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*Introduction*

# The future of South East Asian rainforests in a changing landscape and climate

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With a focus on the Danum Valley area of Sabah, Malaysian Borneo, this special issue has as its theme the future of tropical rainforests in a changing landscape and climate. The global environmental context to the issue is briefly given before the contents and rationale of the issue are summarized. Most of the papers are based on research carried out as part of the Royal Society South East Asia Rainforest Research Programme. The issue is divided into five sections: (i) the historical land-use and land management context; (ii) implications of land-use change for atmospheric chemistry and climate change; (iii) impacts of logging, forest fragmentation (particularly within an oil palm plantation landscape) and forest restoration on ecosystems and their functioning; (iv) the response and resilience of rainforest systems to climatic and land-use change; and (v) the scientific messages and policy implications arising from the research findings presented in the issue.

**Keywords:** rainforest; climate change; land-use change; land management; landscape

Forests are valued both for their biodiversity and for the many ecosystem services that they provide at the local, regional and global level. For example, deforestation and forest degradation contribute between 15 and 25 per cent of current human-associated greenhouse gas emissions. Forests are under threat from many quarters including clear-cut and selective logging and conversion to agriculture and other land uses. Fragmentation and degradation of the remaining forest (including over-harvesting of bush meat) and the effects of climate change including increased risk of drought and forest fires further threaten this vital resource. It is no surprise then that forests are intricately involved in many current global environmental initiatives including the Convention on Biodiversity and the successor to the Kyoto Protocol. Efforts to bridge the gap between policies concentrating on biodiversity and those focused on greenhouse gases include the REDD+ initiative that aims to integrate efforts to Reduce Emissions from Deforestation and forest Degradation with conservation and the sustainable management of forests. The current importance of forests is further reflected in the fact that 2011 is the United Nations International Year of the Forests.

This theme issue addresses the future of rainforests in a changing landscape and climate. Although the coverage is the global tropics, the focus is on the island of Borneo, as most of the papers are based on research carried out as part of the Royal Society South East Asia Rainforest Research Programme (SEARPP) based at Danum Valley in Sabah. This theme issue provides a synthesis of SEARRP research since previous special issues in 1992 [1] and 1999 [2]. Themes of successive 5 year periods of SEARPP research since 2000 have been: *extreme events and sustainability of tropical forests in a changing world* (2000–2004); *supporting biodiversity and biogeochemical flux research in tropical rain forests* (2005–2009); and *the future of tropical forests in a changing landscape and climate* (2010–2014). Most of the papers in this issue were given at a symposium sponsored by the Royal Society within the ATBC (Association of Tropical Biology and Conservation) Conference held in Bali in July 2010.

SEARPP has been based at the Danum Valley Field Centre in the Malaysian state of Sabah in the northeast of the island of Borneo since the inception of the Programme in 1985. The field centre is located at the edge of Danum Valley Conservation Area—an area of 438 km$^2$ of primary, mainly lowland forest with Class I protection—and at the centre of a much larger area of

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One contribution of 16 to a Theme Issue 'The future of South East Asian rainforests in a changing landscape and climate'.

now mostly twice-logged natural forest licensed for timber production [3]. Some of the area has undergone or is undergoing conversion to oil palm or timber plantations and forest rehabilitation projects have also been instituted. The Danum Valley region thus provides the full range of major land-use types and an ideal base for studying lowland dipterocarp rainforests and how they are affected by a combination of land management and global change. The research is carried out in collaboration with several key local institutions, including Yayasan Sabah (the Sabah Foundation) and its commercial arm the Innoprise Corporation; Universiti Malaysia Sabah (UMS); the Sabah Forestry Department; the FACE Foundation; the Sime Darby Foundation; and the Malaysian Meteorological Department.

The theme issue is divided into five sections. An initial short section comprises this introduction and an analysis of land-use and land management change since 2000 in Sabah, and the Danum Valley region in particular, in order to provide a context for most of the papers of the issue. The three core sections focus on: rainforest land-use change and implications for atmospheric chemistry and climate; impacts of logging, forest fragmentation and restoration on ecosystems and their functioning; and the response and resilience of rainforest systems to climatic and land-use change. The conclusion explores some of the scientific messages and policy implications arising from the research findings.

The section on atmospheric chemistry presents results from the 'OP3' consortium, via a NERC Thematic Programme on 'Oxidant and Particle Photochemical Processes above a South-East Asian tropical rainforest', consisting of 23 Principal Investigators (PIs) and co-PIs from eight UK institutions (including the NERC Facility for Airborne Atmospheric Measurements) and their partners the Malaysian Meteorological Department, UMS and Yayasan Sabah (the Sabah Foundation). The project also contributes to the activities of the European Commission Network of Excellence 'ACCENT' (Atmospheric Composition Change, the European NeTwork) and uses the Danum Valley research facilities, including the 100 m Global Atmospheric Watch research tower, sited in rainforest at Bukit Atur, from which the net surface to atmosphere exchange of heat, momentum and a range of trace gases and particles have been measured. Additional sites in the region provide measurements at the soil surface and over tree canopies to allow the differences between rainforest and oil palm plantations in the net exchange of trace gases and particles to be quantified. Three papers describe the measurements and summarize the main differences in net exchanges of greenhouse gases and other trace gases involved in the production of photochemical oxidants in the atmosphere and particles over the two contrasting land uses (lowland dipterocarp rainforest and oil palm plantations). The measured fluxes of trace gases and particles are then used within atmospheric chemistry and transport models to quantify the feedbacks between the different land uses and air quality and climate at local, regional and global scales. The final paper in this section by Malhi *et al.* [4] addresses the terrestrial carbon cycle of tropical rainforest areas and assesses spatial variations in the allocation of ecosystem net primary productivity between canopy, woody tissue and fine roots across the global tropics.

Section three examines the impacts of logging, forest fragmentation and forest restoration on these ecosystems, including their functioning. Bagchi *et al.* [5] address one of the main mechanisms proposed for the maintenance of biodiversity in tropical forests and examine how it is affected in selectively logged forests. The Janzen–Connell hypothesis is a coexistence mechanism based on density-dependent effects of natural enemies on recruitment: higher levels of attack by specialist seed predators limit recruitment by abundant tree species and generate a rare species advantage for their competitors. While logged forests lack many of the features of primary forests, they may nevertheless be of conservation value, especially in comparison to alternative land uses. The papers by Woodcock *et al.* [6] and by Hill *et al.* [7] address the conservation values of heavily degraded forests and remnant forest fragments, respectively. When secondary forest is lost, it is often through conversion for palm oil production. Foster *et al.* [8] examine the biodiversity found in oil palm plantations and ask whether biodiversity could be increased in these areas, ideally while bringing associated ecosystem service benefits. The final two papers in this section describe two new long-term (decadal) ecological studies that must rank among the biggest ever attempted. Ewers *et al.* [9] introduce the Stability of Altered Forest Ecosystems Project that is the latest in a small number of landscape-scale habitat fragmentation experiments. The project will examine the impacts of forest fragmentation in Malaysian Borneo through conversion to oil palm plantation using a state-of-the-art design that builds on earlier pioneering efforts, including the well-known BDFP experiment on the other side of the world in the Brazilian Amazon. The Sabah Biodiversity Experiment presented by Hector *et al.* [10] also addresses the stability and functioning of forest ecosystems but in this case through their restoration and in particular the use of tree diversity. Essentially, it extends the widely used experimental approach to examining the link between biodiversity and ecosystem functioning to these palaeo-tropical systems and asks whether they function better when enrichment planted with a greater diversity of tree species.

Section four focuses on the response and resilience of rainforest systems to land use and, in particular, climatic change. Mercado *et al.* [11] ask to what degree variability in the rate of above-ground woody biomass production across Amazonia can be explained by differences in photosynthetic carbon fixation rates and the underpinning supply of key nutrients, notably phosphorus. Walsh *et al.* [12] consider longer term effects of land use and climate change on rainforest erosion processes. They use a combination of long-term monitoring and sediment dating and fingerprinting techniques to assess how erosional impacts at different spatial scales in the Segama catchment in Sabah have varied with logging methods, terrain steepness and climatic change over the past 22–50 years. One key approach in the study of climate in temperate areas is the use of tree rings to infer past conditions. Tree-ring methods developed in temperate zone cannot be applied in tropical rainforest areas with little seasonal change. However,

Loader *et al.* [13] apply isotope analysis to wood from tree rings to examine the age of trees in these forest areas and to test for effects of increasing $CO_2$ levels on water use efficiency.

Finally, we take the opportunity to acknowledge and thank some of the key people and organizations that have helped to support the decade of SEARPP activity synthesized in this issue. In particular, we thank members of the SEARPP Committee over the period, including current chair John Pyle and the chair from 2000 to 2010, Charles Godfray, who spearheaded the successful strategy in that period of establishing major long-term experiments and research facilities at Danum to act as platforms and foci for groups of individual projects. We also thank Lorna Casselton, the current Foreign Secretary of the Royal Society, for her support for the Programme and for chairing the Bali Symposium in July 2010, where most of the papers were presented. In Sabah, we are indebted to the Danum Valley Management Committee, the Sabah Forestry Department, Yayasan Sabah and UMS for the tremendous support and collaborative research links without which the research would have been impossible. We also thank the Economic Planning Units of the Prime Minister's Office in Kuala Lumpur and the Chief Minister of Sabah's Office in Kota Kinabalu for granting research permission for the projects upon which most of the papers were based. We thank Bruce Cleghorn and Boyd McCleary, successive British High Commissioners in Malaysia during the period, for their great help to the Programme. Finally, we thank Joanna Bolesworth and the rest of the team at the editorial office of *Philosophical Transactions B* for their help and patience in bringing this special issue to fruition.

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