The Planter, Kuala Lumpur, ***88*** *(1036): 453-468 (2012)*

The Stability of Altered Forest Ecosystems Project: Investigating the Design of Human-Modified Landscapes for Productivity and Conservation

EDGAR C TURNER[1,2], YATELA ZAINAL ABIDIN[3], HENRY BARLOW[3], TOM M FAYLE[1,4], MOHD HATTAH HJ. JAAFAR[5], CHEY VUN KHEN[6], JONNY LARENUS[7], ANAND NAINAR[8], GLEN REYNOLDS[7], YUSRIN BIN YUSOF[5], MIN SHENG KHOO[1] AND ROBERT M EWERS[1]

With growing global demands for palm oil, there is mounting pressure on limited natural resources to support the dual services of agricultural productivity and maintenance of biodiversity. Balancing these two services requires detailed research on four themes: i) the impacts on biodiversity of forest conversion and fragmentation, ii) which factors drive these changes in biological communities, iii) what impacts changes have on ecosystem functioning and, iv) the management and design of multifunctional landscapes. Such questions are often difficult to answer as data must be collected at the landscape scale and over long time periods.

The Stability of Altered Forest Ecosystems (SAFE) Project (see www.safeproject.net for more details) is a ground-breaking scientific study based in Sabah, Malaysia which investigates the impacts of forest conversion to oil palm on biodiversity, ecosystem functioning and productivity. Funded by the Sime Darby Foundation with support from Benta Wawasan and the Sabah Forestry Department, the project is a collaboration between research institutions and the oil palm industry. The project takes advantage of a 7 900 ha area of forest which was scheduled for conversion to oil palm in 2012, allowing the consequences of habitat conversion to be directly measured.

Now at the beginning of its third year, the SAFE Project is already yielding results of direct relevance to tropical conservation and plantation management. As well as a core team of nearly thirty researchers and research assistants working full-time on the project, SAFE has also provided a platform for collaborative scientists studying a wide range of taxa and ecosystem functions. To date over 90 researchers from 23

---

[1] *Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, Berkshire SL5 7PY,United Kingdom.*
[2] *Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, United Kingdom.*
[3] *Yayasan Sime Darby, 13th Floor, Wisma Sime Darby, Jalan Raja Laut, 50350 , Kuala Lumpur, Malaysia.*
[4] *Laboratory of Tropical Ecology, Faculty of Science, University of South Bohemia, Branišovská 31, 370 05 České Budějovice, Czech Republic.*
[5] *Benta Wawasan Sdn Bhd, Perdana Square, TB 9130 & 9131, Mile 3 1/2, Apas Road, P O Box. 62074 Tawau, Sabah, Malaysia.*
[6] *Forest Research Centre, Sabah Forestry Department, P O Box 1407, 90715 Sandakan, Sabah, Malaysia.*
[7] *The Royal Society South East Asia Rainforest Research Programme (SEARRP), Danum Valley Field Centre, P O Box 60282, Lahad Datu 91112, Sabah, Malaysia.*
[8] *Water Research Unit, School of Science and Technology, Universiti Malaysia Sabah, Sabah, Malaysia.*

* *Modified from a paper submitted to the 3rd ICOPE meeting 2012, held in Bali, Indonesia. Submitted with permission of the organisers.*

different institutions have been involved with research projects in the SAFE area. The SAFE Project provides a good example of the benefits of closer collaboration between stakeholders in the development of conservation initiatives and a more sustainable palm oil industry.

***Keywords**: Biodiversity, carbon, deforestation, invertebrate and oil palm.*

Agricultural land has expanded dramatically in the tropics over the last few decades (Foley *et al.*, 2005; Green *et al.*, 2005), often at the expense of natural forests (Gibbs *et al.*, 2010). This expansion has brought economic benefits but has come at a cost to global biodiversity. Indeed many of the regions with the highest levels of habitat change are also those which house the greatest diversity of species (Turner *et al.*, 2008). Southeast Asia is one such hotspot of global biodiversity (Myers *et al.*, 2000; Orme *et al.*, 2005), which has experienced very high levels of habitat conversion in recent years (Sodhi *et al.*, 2010). In Southeast Asia a major driver of this habitat change has been expansion in oil palm cultivation (Koh & Wilcove, 2007). Palm oil is among the most important sources of vegetable oil worldwide (Corley, 2009). A wide and expanding range of uses have now been identified for palm oil (Henderson & Osborne, 2000). In particular, it is increasingly being used as a feedstock for biofuel production (Koh, 2007), the global demand for which is set to increase (Koh & Ghazoul, 2008) as fossil fuel reserves dwindle and policy on climate change mitigation take effect.

Despite the undoubted economic importance of palm oil globally, conversion of forested land to oil palm plantation has had a severe negative impact on biodiversity (Fitzherbert *et al.*, 2008; Foster *et al.*, 2011). Studies comparing forested land and oil palm have found a dramatically lower diversity of species in oil palm plantations than in forest across a wide range of different groups. However, there are still species to be found in oil palm plantations, and particularly in fragments of natural habitat which may be left on steep slopes and along riverine margins (e.g. Maddox *et al.*, 2007). At a smaller scale, remaining natural vegetation within oil palm plantations (such as epiphytes) can also support a significant level of biodiversity (Fayle *et al.*, 2010). Most species inhabiting plantations are not those that were originally found in the forest, but rather are species more specialised to living in open habitats, which are often of lower conservation importance because they are widespread (tramp species) and not from that area originally (invasive species) (Fayle *et al.*, 2010).

Owing to the suite of important functions which different species can support (Schmid *et al.*, 2009), losses of biodiversity may also be associated with impaired ecosystem functioning in human-dominated landscapes as well as loss of resilience and ability for ecosystems to adapt to future changes (Jackson *et al.*, 2010). These functions, which include pollination, pest control, decomposition, and carbon sequestration, are sometimes crucial for the productivity of agricultural areas as well as for the future health and wellbeing of local communities.

It is clear that research to understand how landscapes can be managed to maintain biodiversity value as well as to provide ecosystem services and sustainable crop production is a priority. Central to this research is understanding the optimal arrangement and size of fragments of natural habitat maintained within agricultural landscapes (Ewers *et al.*, 2011). In the conservation literature, discussion over the best arrangement of natural versus agricultural areas has led to the formulation of two alternative conservation strategies: “land sharing” and “land sparing” (Green *et al*., 2005). Either biodiversity is best served by maintaining larger areas of reserve for wildlife and maximising productivity in non-reserve areas (land sparing) or a more inclusive approach should be taken where wildlife-friendly farming is encouraged over larger areas, but potentially with lower per-area productivity (land sharing). Although the debate continues, evidence is mounting that to maximise biodiversity alone, land sparing offers the best solution (Edwards *et al*., 2010; Phalan *et al*., 2011).

However, these two approaches need not be viewed as alternatives and the adoption of land sparing approaches for conservation should not rule out sustainable agricultural practices being adopted in the wider landscape (Phalan *et al*., 2011). Indeed, extensive areas in agricultural landscapes are not suitable for cultivation (for example steep slopes or riverine margins) and may, therefore, be maintained for conservation at little loss to productivity. It is also possible that areas of natural or semi-natural habitat in agricultural landscapes can provide additional ecosystem functions to plantations (such as acting as a source of pest control agents or pollinators (e.g. Ricketts *et al*., 2004)) and that they may therefore benefit productivity in agricultural areas through the services they support. Finally, a more bio-friendly agricultural landscape could also provide novel resources for forest species and increase permeability for individuals moving between forest areas, thereby aiding species survival in reserves.

It is therefore clear that a research agenda should be set up which implicitly investigates the biodiversity, ecosystem functioning and productivity of such multifunctional landscapes (Gardner *et al*., 2009). Although some work has been carried out on the biodiversity value of forest fragments in oil palm plantations (Struebig *et al*., 2008; Edwards *et al*., 2010), research in this area is sparse. Furthermore, these studies have relied on investigating existing forest fragments, and it is therefore not clear what biodiversity areas would have supported prior to fragmentation. Large-scale fragmentation projects have been set-up before in other tropical regions, the largest and best-known of these being the Biological Dynamics of Forest Fragments Project (BDFFP) in Brazil (Lovejoy & Oren, 1981; Lovejoy *et al*., 1983). This long-term landscape-scale study has acted as a platform for ecological study for over three decades and provided invaluable data on the impacts of forest fragmentation on biodiversity.

In this paper we introduce a new fragmentation project based in Sabah, Malaysia: the Stability of Altered Forest Ecosystems (SAFE) Project (Ewers *et al*., 2011). This ground-breaking research project relies on a close collaboration between industry and research partners, which is essential if past misunderstandings and direct conflicts between stakeholders in the oil palm industry (Koh *et al*., 2010) are to be avoided. Funded by Sime Darby Foundation with in-kind contributions from Benta Wawasan, the project is based in land managed by the Sabah Foundation (a state government body responsible for the socio-economic development of Sabah) and is academically led by Imperial College London and the Royal Society South East Asia Rainforest Research Programme (SEARRP). The project aims to investigate the impacts of forest conversion to oil palm and forest fragmentation on biodiversity and ecosystem functioning at the landscape scale. By working closely with industry partners, this study goes well beyond existing projects of its kind by allowing measured values of biodiversity and function to be linked to agricultural productivity and economics.

OBJECTIVES

In this paper we:

i. Describe the rationale for the design of the SAFE Project,
ii. Detail key achievements to date and growth of the project,
iii. Highlight the importance of close collaboration between the industry and research in allowing projects of this kind to take place, and
iv. Briefly introduce future plans and potential directions for the project.

MATERIALS AND METHODS

In addition to design and sampling, other aspects of the methods, such as rationale, are also considered.

Rationale

SAFE was conceived as a multidisciplinary project that would allow key questions on the impacts of forest fragmentation and conversion to be addressed. Central to this rationale was that results of the project would be applicable to as wide a range of disciplines as possible and answer key questions for both conservationists and agronomists. In particular, outcomes of the project should provide information which would inform sustainable land-management practices, such as those developed through the Round Table on Sustainable Palm Oil (RSPO) (RSPO, 2012). As habitat change can have impacts on biodiversity and ecosystem functioning over long time periods, it was also important that the project had funding for a suitable period of time to allow detection of these changes. Furthermore, the project needed to be designed on a scale that was appropriate for land-management of this kind and, therefore, would rely on the close collaboration and support of the oil palm industry and plantation managers. Related to this, it was also important that project partners were made up of both research and industry-players as this would ensure a realistic approach to management issues as well as effective dissemination of results to the various stakeholders. Finally, it was clear that such wide-ranging research could never be carried out by a single institution or research body. It was therefore crucial for the project to be set up in such a way as to provide infrastructure and a sampling design that would encourage a range of collaborative researchers to get involved, maximising the long-term value of the project and facilitating the development of profitable collaborations and knowledge-transfer between different organisations and disciplines (Barlow *et al*., 2011).

Support

Funding for the SAFE Project from Sime Darby Foundation has been guaranteed for 10 years, allowing for long-term monitoring to take place. The majority of the project is based on land managed by Benta Wawasan, who have guaranteed collaboration and in-kind support over this period. The project includes an area of forest of approximately 7 900 ha, which was earmarked for conversion to oil palm before the start of the project (the experimental area). Through agreement with Benta Wawasan, forest fragments of varying sizes will be maintained in this area in an experimental design, thereby manipulating forest fragmentation and enabling a direct test of the impact of habitat change and fragmentation on biodiversity and ecosystem functioning.

Project design

Sampling points for the SAFE Project are arranged across a landscape gradient from primary forest (at Maliau Basin Studies Centre), to logged forest which will remain forested (Ulu Segama Forest Reserve), logged forest earmarked for conversion (experimental area, located on land managed by Benta Wawasan), and existing oil palm plantation (managed by Benta Wawasan and Sabah Softwoods, another subsidiary company of the Sabah Foundation). Within the experimental area, a range of different-sized forest fragments will be maintained following conversion (1 ha, 10 ha, and 100 ha) in six replicate blocks (42 fragments in total), with sampling points included in each fragment and in areas that will be converted to plantation.

An additional experiment has also been set up to explore the role of riverine margins in maintaining river water quality and aquatic biodiversity. In the experimental area, the size of riverine forest margins left after clearance will be experimentally manipulated (treatments: no margin, 5 m, 15 m, 30 m, 60 m and 120 m), allowing the effects of forest cover on river habitats to be directly tested (see *Appendix 1*).

Sampling methodology for core data collection

Several research projects have been established by the core SAFE research team. These include the setting up and re-measurement of a network of 193 vegetation plots (25 m by 25 m each) across the SAFE area. The key aim of these is to investigate changes in carbon sequestration following clearance and fragmentation. Methods for the setting up of these plots follow established RAINFOR protocols (see Malhi *et al*., 2002 for full details) and include the tagging and identification to species of all trees over 10 cm diameter breast height (DBH) within the plot and measurements of DBH, canopy structure, phenology, vine cover, microclimate, leaf-litter fall, deadwood, and soil characteristics. Decomposition rates are also measured within these plots, using litter bags filled with freshly fallen leaves and standard cotton squares. Arranged around each vegetation plot are three insect collection traps (579 in total), specifically designed for the SAFE Project. These traps, which combine aspects of Malaise, pitfall and intercept traps, are engineered to collect a wide range of taxa and collections are planned to take place over a three-day period every 6 months. Owing to the wide range of ecosystem functions that insects support (Weisser & Siemann, 2004), such data will provide important information relevant to ecosystem services. Finally, as part of the initial setup, a 50 m tower will be used to investigate changing carbon dynamics following habitat conversion.

Core data are collected by a team of over 20 SAFE Research Assistants, who have been trained in ecological monitoring and taxonomy, and who will be sent on relevant training courses as they become available, building local expertise. Over time Research Assistants will specialise in particular projects, as they build their knowledge base in key areas. In addition to core data collection, the team of Research Assistants are also available to assist visiting collaborative researchers, allowing a wider range of taxonomic groups and ecological questions to be investigated and encouraging collaborative projects.

The study area, collaborative status and current status are given in *Table 1*.

TABLE 1

STUDY AREA, TITLE, CORE OR COLLABORATIVE STATUS, AND PRESENT STATUS OF PROJECTS PRESENTLY ONGOING AT SAFE. THE LIST DEMONSTRATES THE WIDE RANGE OF DIFFERENT SUBJECTS WHICH SAFE SCIENTISTS ARE PRESENTLY INVESTIGATING

Study area and title	*Core team/ collaboration*	*Status*
Diversity and composition		
Spatial scaling of beetle community diversity	core team	data collection underway
Mosquito community composition	collaboration	first round of data collection completed, masters project written
Ants and dung beetles in riparian margins	collaboration	data collection underway
Ant and termite assemblages	collaboration	data collection completed, masters project written
Canopy invertebrate assemblages	collaboration	data collection underway
Composition of ant communities	core team	data collection underway
Leaf litter ant communities	collaboration	data collection underway
Ant communities in oil palm of different ages	collaboration	data collection underway
Composition of butterfly communities	collaboration	data collection to begin in 2012
Composition of mammal communities	collaboration	data collection underway
Small mammal sampling methodology	collaboration	data collection completed, masters project written
Composition of primate communities	collaboration	data collection underway
Vertebrate scavenger communities	collaboration	start date uncertain
Composition of bird communities	collaboration	data collection underway
Amphibians in riparian margins	collaboration	data collection underway
Composition of amphibian communities	collaboration	data collection underway
Beta diversity of amphibian communities	collaboration	data collection underway
Composition of bat communities	collaboration	data collection underway
Fungal litter trapping systems	core team	data collection underway
Fish community composition	collaboration	data collection underway
Diversity and function of aquatic invertebrates	collaboration	data collection underway
Species interactions		
Food web structure of beetle communities	core team	data collection underway
Ant and termite interactions	collaboration	data collection underway
Tree-liana interactions in fragmented forests	core team	data collection underway
Parasites in tropical birds	collaboration	data collection underway
Ectoparasites on anurans	collaboration	data collection underway
Functional diversity of amphibians	collaboration	data collection underway
Seed dispersal and predation	collaboration	data collection to begin 2012

TABLE 1
STUDY AREA, TITLE, CORE OR COLLABORATIVE STATUS, AND PRESENT STATUS OF PROJECTS PRESENTLY ONGOING AT SAFE. THE LIST DEMONSTRATES THE WIDE RANGE OF DIFFERENT SUBJECTS WHICH SAFE SCIENTISTS ARE PRESENTLY INVESTIGATING (CONTD.)

Study area and title	*Core team/ collaboration*	*Status*
Insect pollination	collaboration	data collection to begin 2012
Physiology		
Stress levels in tropical birds	collaboration	data collection underway
Ecosystem processes		
Above-ground net primary productivity	core team	data collection underway
Herbivory rates in modified forests	core team	data collection underway
Ant-mediated ecosystem processes	collaboration	data collection underway
Termite-mediated wood decomposition rates	collaboration	data collection underway
Dung beetles and their impacts on nutrient cycling and seed dispersal	collaboration	data collection underway
Land use change and species invasions	collaboration	data collection underway
Functional composition of tree communities	collaboration	data collection to begin 2012
Impacts of riparian width on river water quality	collaboration	data collection underway
Land use change and stream flow rates	collaboration	data collection underway
Water sediment loads and stream channel morphology	collaboration	data collection underway
Microclimate stratification in modified forests	core team	data collection underway
Carbon budgets in modified forests	collaboration	data collection underway
Changing CO_2 and water budgets from habitat modification	collaboration	data collection underway
Soil nutrient cycling patterns in modified forests	core team	data collection underway
Land use impacts on erosion and sedimentation	collaboration	data collection underway
Plantation management		
Epiphytes in palm plantations: diversity and pest control	collaboration	data collection underway
Designing biodiversity-friendly palm plantations	collaboration	data collection underway

RESULTS

Achievements in the core project over the first two years

An early key milestone for the project was the establishment of 897 individual sampling points spread throughout the SAFE area. To access these points, it was necessary to survey and clear over 90 km of trails. Also important were the provision of extensive labs at Maliau Basin Studies Centre (the field base for the project) and the building of a large campsite in the middle of the SAFE experimental area.

Having gained access to all of the sites, the team involved in the SAFE project then concentrated on collecting baseline environmental data for each collection point. These basic data included measurements of slope, aspect, forest quality and canopy cover and were important in allowing sites to be graded in terms of quality, so decisions over future sampling priorities could be made. These data demonstrated how variable forest quality is across SAFE plots, indicating that results from this project may be applicable to a range of forest types across Sabah and globally (*Figure 1*).

Over the first year and a half, the SAFE team also marked and set up the network of 193 vegetation plots. These were also found to be highly variable in forest quality, again indicating that results will be of relevance to a wide range of forest areas (*Figure 2*). We are now in the process of re-measuring vegetation plots, allowing estimates of tree growth and mortality to be calculated - key variables in calculating carbon flux. Associated with this

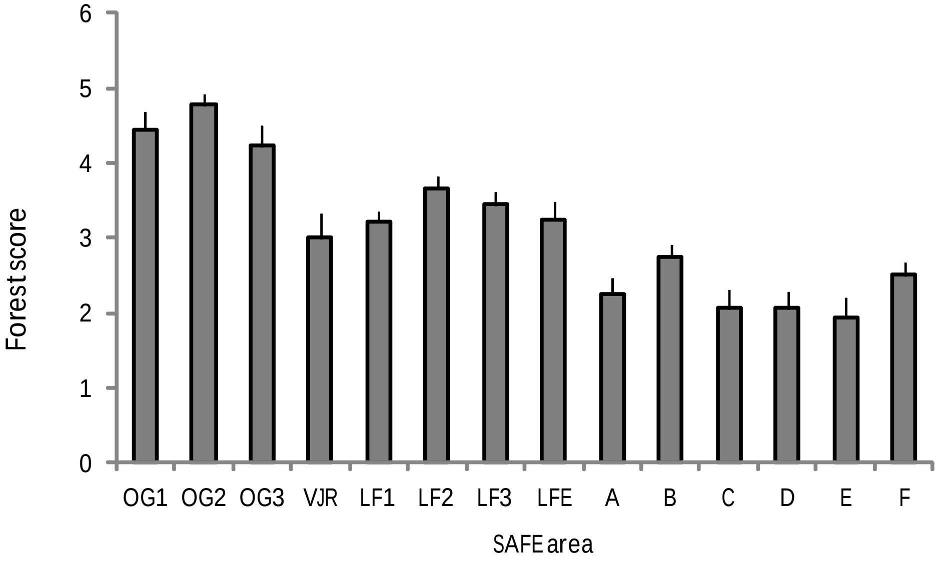

Figure 1 *Range of forest scores displayed across different survey areas in the SAFE Project. An average forest score was taken for the range of vegetation plot sampling locations in each area (Standard Error bars shown)*

Note:
Forest score:
1- very poor, no trees - open canopy with ginger/vines or low scrub,
2 - poor, open with occasional small trees over ginger/vine layer,
3 - ok, small trees fairly abundant/canopy at least partially closed,
4 - good, lots of trees, some large, canopy closed,
5 - very good, no evidence of logging, closed canopy with large trees.
OG1-3 - areas within primary forest area,
VJR – primary forest control area close to the experimental sites,
LF 1-3 - logged forest control area, LFE – logged forest area near to experimental sites,
A-F - replicate areas within experimental logged forest area.

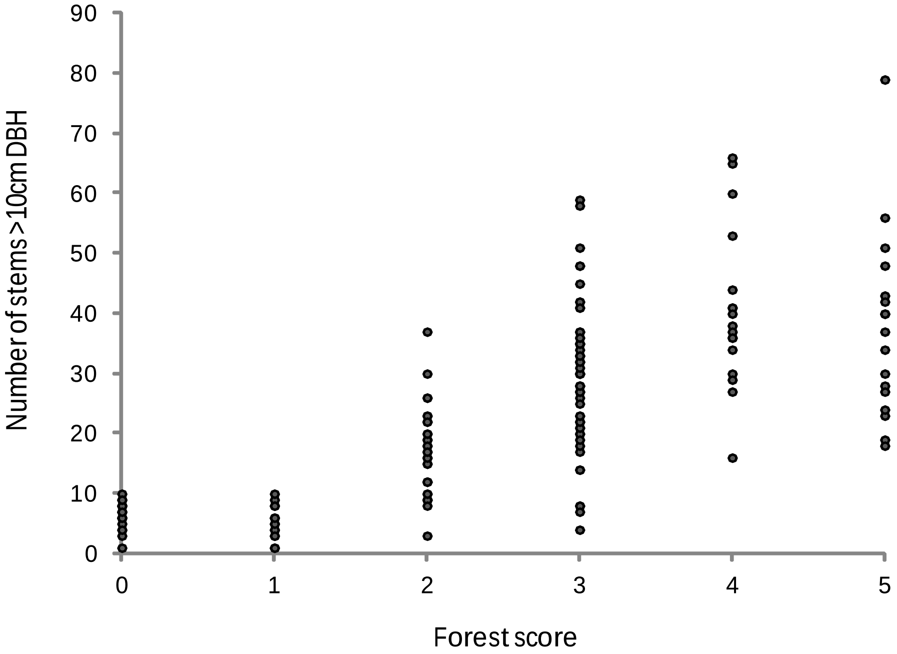

Figure 2 Number of stems over 10 cm diameter breast height (DBH) plotted against forest score for 193 individual 25 by 25 m vegetation plots set up across the SAFE area

Note:

Forest score:

0 - oil palm plantation,
1 -very poor, no trees - open canopy with ginger/vines or low scrub,
2 - poor, open with occasional small trees over ginger/vine layer,
3 - ok, small trees fairly abundant/canopy at least partially closed,
4 - good, lots of trees, some large, canopy closed,
5 - very good, no evidence of logging, closed canopy with large trees.

work, the carbon flux tower (*Figure 3*) was also completed in 2011, with direct measurements of carbon release and sequestration now underway.

In 2011, two rounds of insect collections took place across the network of 579 insect collection points using combination insect traps (*Figure 4*). These collections, which represent one of the most comprehensive across a habitat disturbance gradient in Southeast Asia, are presently stored at Maliau Basin Studies Centre and are in the process of being identified. In the future, ants and beetles from this collection will be identified to species, allowing estimates of species compositional changes to be measured for these important groups.

Across the insect and vegetation plot collection points, dataloggers have been installed to measure temperature and humidity at three-hourly intervals, with several months of data already collected. Finally, a pre-clearance litter decomposition study has also been carried out, with litterbags placed at the centre of each of the vegetation plots and collected over set time

Figure 3 Carbon flux tower in the SAFE experimental area. This 50 m-high tower is situated in an area of forest that will be converted to oil palm during 2012. By recording detailed measures of carbon flux over this period, the impact of the establishment of a new plantation on an area's carbon balance can be measured

Figure 4 A combination flight intercept, pitfall and Malaise insect trap being set in the SAFE Project area.

periods to allow estimates of the rates of litter decomposition in different habitat types to be calculated.

Collaborative research

In addition to the projects set up by the core SAFE team, numerous other scientists have also visited the SAFE site and carried out their own research, dramatically enhancing the range and volume of data collected. Some of these were Malaysian and International postdocs, Ph D students and M Sc students who were funded directly through the SAFE Project (four postdoctoral researchers, four Ph D students and two M Sc students). In total in the first 2 years some 90 external researchers and their assistants have visited the SAFE site to establish projects. Together they represent 23 different institutions and 15 countries. This amounts to over 2 700 additional research days on the project for 2011 alone (compared to over 10 000 Research Assistant days spent on the project over the last 2 years).

Together collaborative and core work already underway can be divided into several key areas including: biodiversity and composition studies, species interactions, physiology, ecosystem processes and plantation management (see *Table 1* for details of projects). Taxa studied are very wide-ranging and include: large mammals, small mammals, bats, birds, amphibians, fish, beetles, dung beetles, ants, termites, mosquitoes, and trees. Taken together these data will provide a unique insight into the impacts of habitat change.

DISCUSSION AND CONCLUSION

It is clear that collaborative projects such as SAFE can be extremely productive in terms of the volume of data collected and scope of questions that can be answered. Key to the establishment of the SAFE Project is the close collaboration of different institutions and stakeholders in oil palm cultivation. Without industry involvement in scientific projects of this kind, it would be extremely difficult to secure funding over the appropriate time-scale to study the impacts of habitat change and fragmentation and near-impossible to establish experiments in plantation areas at the appropriate scale and ensure results are used to inform best management practices.

We hope that in the future the SAFE Project and other similar schemes will enable closer collaboration between conservationists and the oil palm industry with benefits for both conservation and agriculture alike. Only thus can we move away from approaches that polarise conservation and agricultural productivity, to the development of truly multifunctional tropical landscapes.

ACKNOWLEDGEMENTS

We would like to thank Yayasan Sime Darby, Yayasan Sabah and Benta Wawasan, the Sabah Forestry Department and the Royal Society South East Asia Rainforest Research Programme for supporting the SAFE Project, and, most importantly, the team of SAFE Project Research Assistants who carried out the lion's share of setting up the project and data collection. Researchers interested in collaborating on the SAFE Project should visit the SAFE Project website (www. safeproject.net) for more information.

REFERENCES

BARLOW, J, EWERS, R M, ANDERSON, L, ARAGÃO, L E O C, BAKER, T R, BOYD, E, FELDPAUSCH, T R, GLOOR, E, HALL, A, MALHI, Y, MILLIKEN, W, MULLIGAN, M,

PARRY, L, PENNINGTON, T, PERES, C A, PHILLIPS, O L, ROMAN-CUESTA, R M, TOBIAS, J A and GARDNER T A. 2011. Using learning networks to understand complex systems: a case study of biological, geophysical and social research in the Amazon. *Biological Reviews* 86:457-474.

BREN, L J. 2000. A Case Study in the Use of Threshold Measures of Hydrologic loading in the design of stream buffer strips. *Forest Ecology and Management* 132: 243-257.

CLINNICK, P F. 1985. Buffer Strip Management in Forest Operations: A Review. *Australian Forestry* 48: 34-45.

CORLEY, R H V. 2009. How much palm oil do we need? *Environmental Science and Policy* 12: 134-139.

EDWARDS, D P, HODGSON, J A, HAMER, K C, MITCHELL, S L, AHMAD, A H, CORNELL, S J and WILCOVE, D S. 2010. Wildlife-friendly oil palm plantations fail to protect biodiversity effectively. *Conservation Letters* 3 (4): 236-242.

EWERS, R M, DIDHAM, R K, FAHRIG , L, FERRAZ, G, HECTOR, A, HOLT, R D, KAPOS, V, REYNOLDS, G, SINUN, W, SNADDON, J L and TURNER, E C. 2011. A large-scale forest fragmentation experiment: the Stability of Altered Forest Ecosystems Project. *Philosophical Transactions of the Royal Society of London B* Vol. 366: 3292-3302.

FAYLE, T M, TURNER, E C, SNADDON, J L, CHEY, V K, CHUNG, A Y C, EGGLETON, P and FOSTER, W A. 2010. Oil palm expansion into rain forest greatly reduces ant biodiversity incanopy, epiphytes and leaf-litter. *Basic and Applied Ecology* 11 (4): 337-345.

FITZHERBERT, E B, STRUEBIG, M J, MOREL, A, DANIELSEN, F, BRÜHL, C A, DONALD, P F and PHALAN, B. 2008. How will oil palm expansion affect biodiversity? *Trends in Ecology and Evolution* 23 (10): 538-545.

FOSTER, W A, SNADDON, J L, TURNER, E C, FAYLE, T M, COCKERILL, T D, ELLWOOD, M D F, BROAD, G R, CHUNG, A Y C, EGGLETON, P, CHEY, V K and M YUSAH, K. 2011. Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia *Philosophical Transactions of the Royal Society of London B* 366: 3277-3291.

FOLEY, J A, DEFRIES, R, ASNER, G P, BARFORD, C, BONAN G, CARPENTER, S R, CHAPIN, F S, COE, M T, DAILY, G C, GIBBS, H K, HELKOWSKI, J H, HOLLOWAY, T, HOWARD, E A, KUCHARIK, C J, MONFREDA, C, PATZ, J A, PRENTICE, I C, RAMANKUTTY, N and SNYDER, P K. 2005. Global consequences of land use. *Science* 309 (5734): 570-574.

GARDNER, T A, BARLOW, J, CHAZDON, R L, EWERS, R M, HARVEY, C A, PERES, C A and SODHI, N S. 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters* 12, 561-582.

GIBBS, H K, RUESCH, A S, ACHARD, F, CLAYTON, M K, HOLMGREN, P, RAMANKUTTY, N and FOLEY, J A. 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. In: *Proceedings of the National Academy of Sciences,* Vol.107, No.38: 16732-16737.

GREEN, R E, CORNELL, S J , SCHARLEMANN, J P W and BALMFORD, A. 2005. Farming and the fate of wild nature. *Science* 307 (5709): 550-555.

HENDERSON, J and OSBORNE, D J. 2000. The oil palm in our lives: how this came about. *Endeavour* 24(2): 63.

JACKSON, L, VAN NOORDWIJK, M, BENGTSSON, J, FOSTER, W, LIPPER, L, PULLEMAN, M, SAID, M, SNADDON, J L and VODOUHE, R. 2010. Biodiversity and agricultural sustainagility: from assessment to adaptive management. *Current Opinion in Environmental Sustainability,* Vol.2, No.1-2, pp.80-87.

KLAPPROTH, J C. 2009. Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality. Virginia Cooperative Extension (Online). Available online at http://pubs.ext.vt.edu/420/420-151/420-151.html.

KOH, L P. 2007. Potential habitat and biodiversity losses from intensified biodiesel feedstock production. *Conservation Biology* .21:.1373-1375.

KOH, L P and WILCOVE, D S. 2007. Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters* 1: 60-64.

KOH, L P and GHAZOUL, J. 2008. Biofuels, biodiversity, and people: understanding the conflicts and finding opportunities. *Biological Conservation* 141 (10): 2450 - 2460.

KOH, L P , GHAZOUL, J, BUTLER, R A, LAURANCE, W F, SODHI, N J, MATEO-VEGA, J and BRADSHAW, C J A. 2010. Wash and spin cycle threats to tropical biodiversity. *Biotropica* 42 (1): 67-71.

LOVEJOY, T E, BIERREGAARD, R O, RANKIN, J

M and SCHUBART, H O R. 1983. Ecological dynamics of tropical forest fragments. In: *Tropical Rain Forest: Ecology and Management* (S L Sutton, Whitmore, T C and Chadwick A C, eds.). 377-384. Oxford: Blackwell Scientific Publications.

LOVEJOY, T E and OREN, D C. 1981. The minimum critical size of ecosystems. In: *Forest Island Dynamics in Man-Dominated Landscapes* (R L Burgess and Sharpe D M, eds.). 7-12. New York, USA: Springer-Verlag.

MADDOX, T, PRIATNA, D, GEMITA, E and SALAMPESSY, A. 2007. The conservation of tigers and other wildlife in oil palm plantations. *ZSL Conservation Report*, No.7

MALHI Y, PHILLIPS O L, LLOYD J, BAKER, T R, WRIGHT J, ALMEIDA S, ARROYO L, FREDERIKSEN T, GRACE J, HIGUCHI N, KILLEEN T J, LAURANCE W F, LEAÑO C, LEWIS S L, MEIR P, MONTEAGUDO A, NEILL D.A, NÚÑEZ VARGAS P, PANFIL S, PATIÑO S, PITMAN N C, QUESADA CA, RUDAS A., SALOMÃO R, SALESKA S, SILVA J N, SILVEIRA M, SOMBROEK W G, VALENCIA R, VÁSQUEZ MARTÍNEZ R, VIEIRA I C and VINCETI B. 2002. An international network to monitor the structure, composition and dynamics of Amazonian forests (RAINFOR). *Journal of Vegetation Science* 13: 439-450.

MYERS, N, MITTERMEIER, C G, MITTERMEIER, R A, FONSECA, G A B and KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

ORME, C D L D L, DAVIES, R G, BURGESS, M, EIGENBROD, F, PICKUP, N, OLSON, V A, et al. 2005. Global hotspots of species richness are not congruent with endemism or threat. *Nature* 436: 1016–1019.

PHALAN, B, ONIAL, M, BALMFORD, A and GREEN, R E. 2011. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science* 333: 1289-1291.

PHILLIPS, J D. 1989. Nonpoint source pollution control effectiveness of riparian forest along a coastal plain river. *Journal of Hydrology* 110: 221-237.

RADOJEVIC, M, ABDULLAH, M H and ZAHARIN, A. 2007. Analisis Air. Kuala Lumpur: Scholar Press.

RICKETTS, T H, DAILY, G C, EHRLICH, P R and MICHENER C.D. 2004. Economic value of tropical forest to coffee production. In: *Proceedings of the National Academy of Sciences of the United States of America*, Vol.101, No.34: 12579-12582.

ROUND TABLE ON SUSTAINABLE PALM OIL (RSPO) website (2012) www.rspo.org

SCHMID, B, BALVANERA, P, CARDINALE, B J, GODBOLD, J, PFISTERER, A B, RAFFAELLI, D, SOLAN, M and SRIVASTAVA, D S. 2009. Consequences of species loss for ecosystem functioning: meta-analyses of data from biodiversity experiments. In: *Biodiversity, Ecosystem Functioning, and Human Wellbeing an Ecological and Economic Perspective* (S Naeem, D E Bunker, A Hector, M Loreau and C Perrings eds.). 14-29. Oxford University Press, ISBN 0199547955, Oxford, UK.

SODHI, N S, POSA, M R C, LEE, T M, BICKFORD, D, KOH, L P and BROOK, B W. 2010. The state and conservation of Southeast Asian biodiversity. *Biodiversity and Conservation* 19 (2): 317-328.

STABILITY OF ALTERED FOREST ECOSYSTEMS (SAFE) PROJECT. 2012. Accessed February 2012, Available from www.safeproject.net

STRUEBIG, M, KINGSTON, T, ZUBAID, A, ADNAN, A and ROSSITER, A. 2008. Conservation value of forest fragments to Palaeotropical bats. *Biological Conservation* 141 (8): 2112-2126.

TURNER, E C, SNADDON, J L, FAYLE, T M and FOSTER, W A. 2008. Oil palm research in context: identifying the need for biodiversity assessment. PLoS ONE, 3 (2): 2579.

VIESSMAN, W J and LEWIS, G L. 2003. Surface Water Hydrology. In: *Introduction to Hydrology*. 5th Edition. 209-256. Upper Saddle River: Pearson Education Inc.

WEISSER, W W and SIEMANN, E. 2004. *Insects and ecosystem function*. Berlin, Germany: Springer.

Editor's note:

The Planter decided to publish this paper even though no results are available as yet, to inform readers and concerned groups that the industry is also concerned with the stability of ecosystems and eagerly awaits the findings to enhance the environment of future developments.

APPENDIX 1

FOCUS ON THE HYDROLOGY PROJECT

Introduction

The hydrology component of the SAFE project aims to experimentally vary the widths of riparian zones to test the effect of this on stream channel morphology, sediment transport and water quality.

Maintaining riparian reserves during logging is thought to be important for intercepting sediment, nutrients, pesticides and other materials in overland and shallow subsurface flow (Klapproth, 2009). As a result, many countries retain riparian buffer zones during logging and agricultural activities. In Malaysia, the current legal requirement is for 30 m riparian width. However, this varies between countries and regions (20 m in Victoria, Australia, for example (Bren, 2000)). Several studies have been carried out to determine the optimal width of riparian zones worldwide. Phillips (1989) suggested a range of widths from 15 - 80 m, depending on the situation. Clinnick (1985) suggested that 20 m is the average requirement for well-defined streams while 5 m is needed for ephemeral streams. There is currently no consensus on the optimal width of forest margin to maintain following oil palm plantation establishment.

This project aims to determine the optimal width of riparian buffer zones to maximise sediment filtration and minimise nutrient loss during logging and conversion of forest into oil palm plantation.

Experimental design and methods

Within the SAFE Project experimental area, six catchments have been identified and marked as study catchments with plans of retaining riparian buffer zones of 0 m, 5 m, 15 m, 30 m, 60 m, and 120 m. Besides the experimental catchments, there are also four control catchments comprising of the Virgin Jungle Reserve (VJR), logged forest control, established oil palm control and a primary forest catchment in the Danum Valley Conservation Area, which has been monitored over a longer time period. All catchments are of a similar catchment size and slope (260 ha ± SD 10 with a slope of 16^0 ± SD 2).

Gauging stations

At each catchment, gauging stations with attached sensors and dataloggers have been established. This system measures water level, turbidity, conductivity and water temperature every 5 minutes, storing a mean hourly and daily reading. Water level can be converted to stream discharge while conductivity indicates total dissolved solids. By collecting water samples on a regular basis, recorded turbidity will be correlated to total suspended solids over time. Rainfall will also be measured using tipping bucket rain gauges. With this frequency of data collection, the data logger can store measurements for up to 3 months, allowing a constant monitoring of all these aspects of a river's ecology.

Stream cross section

Recording stream cross section characterises the area and shape of a stream at fixed points along its length. To achieve this, width and cross-sectional profile are measured at approximately 50 m intervals, following established methodology (Viessman & Lewis, 2003). By re-measuring a stream cross section every 6 months, changes in the channel as a result of habitat conversion can be quantified.

Nutrient analysis

Water samples for nutrient analysis will be taken on a monthly basis as well as during storm events from each

Contd....

FOCUS ON THE HYDROLOGY PROJECT (CONTD.)

stream. Samples will be analysed for nitrates, phosphates and potassium, using chemical test kits in the lab (Radojevic *et al*., 2007). A subsample of each collection will be stored for future analyses.

Conclusion

This project represents an unparalleled opportunity to test the optimal size of riparian margin to maintain during conversion of forest to plantation. By experimentally varying riparian margin widths and measuring the impact of this on a wide range of physical and chemical parameters of the streams, this project will go a long way to answering questions of optimal riparian width. The results of this work will be of importance in the development of more-sustainable oil palm cultivation.