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Review

Conclusion: applying South East Asia Rainforest Research Programme science to land-use management policy and practice in a changing landscape and climate

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The context and challenges relating to the remaining tropical rainforest are briefly reviewed and the roles which science can play in addressing questions are outlined. Key messages which articles in the special issue, mainly based on projects of the Royal Society South East Asia Rainforest Research Programme (SEARRP), have raised of relevance to policies on land use, land management and REDD+ are then considered. Results from the atmospheric science and hydrology papers, and some of the ecological ones, demonstrate the very high ecosystem service values of rainforest (compared with oil palm) in maintaining high biodiversity, good local air quality, reducing greenhouse emissions, and reducing landslide, flooding and sedimentation consequences of climate change—and hence provide science to underpin the protection of remaining forest, even if degraded and fragmented. Another group of articles test ways of restoring forest quality (in terms of biodiversity and carbon value) or maintaining as high biodiversity and ecological functioning levels as possible via intelligent design of forest zones and fragments within oil palm landscapes. Finally, factors that have helped to enhance the policy relevance of SEARRP projects and dissemination of their results to decision-makers are outlined.

Keywords: applying science; land use; land management; rainforest; Sabah

1. THE CURRENT CONTEXT AND FUTURE CHALLENGES

This concluding section considers some of the policy messages of the Royal Society South East Asia Rainforest Research Programme (SEARRP) science presented in the special issue. First, the context and challenges facing rainforest science and the roles of science in addressing these needs are briefly outlined. Then, some of the main scientific messages of policy relevance arising from the articles in the special issue are summarized. Finally, some of the factors that have helped the policy relevance of SEARRP projects and aided the dissemination of their findings to policy-makers are considered. It is now widely recognized that the current rate of global forest loss, and particularly loss of tropical forests, is unsustainable and has potentially disastrous implications for climate, biodiversity, ecosystem services and people. Science has played a pivotal role in identifying and understanding these impacts, notably via the successive reports of

the International Panel on Climate Change (IPCC) and the Convention on Biological Diversity (CBD). The IPCC brought together leading scientists from around the world, who reviewed and synthesized hundreds of different papers to arrive at conclusions which were powerful enough to convince most world leaders that climate change was real. The CBD, launched in 1992 at Rio de Janeiro, has played a major role in bringing to governments (and the public) the importance of biodiversity and commitments to its conservation.

Getting governments and society to agree there is a problem—however challenging—is still the easy part. The challenge now is finding acceptable solutions and science will have to play an equally pivotal role in this if there is to be a real chance of success. But this will not be easy as there are many different facets—conservation of biodiversity, maintenance of ecosystem services, livelihoods and development, global food security—involved. Managing the conflicting pressures for conservation and production is a huge challenge and requires radical and unprecedented changes in policy and practice at local to global scales. Furthermore, this has to be achieved within the context of climate change which will have its own impact irrespective of policy decisions.

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There are, however, some positives in terms of several global initiatives that are helping to produce a conducive policy environment. These include: (i) REDD+: the current focus on reducing emissions of greenhouse gases from deforestation and forest degradation aims to give forests a greater financial value and has already provided an increase in political will; (ii) the CBD: though less high-profile politically, it nevertheless continues to focus attention on protection and loss of biodiversity; and (iii) sustainable consumption initiatives: there is an increasing focus in consumer countries on reducing the negative impact of consumption through safeguards, legislation and certification.

There remain some huge challenges: (i) unsustainable consumption patterns—in general, the developed world has been a major force driving deforestation with continuing demand for cheap food, feed, oils and other resources, but growing affluence in some developing countries, including China, India and much of South East Asia, is rapidly increasing the number of people aspiring to this pattern of consumption; (ii) poor governance in many countries with large areas of tropical forest remains common and makes it difficult to implement the type of paradigm change needed; (iii) rising food prices are leading to pressure to increase production to meet growing needs without price increases—and are also making agriculture more profitable and so providing an incentive to clear forest; (iv) population growth in some areas (but not all) continues to increase pressure on forests; and (v) the use of biofuels as an alternative to fossil oil is leading to clearance of forest for their growth in some areas, though the overall impact to date is perhaps overestimated.

2. THE ROLE OF SCIENCE

Within this very challenging context, scientists have crucial roles to play. These include:

- work on how to maintain forests in a changing climate—crucial for the success of REDD+ and for planning for conservation of biodiversity.
- providing a better understanding of the local and regional impacts of changes in forest cover and climate—crucial for local agricultural production (both commercial and subsistence).
- providing an improved understanding of the consequences of different land-use options (including fragmented landscapes) for local to global atmospheric composition and climate change.
- understanding how to optimize the protection of biodiversity and other ecosystem services in a changing and fragmented landscape since this will increasingly become the norm.
- continuing to monitor status and impacts as these change rapidly, and continually reminding decision-makers and the public of the issues.

3. SOME POLICY MESSAGES OF SCIENTIFIC FINDINGS PRESENTED IN THIS ISSUE

Some of the findings emerging from this issue have direct and important messages for policy on issues related to climate change, land-use and land management strategy. It should be emphasized that many of

these studies and their findings have only been possible as a result of the cumulative knowledge provided by the long-term data series and hundreds of publications produced by SEARRP since 1985.

(a) *Land use and local air quality, atmospheric chemistry and climate modelling*

The key findings of the three OP3 Project papers [1–3] comparing atmospheric chemistry above oil palm and rainforest have potentially very important policy implications. The fivefold greater isoprene levels, substantial estragole levels and 25 per cent higher soil nitrous oxygen emissions recorded in oil palm compared with above regenerating rainforest are of major significance for both local air quality and global climate change. They found that effects on local air quality (including ozone) are enhanced by low surface horizontal windspeeds of the equatorial environment, whereas effects on regional and global circulation may be magnified by vertical airflows in the exceptionally deep convection layer (extending to the lower stratosphere) associated with the Maritime Continent. Numerical modelling of the results indicates that further spread of oil palm at the expense of forest in the region is likely to produce higher NO_x emissions and local increases in ozone of 50 per cent. The changes would also have important consequences for further global climate change. The findings clearly have important implications in any national and international considerations of the value of ecosystem services (clean air) associated with rainforest and the environmental costs of oil palm in future debates over land-use strategies and REDD+ policies supporting forest retention. Mitigating strategies that can be assessed include (i) the possible local air quality benefits of maintaining or restoring a significant proportion of forest cover within oil palm landscapes or (ii) reductions in the scale of fertilizer applications. The models developed in the studies furthermore provide a powerful diagnostic and prognostic framework for investigation of such scenarios.

The results presented by Malhi *et al.* [4], which assess the degree of validity of rainforest carbon estimates derived from component data, are of relevance in improving the accuracy of terrestrial carbon cycling models and inputs to climate change models. Their finding (based on a global tropical dataset) of greater variability in the proportions of the wood and fine root components, compared with a more constant canopy component, clearly indicates that estimates based on measurements of the canopy component are more reliable. Data from Africa and more data from South East Asia are needed to assess whether the partitioning results are applicable across the global tropics.

(b) *Assessing and modelling impacts of climate change*

The papers by both Mercado *et al.* [5] and Loader *et al.* [6] provide advances in methodology in assessing the effects of rising carbon dioxide and climate change on forest vegetation. The findings of Mercado *et al.* [5], demonstrating the importance of nutrient availability as a factor influencing net primary productivity across Amazonia, will be fundamental in improving global

vegetation models and their ability to predict the spatial pattern of vegetation variables (including stem growth rates and carbon biomass stores) both currently and in scenarios driven by climate change. Current models, because they either ignore or greatly simplify nutrient availability, would be unable to predict the spatial variability in stem growth rates evident across Amazonia. The dendroclimatological approach of Loader *et al.* [6] provides a way of measuring and monitoring the response of ringless trees of a rainforest to increasing atmospheric carbon dioxide in terms of their changes in intrinsic water-use efficiency (IWUE). A similar methodology could be applied in other locations to determine whether the sustained rise in IWUE found in Sabah, which is in contrast to the plateau in response exhibited in temperate trees, is found in rainforest areas of contrasting degrees of perhumidity across the global tropics.

(c) Biodiversity and ecosystem functioning in logged forest and in oil palm landscapes with forest fragments

The paper by Woodcock *et al.* [7] demonstrates that, on the basis of bird, ant and dung beetle populations, even twice-logged, degraded forest at Danum retains much of its species richness at the largest spatial scale, though reductions are greater at smaller spatial scales. This pattern is largely a function of the cumulative value of intact or lightly disturbed patches within the post-logging mosaic. Even heavily degraded forest is of much greater biodiversity value than oil palm. The findings of Bagchi *et al.* [8], however, suggest that, if findings for *Parashorea malaanonan* are representative of other canopy-tree species, then recruitment levels in non-mast years may be severely reduced compared with in primary forest, with negative implications for the speed and quality of canopy species recovery.

The results of surveys of birds, Lepidoptera and ants in forest fragments of differing size by Hill *et al.* [9] suggest that whereas small fragments are of little conservational value for birds, they may be for butterflies, moths and ants, as many species are found in small fragments that are additional to those found in larger ones. This means that there may be advantages from the point of view of regional biodiversity of having a larger number of small fragments within oil palm landscapes rather than a small number of larger fragments, though the long-term viability of small fragments in terms of ecological functioning is questionable and remains untested. Foster *et al.* [10] quantify for different taxa the substantial losses in species richness associated with oil palm conversion, but they also explore how local and landscape complexity might not only enhance biodiversity within a part-forest, part-oil palm landscape, but also support ecosystem functioning and ecosystem services within such landscapes. They argue that ecologists first need to provide robust scientific evidence for this and then use such evidence to persuade policy-makers and the palm oil industry to design and adopt oil palm landscapes that will function in a healthier and more sustainable way. As the Roundtable on Sustainable

Palm Oil and the individual initiatives of some of the oil companies are already implementing and seeking to test the effectiveness of some conservational strategies, there will be a willingness to learn about and consider any scientific advice that is conveyed.

(d) Hydrological and erosional ecosystem service benefits of rainforest

A number of key policy messages are clear from the hydrological work of Walsh *et al.* [11]. The historical record of sedimentation rate for the upper Segama reconstructed using caesium-137 and lead-210 showed the striking differences in erosional consequences of logging terrain of varying steepness. When combined with landslide frequency data and evidence that the IPCC-predicted trend towards more frequent and larger extreme rainstorms may already be evident in Sabah, it showed the crucial importance of not logging (or clearing for oil palm) slopes above 25° (as in Reduced Impact Logging) and keeping them under forest. The consequence otherwise would be a major landsliding phase, enhanced in disturbed steeper terrain, and downstream flooding and sedimentation, including economically valuable floodplain oil palm plantation land. These ecosystem services of forest are additional to the clean water supply role of forest.

(e) The policy orientation and potential of current projects to underpin forest restoration of forest and the ecological functioning of part-forest/part-plantation landscapes

The large-scale experiments described by Hector *et al.* [12] (the Sabah Biodiversity Experiment) and Ewers *et al.* [13] (the Stability of Altered Forest Ecosystems (SAFE) Project) in their articles represent the current direction of SEARRP science in seeking to provide the science directly to underpin two key land management issues of South East Asia, namely (i) the design and use of enrichment planting strategies with native canopy-tree seedlings to rehabilitate logged-over or repeatedly logged rainforest; and (ii) the effectiveness of forest fragments of different size and riparian forest zones of different width within oil palm landscapes in retaining biodiversity and ecosystem functioning, mitigating effects of oil palm on local air quality, global climate change and water pollution and reducing downstream effects on sedimentation and runoff. The SAFE Project thus involves and potentially integrates the breadth of science covered by SEARRP and directly addresses some of the key needs identified by Foster *et al.* [10] regarding the ecosystem functioning of part-forest, part-oil palm landscapes (see above). In their article on the Sabah Biodiversity Experiment, Hector *et al.* [12], by comparing a regenerating forest 22 years after selective logging with primary forest, demonstrate the scale of total carbon gain (100 tonnes of carbon per hectare or 40% of primary rainforest values) and biodiversity and other ecosystem services that could be obtained if enrichment planting is employed. These data will potentially be of direct value in assessing the carbon-offset value of restoration forest stands in REDD+ proposals and negotiations.

(f) Synthesis

The key findings of the articles in this special issue reported above relate to most of the challenges listed particularly in §2*a,c,d*. Several articles from atmospheric chemistry, ecology and hydrology provide evidence demonstrating the very high ecosystem service values of rainforest (compared with oil palm) in maintaining high biodiversity, good local air quality, reducing greenhouse emissions, and reducing the likely landslide frequency and downstream flooding and sedimentation consequences of climate change—and hence present cogent arguments for protection of remaining forest, even if degraded and fragmented. Another group of articles test ways of restoring forest quality (in terms of biodiversity and carbon value) or maintaining as high biodiversity and ecological functioning levels as possible via intelligent design of forest zones and fragments within oil palm landscapes. Many therefore contribute scientific knowledge that is directly relevant to REDD+ proposals and negotiations and to critical land-use and land management strategies and decisions that are being faced by governments both in Sabah and across South East Asia.

4. FACTORS AIDING THE APPLICATION OF SE ASIA RAINFOREST RESEARCH PROGRAMME SCIENCE WITHIN SABAH AND SOUTH EAST ASIA

A number of factors have aided the policy relevance of its research and its dissemination. Of prime significance are the direct two-way links which SEARRP has had from the inception of the Programme in 1985 with Yayasan Sabah, its commercial arms and its Environment and Conservation Division and with the Sabah Forestry Department. The Royal Society was invited to lead collaborative science at Danum with twin objectives of (i) excellent rainforest science, particularly that of relevance to enhancement of forest conservation and recovery following logging, and (ii) training of Sabahan/Malaysian and British (and later European) young researchers. As all projects need to be formally approved at Danum Valley Management Committee as well as State and Federal level and copies of all research papers and reports are automatically provided to the above bodies, communication of research findings is enhanced. Furthermore, members of these bodies are often research collaborators in projects and indeed increasingly are graduates of the Programme, reflecting the very strong capacity-building role it has played.

Associated with this has always been the understanding that the role of SEARRP was to provide the sound and unbiased science to test and underpin existing and alternative improved land management techniques and strategies and to provide the scientific evidence of their consequences. This enables policies and decisions to be made in the light of the science by decision-makers of Sabah and Malaysia. Together with the long-term commitment of SEARRP (extending now over 25 years), this has meant that there is unquestioned respect for the scientific findings of SEARRP projects regardless of the extent to which they influence land-use and land management policies. A mark of this respect for the science at Danum is that increasingly in recent years, SEARRP and its scientists are invited to participate in

conferences and workshops organized at official level by Yayasan Sabah or the Sabah Forestry Department on tropical forest, biodiversity and climate change issues including the Sabah response to the REDD+ process in 2010. Also the Director of SEARRP in Sabah has been asked to sit in an advisory capacity on key policy-forming bodies.

Thirdly, and increasingly, many research projects are formulated specifically to provide the science and understanding to test, develop or underpin forest management techniques and strategies or scientific issues that have implications for and/or are strongly influenced by land-use change and management and global change.

Finally, there is a willingness to address today's reality. In the Sabah context, this means engagement with rehabilitation and restoration of logged-over forest and ways of enhancing the biodiversity value of oil palm plantation landscapes and reducing the impacts of partial conversion to oil palm. Increasingly this involves working with oil palm companies and the Roundtable on Sustainable Palm Oil. As long as the integrity of the science and the same freedom to publish that the Programme has enjoyed with Yayasan Sabah is ensured, then there can be distinct advantages to this (in addition to funding). These include: (i) that projects are designed with inputs and knowledge from the industry, thus ensuring that existing practices including their own conservational strategies can be accurately included and alternatives that might be impracticable can be modified or excluded; (ii) that the findings automatically reach land management decision-makers and thus have a better chance that they might be adopted and more widely disseminated; (iii) that one can avoid or break down the 'confrontational' attitudes that otherwise can tend to prevail; and (iv) that it can facilitate more robust and extensive experimental designs than would otherwise be the case. This has been a huge advantage, for example, in the conception, design and implementation of the SAFE Project, which would have been totally impossible without the active involvement from the outset of Yayasan Sabah, the Sabah Forestry Department and Sime Darby—and has also been true in the cases of the OP3 Atmospheric Chemistry Project and in forest fragment and erosion projects involving the Wilmar Group at their Sabahmas plantations.

The SEARRP approach of addressing much of the science at Danum in part to key land management and ecosystem services issues and of active engagement with Yayasan Sabah, government departments and now the oil palm industry is thus arguably bearing fruit both in terms of the quality and policy relevance of the science. As reported by Reynolds *et al.* [14], there have been positives, particularly recently, in Sabah in terms of the extent of protected forest, both primary and managed, and in rehabilitating depleted forest. Also the larger oil palm companies are actively seeking to improve the sustainability and biodiversity of their land holdings, including in some cases by increasing the extent and quality of riparian forest zones and releasing steeper slopes back to forest. This special issue has reported how SEARRP science is contributing policy-relevant evidence relating to

this changing landscape and the crucial roles which rainforest plays within it.

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