Meteorology and Environmental Studies. Institutional Technical and Scientific capacity to support reducing emissions from deforestation and forest degradation projects –REDD – in Columbia. The Forest and Carbon initiatives of the Group on Earth Observations GEO COP – 17 Durban (Dec 2011).

#9. BBC Brasil 2010: Fires can anulate REDD gains in Amazonia http://www.bbc.co.uk/blogs/portuguese/planeta_clima/2010/06/queimadas_na_floresta_amazonic.shtml and http://www.bbc.co.uk/news/10228989

#10. Martinelli, L.A., Pinto, A.S., Rocha, H., Ometto, J.P., Nardoto, G.B. (2012) Volume 1. Scientific Basis of Climate Change. Chapter 5 Biogeochemical Cycles and Environmental Change. Brazilian Panel on Climate Change (http://www.pbmc.coppe.ufrj.br/documentos/PBMC-VOLUME1-RAN1.pdf)