SOS: save our swamps for peat's sake

Jason Hon

Abstract
The Malaysian government's scheme for the agricultural intensification of oil palm production is putting increasing pressure on lowland areas dominated by peat swamp forests. This paper focuses on the peat swamp forests of Sarawak, home to 64 per cent of the peat swamp forests in Malaysia and earmarked under the Malaysian government's Third National Agriculture Policy (1998–2010) for the development and intensification of the oil palm industry. Sarawak's tropical peat swamp forests form a unique ecosystem, where rare plant and animal species, such as the alan tree and the red-banded langur, can be found. They also play a vital role in maintaining the carbon balance, storing up to 10 times more carbon per hectare than other tropical forests. Draining these forests for agricultural purposes endangers the unique species of flora and fauna that live in them and increases the likelihood of uncontrollable peat fires, which emit lethal smoke that can pose a huge environmental risk to the health of humans and wildlife. This paper calls for a radical reassessment of current agricultural policies by the Malaysian government and highlights the need for concerted effort to protect the fragile ecosystems of Sarawak's endangered peat swamp forests.

Keywords
Peat swamp forests, Sarawak, oil palm, agricultural policy, conservation

Introduction

Peat is often viewed unfavourably as dirty, sticky and sometimes smelly. It nevertheless provides an important source of fuel in many parts of the world, where it is harvested from wetland bogs, moors and mires (just three terms for the areas where peat is deposited). Peatlands cover an estimated 400 million hectares or 3 per cent of the Earth's land surface (Strack 2008). Although located primarily in the cold tundra regions of northern Russia and Canada — and other northern countries such as Finland, Scotland, Ireland, northern Germany and the Netherlands — peatlands are also found in the southern hemisphere. Tropical peatlands are mostly found in the Indo-Malayan region, where they account for more than 60 per cent of the total land area, mainly distributed in Indonesia (80 per cent), Malaysia (11 per cent) and Papua New Guinea (6 per cent) (Rieley et al. 1996; Page et al. 2006).

In tropical regions, most peatland consists of peat swamp forests, often inundated

in water. Here, the term "peat swamp forest" connotes mosquito-infested, waterlogged, uninhabitable areas that are often regarded as unusable by humans. This is probably because peat in its original form is not harvested for fuel in tropical regions. These forests are constantly waterlogged, which means that fallen leaves and branches do not decompose fully, resulting in multiple layers of acidic peat. Over time this creates an acidic environment not favourable to many organisms, resulting in poor species composition. Despite this limited species biodiversity, peat swamp forests are valuable for the endemic, unique and rare communities of plants and animals that live in them. They also perform a host of other important ecological functions, such as preventing floods (by storing water and controlling hydrological processes), storing nutrient elements and environmental contaminants and acting as a carbon sink (Riley 1992; Lim and Tan 1999).

The following discussion focuses on the regional situation of peat swamps in the tropical area of Sarawak, a Malaysian state located in Borneo. I have chosen to write on this subject because it is close to my heart — over eight years I conducted extensive fieldwork and research in peat swamp forests in various locations in Sarawak between October 2001 and October 2009. By outlining some of the key issues pertaining to land use and its consequences for peat swamp forests, I hope to address some doubts concerning their usefulness or function and dispel the commonly held opinion that these regions are wastelands. Negative perceptions of peatlands often arise from skewed economic perspectives driven by short-term considerations. However, peat swamp forests are ecologically important ecosystems and sound conservation measures to maintain them must be made a priority if the valuable environmental services they perform are to be preserved for posterity.

The peat swamp forests of Sarawak

In Malaysia, peat swamp forests account for up to 75 per cent of the total wetland areas (United Nations Development Programme 2006). Sarawak is home to about 64 per cent of the total 2.6 million hectares of peat swamp forests in Malaysia, with most situated in the lowland or coastal plains (Figure 1). The districts of Sibu, Sri Aman (including Betong) and Mukah account for about 60 per cent of the total peatland areas in Sarawak (Sime Darby Services 1999). The lowland peat swamps of Sarawak are waterlogged almost throughout the year because they are mainly located between the lower stretches of main river courses and in poorly drained interior valleys (Mutalib et al. 1992).

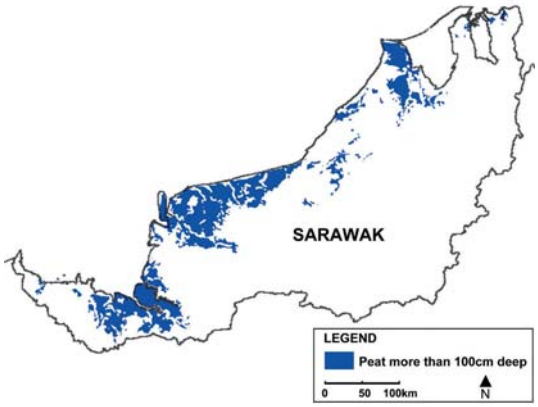

Figure 1. Distribution of peat swamps in Sarawak
Source: Tie and Kueh 1979

Unique communities — do numbers matter?

Often mistaken for an inhabitable environment, peat swamp forest is in fact not as "bare" or "useless" as many perceive it to be. In fact, a mature peat swamp forest is represented by six phasic communities, a term used by J.A.R Anderson (1963) to categorise the types of vegetation or trees found in peat swamp forests. These phasic communities form concentric zones of plant communities that intergrade and then slowly replace each other from the perimeter to the centre of the swamp. Within these phasic communities, more than 240 species of plants have been recorded (Rieley 1992). A unique tree species, *Shorea albida* (known as alan and endemic to northern Borneo and Sumatra), is the main species in some peat swamp forests, creating a homogenous community of tall-standing, even-height and closed-canopy forests (Figure 2). In Sarawak, peat swamp forests contain endemic species such as *Eugenia nemestrina* and *Garcinia eugenaefolia* (Rieley and Ahmad-Shah 1996) while keystone species — those that are important to the forest ecosystem — such as figs (*Ficus* spp.) are found in abundance (Anderson 1963). Indeed, most of the principal aboreal families that occur in lowland dipterocarp forests can be found in peat swamp forests, with the distinct difference being the absence of herbaceous

Figure 2. Tall stands of alan (*Shorea albida*) forest in Maludam National Park, Sarawak
Source: author

vegetation in peat swamps due to their extremely acidic and anaerobic conditions (Ibid).

The highly acidic nature of a peat swamp forest may make it unfavourable to many faunal species. Also, the forest's flora is limited — often dominated by a single species such as alan — and these limited food resources restrict the diversity of fauna. Nevertheless, peat swamp forests contain some of the most interesting animal species known. The forest of Maludam National Park, situated in the Sri Aman administrative division of Sarawak, is home to about 300 individuals of the locally endemic sub-species of banded langur, also known as the red-banded langur (Hon and Gumal 2004, 2005). In the latest evaluation carried out by the International Union for Conservation of Nature's Primate Specialist Group, this species is categorised as a distinct endangered species, known as the Sarawak Surili (*Presbytis chrysomelas*) (International Union for Conservation of Nature 2010) (Figure 3). In the same location, a large population of another Bornean endemic, the proboscis monkey (*Nasalis larvatus*) (Figure 4), occurs alongside three other diurnal primate species. Altogether, the primate communities in this one park alone constitute almost half of the 11 diurnal primate species known to live in Borneo.

Figure 3. There are now fewer than 300 individual Sarawak Surilis, all of which are confined to the peat swamp forest of Maludam National Park, Sarawak, Malaysia
Source: author

Figure 4. The proboscis monkey, which is endemic to Borneo, is found in peat swamp and mangrove forests
Source: author

What peat swamp forests may lack in species assemblage, they make up for in terms of globally significant and endemic species. For instance, Loagan Bunut National Park in Sarawak, a protected peat swamp forest, is home to a seasonal population of more than 20,000 flying foxes (*Pteropus vampyrus*) (Gumal et al. 2008), a type of fruit bat that also holds the record as the largest species of bat in the world. The distribution of flying fox maternity colonies in Sarawak is believed to be restricted to the lowland peat swamp forests (Gumal 2001, 2004). Other significant populations of flying fox are found in Sedilu, a peat swamp forest that is undergoing the process of being ga-

zetted as a national park. It also contains the highly charismatic yet endangered orangutan (*Pongo pygmaeus*). There are a number of bird species, such as the Storm's stork (*Cicornia stormi*) and masked finfoot (*Heliopais personata*), that are so far only known to occur in peat swamp forests. The only record to date of the masked finfoot in Borneo was from the peat swamp forests of Maludam. As for smaller-scale organisms, Yule (2010) has reported on the microbial communities of peat swamp forests, noting that microbes form an integral part of peat swamp forest ecosystems, of which litter decomposition is a crucial aspect.

Scientific research on peat swamp wildlife, especially relating to terrestrial and arboreal species, remains lacking, judging from the paucity of literature available. Rieley et al. (1996) have stressed the importance of investigating the ecology of animal communities in tropical peat swamps to assess their contributions to forest function and global biodiversity. The importance of peat swamp vegetation to wildlife was underlined by Rieley and Ahmad-Shah (1996), when they wrote that forest degradation is associated with loss of habitat for almost all animals except forest-edge species. The long-term effects of peat swamp forest disturbances on wildlife in Sarawak are also largely unstudied (Bennett and Gombek 1992). Recent studies have focused increasingly on the anthropogenic factors affecting peat swamp forests, their role as carbon sinks and their potential use in carbon credit schemes. Undoubtedly, such studies may yet play an important role in helping to draw up sound management measures for protecting the habitat and, therefore, the species living within. Nevertheless, more pure scientific research into some of the most unique communities living within the peat swamp forests needs to be conducted while they still exist.

A fragile environment

Tropical peat swamp forests are unique ecosystems with chemical, physical and biological attributes that distinguish them from all other terrestrial and wetland areas (Rieley et al. 1996). The hydrologic properties of peat swamps are perhaps the most important aspects that govern the characteristics and behaviour of peat.

Water tables are lowered and irreversible subsidence and oxidation occur when peat forests are drained (Lim and Tan 1999; Mamit and Sawal 1999). The peat itself, consisting mostly of organic matter, starts to decompose and subsequently loses volume as it shrinks (Rieley 1992). Subsidence of 60 cm initially followed by a rate of 6 cm per year has been recorded and subsidence of approximately 2 m can be expected over a 25-year period (Tie and Kueh 1979; Melling 1999). Similarly, severe loss of peat of between 2 cm and 5 cm per year and subsidence of up to 1 cm per year was recorded in Kalimantan, Indonesia, after peat swamp forests were cleared and drained for agricultural activities (Anshari and Armiyarshi 2005). Some shallow peat areas may

disappear within five to 10 years after clearance of the forest cover and drainage (Rieley 1992). Since some areas in Sarawak depend entirely on peat groundwater resources for their water supply, the drainage of peat will also affect neighboring water catchments areas, which could have a devastating impact on the residents who depend on them (Ong and Yogeswaran 1992; Shakeran 1999).

Peatlands are also important for their role in maintaining a carbon balance (Armentano 1990). Peatland carbon is estimated to constitute about 20 per cent of all the carbon in world soils (Maltby 1997). It has also been estimated that a 10m-deep, one-hectare peat swamp forest can store 5,800 tonnes of carbon (United Nations Development Programme 2006). In south-east Asia, peatlands store more than 50 billion tonnes of carbon, with peat swamp forests storing up to 10 times more carbon per hectare than other tropical forest types (Association of South-East Asian Nations (ASEAN) Peatland Forests Project 2010). When peatlands are disturbed, they lose their carbon sink capacity and release accumulated carbon into the atmosphere as carbon dioxide. They also emit methane, which is about 20 times more powerful a greenhouse gas than carbon dioxide (Strack 2008; Maltby 1997). In Malaysia, the contribution of peat subsidence to the release of carbon dioxide due to oxidation and shrinkage is estimated to be 27 tonnes per hectare per year (Wösten et al. 1997). The environmental implications of peat forest destruction in terms of climate change are unavoidable.

Other environmental hazards, such as fire, cannot be neglected. When peat swamp forests are drained, the risk of fire increases (Ten and Murtedza 2004). Drained peat is highly inflammable and degraded peat that has become oxidised carries the greatest risk (Yule 2010). In 1997, more than 2.7 million hectares of peat were burnt, triggering widespread forest fires in late 1997 and early 1998 in south-east Asia. The peat fires released a huge amount of carbon dioxide and the resulting haze caused problems such as poor visibility, respiratory illness and traffic disruption (Page et al. 2006; Yule 2010). The major fires that occurred in peat swamps across Indonesia and Malaysia in 1997 — lit deliberately on forest debris left behind by the expansion of oil palm plantations — generated thick smoke that blanketed the region in an unhealthy haze and caused a wide range of health problems. More than 5 million hectares of forest were destroyed before the fires could be put out (Butler 2006). Once a fire has started in a peatland, areas of burned peat may take months or even years to be extinguished successfully (Yule 2010). Inevitably, a significant proportion of wildlife perished in these forest fires.

Land-use scenarios

Peat swamp forests are difficult to work on because of their waterlogged environment and soft soil structure. Peat forest soil is regarded as problematic for use in agriculture

(Jamaludin et al. 2004) because it requires a very high expenditure on development and maintenance (Anang 2001), which makes the cultivation of perennial crops challenging (Kanapathy 1984). In recent decades, however, land scarcity and intensification of certain agricultural sectors, notably oil palm, have shifted people's attention towards the vast areas of underdeveloped peat swamp forests that are close to human settlements and roads.

Where formerly the development of peatlands was confined mainly to the shallower peat at the fringes of peat swamp forests, activities are shifting to large areas of peat swamp forests, which are now being drained and converted to agricultural land. This shift was vastly accelerated in 1999, when the Malaysian government answered the rocketing global demand for palm oil — used primarily for food products such as margarine and chocolate but increasingly sought after for use in biodiesel — by instituting an agricultural intensification scheme for oil palm that stimulated the demand for agricultural land. Malaysia has been at the forefront of global palm oil production since the early 1970s (Food and Agriculture Organization 2010). The country's Third National Agriculture Policy (1998–2010) emphasised the development and intensification of the palm oil industry, setting aside 1.12 million hectares of land — 27 per cent of which was situated within peat swamp forests — for plantation purposes (Drahman 1999). Successive policies have had a dramatic effect on the country: a million hectares of Malaysian peatlands have been converted for agricultural purposes since the 1980s (Global Environment Facility 2006), their loss translating as gain for the global palm oil economy. In 2008, Malaysia and Indonesia together contributed about 86 per cent of the world's 43.1 million tonnes of crude palm oil production (Food and Agricultural Organization 2010). Malaysia's export earnings from oil palm products were RM49.6 billion or approximately US$14.1 billion in 2010 (based on an exchange rate of RM1=US$0.284), with earnings reaching a record of RM65.22 billion or approximately US$18.5 billion in 2008.

Sarawak has played a pivotal role in all this. It, along with the state of Sabah, was earmarked early on for expansion because of the availability of its underdeveloped land (Ministry of Agriculture Malaysia 1998). Sarawak set itself an agricultural development target to become a new leader in palm oil production by 2010, hoping to increase planted areas from 300,000 hectares in 2000 to 1 million hectares in 2010 (Sahamat 1999). Until the late 1990s, Sarawak, despite being the largest state in Malaysia, covering 124, 450 hectares, lagged behind smaller states in terms of the total area of oil palm plantations. Before 2008, Sarawak's total planted area for oil palm was less than that of either Johor or Pahang, the top two states in terms of oil palm acreage in Peninsular Malaysia, even though the total land area of Johor and Pahang are only 16 per cent and 29 per cent, respectively, of that of Sarawak. In 2008, however, Sarawak experienced the largest increase in oil palm plantations, growing by 12.8 per cent against the national

figure of only 4.5 per cent (Malaysian Palm Oil Board 2010). This brought the total planted area for oil palm in Sarawak to 744,372 hectares (Malaysian Palm Oil Board 2008), surpassing both Johor and Pahang and putting Sarawak well on the way to achieving its 1 million hectare target by 2010.

Sarawak's "success" story has been boosted by recent infrastructure developments and economic stimulus initiatives promoted by the Malaysian government. Road development in the coastal plains of Sarawak was enhanced in the late 1990s. This enabled the peat swamp forests that dominate the plains to act as a fast-track resource for large-scale oil palm expansion (Sahamat 1999). A state-wide independent peat basin (IPB) study, conducted in 1992, had classified 91 out of the 109 IPBs (or one-third of the total 825,156 hectares of IPBs identified) as having potential for agricultural development (Sime Darby Services 1999; Kamaruddin et al. 1999). This potential was tapped almost immediately: between 1997 and 2001, Sarawak's oil palm plantations doubled in size, reaching 374,827 hectares (more than 46 per cent) of the agricultural land in use and constituting the largest area of commercial crops by 2005 (Department of Statistics Sarawak 2005). Export values for palm oil in Sarawak were RM1.38 billion in 2003, the highest among the principal agricultural products (Department of Statistics Sarawak 2005). SCORE (Sarawak Corridor of Renewable Energy), Sarawak's long-term development strategy for the central region, which was launched in 2006 to propel the state into the ranks of Malaysia's most developed states by 2020, reaffirmed the state's commitment to further oil palm expansion, identifying it as a key growth industry in three centres, Tanjung Manis, Mukah and Similajau. All three areas were dominated by peat swamp forests.

Oil palm is gradually expanding but the logging industry, boosted by the recent expansion of planted forests, still maintains a commanding influence on the economy. Sarawak's economy has been driven primarily by natural gas and timber, with the logging industry accounting for almost 40 per cent of the state's gross domestic product (The Star 2010). Malaysia is the world's top producer of tropical round wood — it has earned well over US$400 million annually in exports since the 1990s, peaking at nearly US$1.5 billion a year in the early 1990s (Food and Agricultural Organization 2010). In 2007, the export of logs from Sarawak accounted for 77.5 per cent of Malaysia's total production of 4.65 million cubic metres (Department of Statistics Sarawak 2009), making the state a powerhouse for tropical log production and earnings for the country. The export value in Sarawak stood at RM1.67 billion in 2007, or approximately US$474 million.

Today, logging's continued prominence as a major money earner for Sarawak accounts for the strong relationship between its peat swamp forests and export earnings from palm oil and tropical timber. A hike in palm oil prices since 2000 has placed a greater focus on developing the palm oil industry, so the production of palm oil

and expansion of plantations has resulted in a higher demand for land. Large expanses of hill forests — many in remote places that are difficult to access — are already dominated by loggers for timber extraction. Since these already developed areas have remained "reserved" for the timber sector, the oil palm industry is obliged to establish itself in lands that have not yet been developed. This is putting great pressure on previously untouched peat swamp forests.

Conserving peat swamp forests

Little scientific research has been conducted on Sarawak's peat swamp forests, despite their abundance and ecological importance. What studies there are, focus primarily on the properties of peat soils carried out for agricultural advancement. The properties and behaviour of peat are inadequately understood because most studies have been short term, inconclusive and have presented results based on ad-hoc basis (Ten and Murtedza 2004). Without proper planning and guidelines, the exploitation and conversion of these fragile ecosystems may deleteriously affect the ecological and hydrological health of the peat swamp forests and the areas that surround them (Melling and Hatano 2005; Tie et al. 2005) as well as the health of the wildlife and plant populations that live in them.

Immirzi (1997) highlighted the dilemmas posed by trying to respond to varying economic demands while conserving peatlands, noting that the crusade for wildlife conservation will be difficult as long as economic pressures remain. In the case of Sarawak, the desire to generate income from cash crops outweighs conservation considerations and the meagre revenues raised by nature-based tourism activities, such as wildlife observation in peat swamp forests. The Maludam National Park technical working committee's recommendation to extend the park's boundary to cover a unique patch of peat swamp forests known as the peat dome was not successful. Instead, the area was earmarked to be converted to oil palm plantations (Berg et al. 2004), even though extending the park boundary would have accorded better protection for the endangered Sarawak Surili.

There are many ways in which humans are contributing to the endangerment of endemic species, one of these being deforestation. Loss of habitat is a major problem in almost every ecosystem on earth (Ehrlich and Ehrlich 1981; Sinclair 1998). Where habitats are lost or fragmented, species dependent on those habitats may eventually become extinct. From the perspective of landscape ecology, the process of fragmentation will eventually lead to the creation of smaller patches of habitat. These patches become prone to chance extinctions of species due to factors such as disease or weather. Where fragments are too far apart, the distances may become so large that they affect dispersal and reduce the immigration rate for organisms. In peat swamp

forests, clearance results in fragmentation and, when regeneration fails, shrubs, pandan, ferns and sedges become dominant (Rieley and Ahmad-Shah 1996). This alters the composition of the forests' vegetation and, therefore, affects wildlife viability and survival.

It is important to note that habitat fragmentation does not always have a significant effect on population viability because other factors, such as animal movement and recolonisation ability, come into play (Lindenmayer et al. 1999). So it is important to explore the theory of population dynamics before any conclusive remarks can be made about the chances of species survival in the peat swamp forests of Sarawak, given the rate of habitat degradation that has already taken place and the scale of deforestation to come. One approach would be to study how fragmentation affects the distribution and feeding ecology of the flying foxes in Sarawak, where many remnant populations are now restricted to peat swamp forests.

Some swamps are protected

Despite the onslaught from the expansion of plantations and the conversion of peat swamp forests, Sarawak maintains a protected area system network. However, it does not cover a wide enough area. Two areas of predominantly peat swamp — Loagan Bunut National Park and Maludam National Park — are classified as Totally Protected Areas. Another site, Sedilu, is in the final stage of designation as a national park. In Sarawak, areas meant to remain under permanent forest cover are known as Permanent Forest Estate. Peatlands catergorised as Permanent Forest Estate account for 1.08 million hectares (Department of Statistics Sarawak 2009) but, in reality, only about two-thirds are peat swamp forests and they are mostly managed for timber extraction (Sime Darby Services 1999). Unfortunately, only 5 per cent of Permanent Forest Estate — Loagan Bunut National Park and Maludam National Park — are protected. This means that both these parks are crucial, not only for conserving the native flora and fauna of peat swamp forests but for maintaining ecosystem balances and performing ecological functions. More importantly, they are the last bastions for many species of rare and endangered wildlife.

At the moment, the future of peat swamp forests in Sarawak does not look bright. Recent studies have shown that the continued existence of Loagan Bunut National Park is at risk. The park has a seasonal lake within the peat swamp forests, which dries up when the water level from an adjacent tributary falls during the dry season. The drying up of the lake may become more prominent in the future. It is predicted that the lake will disappear in less than 60 years as a result of siltation, which has been mainly attributed to upstream logging activities, the expansion of the oil palm plantations surrounding it and the expansion of human settlements (Sayok et al. 2007). The clearing

of forests has inadvertently caused higher surface run-off and an increase in suspended solids in river water. Since the 1970s, logging and other developments, such as the creation of plantations in the lake's immediate catchment areas, have resulted in deteriorated water quality (Lau et al. 2006; Noweg et al. 2006) and accelerated sedimentation, which threatens to shorten the lifespan of the lake. Natural peat barriers have ensured the continued existence of the lake, separating and isolating it from the waters of nearby rivers. In recent times, the peat has shrunk considerably as the peat swamp forests outside the park have been converted into plantations, resulting in the loss of these natural barriers. In time, the lake may fill with floodwater from adjacent rivers (Hunt et al. 2006) and form a huge shallow flooded area. The lake itself is fed by a major river during high-water periods but this river is threatened by environmental degradation upstream, where surrounding oil palm plantations discharge effluents that may cause damage to the park and peat swamp forests.

Conclusion

The peat swamp forests of Sarawak face an uncertain future. In recent years, conservationists have lobbied vociferously on the local and world stage for the greater designation of peat swamp forests as protected areas. The threat to the peat swamp forests is growing, however, as plantation companies exert increasing demands for land for cash crops, encouraged by a government that has set a target for Sarawak to become a major producer of palm oil in Malaysia. This has put tremendous pressure on the continued existence of some of the remaining peat swamp forests.

For centuries, peat swamp forests were left idle after they were logged. Over time, many of these forests started to regenerate, although they were unlikely to be restored to their original state. Nevertheless, these forest remnants have been, and still are, home to many rare and unique species, such as the Sarawak Surili, orangutan, proboscis monkey, Storm's stork and masked finfoot. These are globally significant species and their current populations inside peat swamp forests are small and under threat. Sarawak has in place a system to preserve some of its peat swamp forests for perpetuity but the area protected is not large, representing a mere 4.2 per cent of the total peat areas. The vast expanse of peatlands, including the peat swamp forests, should be given more protection in view of the importance of the ecological functions and services these ecosystems perform. Past events, such as the major haze that blanketed south-east Asia in 1997/98, should serve as a constant reminder of the risks to humans that result from mismanagement and exploitation of peat swamp forests.

It is true that converting peat swamp forests into agricultural plots yields good economic returns. However, these are likely to be short-term gains that benefit only a limited number of people, such as the owners and developers of large plantations.

Meanwhile, local populations suffer from the environmental pollution caused by land mismanagement and the whole world suffers from the permanent loss of the peat swamp forests. In this paper, I have tried to show that the peat swamp forests of Sarawak — while seeming to be little more than a hostile, mosquito-infested wasteland — are actually home to some of Borneo's rarest endemic species and may harbour some species or important ecological services that have yet to be understood or even discovered.

The Malaysian government — and the Sarawak authorities in particular — should emphasise the importance of conserving peat swamp forest by changing agricultural policy to discourage the conversion of the remaining peat swamp forests. Sarawak should take the bold step of encouraging research to gain a greater understanding of these forests' unique communities. Attention should be paid not only to the flora and fauna of the peat swamp forests but to their social importance, notably to the people whose livelihoods depend on them (this human angle is a subject worthy of another paper). Inevitably, the quest to better understand our peat swamp forests may take longer than expected. There is an urgent need to protect more peat swamp forests in Sarawak and to preserve their natural state before all is lost.

References

Anang, S. H. (2001) 'Crop production on peatland', a paper presented at the workshop on Water Management for Sustainable Agriculture Development of Peatland, 28–29 March 2001, Kuching, Sarawak.

Anderson, J. A. R. (1963) 'The flora of the peat swamp forests of Sarawak and Brunei, including a catalogue of all recorded species of flowering plants, ferns and fern allies', *Gardens' Bulletin*, Singapore, Vol. 20, Part 2.

Anshari, G. Z. and Armiyarsih (2005) 'Carbon decline from peatlands and its implications on livelihood security of local communities', in Mudiyarso, D. and Herawati, H. (eds) *Carbon Forestry. Who Will Benefit?* Proceedings of a workshop on carbon sequestration and sustainable livelihoods. Centre for International Forestry Research, Bogor Barat. Available online at www.cifor.cgiar.org/publications/pdf_files/Books/BMurdiyarso0501.pdf

ASEAN Peatland Forests Project (2010) *Summary Report and Recommendations of the Workshop on Options for Carbon Financing to Support Peatland Management*, Pekanbaru, Riau 4–6 October 2010. Regional Project Executing Agency and Global Environment Centre.

Armentano, T. K. (1990) 'Soils and ecology: tropical wetlands', in Williams, M. (ed.) *Wetlands: a Threatened Landscape*, Oxford, Basil Blackwell.

Bennett, E. L. and Gombek, F. (1992) 'Wildlife and conservation in Sarawak's peat swamp forests', *Tropical Peat: Proceedings of the International Symposium on Tropical Peatland* 6–10 May 1991 Kuching, Sarawak Malaysia, MARDI pp. 307–310.

Berg, J. van den, Salleh, N., Demies, M. and Amir, J. (2004) *Rapid diagnostic appraisal of non-timber forest products of the Maludam National Park, Betong Division, Sarawak*. Sarawak, Malaysia, Forest Department. Joint Working Group Malaysia-the Netherlands: Development and management of Maludam National Park.

Butler, R. A. (2006) *The Asian Forest Fires of 1997–1998*, available online at www.rainforests.mongabay.com and downloaded 22 January 2010.

Department of Statistics Sarawak (2005) *Monthly Statistical Bulletin Sarawak: April 2005*. Dept. of Statistics Malaysia, Sarawak.

Department of Statistics Sarawak (2009) *Yearbook of Statistics Sarawak*. Dept. of Statistics Malaysia, Sarawak.

Drahman, H. H. (1999) 'Land alienation for plantation development', a paper presented at the Working Towards Integrated Peatland Management for Sustainable Development Workshop, 17–18 August 1999, Kuching, Sarawak.

Ehrlich, P. R. and Ehrlich, A. (1981) *Extinction*. Random House, New York.

Food and Agricultural Organization of the United Nations (2010) FAOstat, available online at http://faostat.fao.org/site/339/default.aspx

Global Environmental Facility (2006) 'Rehabilitation and sustainable use of peatlands in southeast Asia: International Fund for Agricultural Development full project brief', GEF, available online at www.peat-portal.net

Gumal, M. T. (2001) 'Ecology and conservation of a fruit bat in Sarawak, Malaysia', PhD thesis, University of Cambridge, England.

Gumal, M. T. (2004) 'Diurnal home range and roosting trees of a maternity colony of *Pteropus vampyrus natunae* (Chiroptera: Pteropodidae) in Sedilu, Sarawak', *Journal of Tropical Ecology* 20: pp. 247–258.

Gumal, M., Hon, J. and Kong, D. (2008) *Birds and bats of Loagan Bunut National Park, Sarawak, Malaysia*, UNDP/GEF-funded Peat Swamp Forest Project, Sarawak, Malaysia and Wildlife Conservation Society. 105 pages

Hon, J. and Gumal, M. (2004) 'Monitoring and conserving primates in Maludam National Park: final report', a paper presented at the Joint Working Group Malaysia-the Netherlands Maludam-Ramin Projects Workshop: Wise Use of Peat Swamp Forests in Malaysia.

Hon, J. and Gumal, M. T. (2005) 'Monitoring and conserving primates in Maludam National Park', in K. M. Jaafar, J. Grinang, and M. S. Sabki (eds) *Maludam Technical Report*, Alterra Wageningen UR, Forest Department Sarawak, and Sarawak Forestry Corp., pp. 203-241.

Hunt, C., Singh, H., Badang, D., Banda, R. M. and Rushworth, G. (2006) 'Landscape development around Loagan Bunut, Sarawak', in A. A. Tuen, A. K. Sayok, A. N. Toh and G. T. Noweg (eds) *Scientific Journey Through Borneo: Loagan Bunut*, Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Kota Samarahan and UNDP-GEF Peat Swamp Project, Forest Research Institute of Malaysia, Selangor.

Immirzi, P. (1997) 'Wasted assets or wasting assets: peatland functions and values' in L. Parkyn, R. E. Stoneman and H. A. P. Ingram (eds) *Conserving Peatlands*, CAB International, pp. 147–157.

International Union for Conservation of Nature (2010) 'International Union for Conservation of Nature Red List of Threatened Species', available online at www.iucnredlist.org and downloaded on 22 January 2010.

Jamaludin, J., Mohamad Hanif, M. J. and Ismail, A. B. (2004) 'Least impact strategy for peatland development and utilization', a paper presented at the International Research Seminar on Strategies for Wise Use of Tropical Peatlands — the Sarawak Context, 24 November 2004, Kuching, Sarawak.

Kamarudin, K. A., Zahari, A. B. and Salmah, Z. (1999) 'Integrated development plan for coastal peatland in Sarawak', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Kanapathy, K. (1984) 'Some factors in the cultivation of perennial crops on peat', in Pushparajah E. and Wong C. B. (eds) *Proceedings of the Workshop on Classification and Management of Peat in Malaysia*, Kuala Lumpur: The Malaysian Society of Soil Science.

Lau, S., Murtedza, M., Apun, K., Bong, A. C. H., Tay, M. G. and Sayok, A. K. (2006) 'The water quality status of Loagan Bunut National Park, Sarawak', in A. A. Tuen, A. K. Sayok, A. N. Toh and G. T. Noweg (eds) *Scientific Journey Through Borneo: Loagan Bunut*, Institute of Biodiversity and Environmental Conservation, University Malaysia Sarawak, Kota Samarahan and UNDP-GEF Peat Swamp Project, Forest Research Institute of Malaysia, Selangor.

Lim, H. H. and Tan, A. K. C. (1999) 'Peat hydrology/water management', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Lindenmayer, D. B., Cunningham, R. B. and Pope, M. L. (1999) 'A large-scale "experiment" to examine the effects of landscape context and habitat fragmentation on mammals', *Biological Conservation* 88: 387–403

Maltby, E. (1997) 'Peatlands: the science case for conservation and sound management', in L. Parkyn, R. E. Stoneman and H. A. P. Ingram (eds) *Conserving Peatlands*, CAB International, pp. 121–131.

Mamit, J. D. and Sawal, P. (1999) 'Environmental issues in peatland development', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Melling, L. (1999) 'Sustainable agriculture development on peatland', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Melling, L. and Hatano, R. (2005) 'Peat soils study', in K. M. Jaafar, J. Grinang, and M. S. Sabki (eds) *Maludam Technical Report*,

Alterra Wageningen UR, Forest Department Sarawak and Sarawak Forestry Corporation.

Ministry of Agriculture, Malaysia (1998) *Third National Agricultural Policy, 1988–2010*, Ministry of Agriculture, Malaysia.

Malaysian Palm Oil Board (2008) 'Distribution of oil palm planted area by states: 2008 (hectares)', available online at http://econ.mpob.gov.my/economy/annual/stat2008/Area1.7.pdf

Malaysian Palm Oil Board (2010) 'Overview of the Malaysian oil palm industry 2009. Malaysian Palm Oil Board', available online at http://econ.mpob.gov.my/economy/Overview_2009.pdf

Mutalib, A. A., Lim, J. S., Wong, M. H. and Koonvai, L. (1992) 'Characterization, distribution and utilization of peat in Malaysia', in Aminuddin, B. Y. (ed.) *Proceeding of the International Symposium on Tropical Peatland*, Serdang: MARDI. 7–16.

Noweg, G. T., Wan Sulaiman, W. H. and Murtedza, M. (2006) 'Estimation of sediment yield in the Loagan Bunut', in A. A. Tuen, A. K. Sayok, A. N. Toh and G. T. Noweg (eds) *Scientific Journey Through Borneo: Loagan Bunut*, Institute of Biodiversity and Environmental Conservation, University Malaysia Sarawak, Kota Samarahan and UNDP-GEF Peat Swamp Project, Forest Research Institute of Malaysia, Selangor.

Ong, B. Y. and Yogeswaran, M. (1992) 'Peatland as a resource for water supply in Sarawak', *Tropical Peat: Proceedings of the International Symposium on Tropical Peatland*, 6–10 May 1991, Kuching, Sarawak Malaysia. MARDI, pp. 255–268.

Page S. E., Rieley, J. O. and Wüst, R. (2006) 'Lowland tropical peatlands of southeast Asia', in Martini, I. P., Martínez Cortizas A. and Chesworth, W. (eds) *Peatlands: Evolution and Records of Environmental and Climate Changes*. Elsevier, The Netherlands, pp. 145–172.

Rieley, J. (1992) 'The ecology of tropical peatswamp forest — a southeast Asian perspective', in *Tropical Peat: Proceedings of the International Symposium on Tropical Peatland* 6–10 May 1991 Kuching, Sarawak Malaysia. MARDI, pp. 244–254.

Rieley, J. O. and Ahmad-Shah, A. A. (1996) 'The vegetation of tropical peat swamp forests', in Maltby, E., Immirzi, C. P. and Safford, R. J. (eds) *Tropical Lowland Peatlands of Southeast Asia: Proceedings of a Workshop on Integrated Planning and Management of Tropical Lowland Peatlands*. Cisarua, Indonesia, 3–8 July 1992. IUCN, Gland, Switzerland, pp. 55–73

Rieley, J. O., Ahmad-Shah, A. A. and Brady, M. A. (1996) 'The extent and nature of tropical peat swamps' in Maltby, E., Immirzi, C. P. and Safford, R. J. (eds) *Tropical Lowland Peatlands of Southeast Asia: Proceedings of a Workshop on Integrate Planning and Management of Tropical Lowland Peatlands*. Cisarua, Indonesia, 3–8 July 1992, IUCN, Gland, Switzerland, pp. 17–53.

Sahamat, A. C. (1999) 'Development of peatland: socio-economic perspective', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Sayok, A. K., Sapuan, A., Melling, L., Efransjah, E. and Rahim Nik, A. (2007) 'Land developers as partners in sustainable management of peat swamp forests resources', in Jol et al. (eds) *Proceedings of the Soil Science Conference of Malaysia*, 17–19 April 2007, Mukah, Sarawak, Malaysia, Malaysian Society of Soil Science, Selangor.

Shakeran, M. S. (1999) 'Water catchment and supply', a paper presented at the workshop on Working Towards Integrated Peatland Management for Sustainable Development, 17–18 August 1999, Kuching, Sarawak.

Sime Darby Services (1999) *Integrated Development Plan Study for Coastal Peatland Sarawak*, Sime Darby.

Sinclair, A. R. E. (1998) 'Natural regulations of ecosystems in protected areas as ecological baselines', *Wildlife Society Bulletin* 26: 399–409.

Strack, M. (ed) (2008) *Peatlands and Climate Change*, International Peat Society.

Ten, W. P. and Murtedza, M. (2004) 'An overview of environmental impacts and impact assessment of peatland development in Sarawak', a paper presented at the International Research Seminar on Strategies for Wise Use of Tropical Peatlands — the Sarawak Context, 24 November 2004, Kuching, Sarawak.

The Star (2010) 'Forestry biggest contributor to Sarawak's GDP', *The Star*, 10 July 2010.

Tie, Y. L. and Kueh, H. S. (1979) 'A review of lowland organic soils of Sarawak', Dept. of Agriculture Sarawak, Technical Paper No. 4.

Tie, Y. L., Kselik, R. A. L. and Tan, A. K. C. (2005) 'Hydrology', in K. M. Jaafar, J. Grinang, and M. S. Sabki (eds) *Maludam Technical Report*, Alterra Wageningen UR, Forest Department Sarawak and Sarawak Forestry Corporation.

United Nations Development Programme (2006) *Malaysia's Peat Swamp Forests: Conservation and Sustainable Use*. MNRE Malaysia, Danida, GEF and UNDP.

Wösten, J. H. M., Ismail, A. B. and van Wijk, A. L. M. (1997) 'Peat subsidence and its practical implications: a case study in Malaysia', *Geoderma* 78: 25–36

Yule, C. M. (2010) 'Loss of biodiversity and ecosystem functioning in Indo-Malayan peat swamp forests', *Biodiversity and Conservation* 19: 393–409.

Jason Hon graduated from Aberdeen University, UK in 2002 with a master's degree in ecology. He is pursuing his doctorate studies with the Graduate School of Global Environmental Studies, Kyoto University, majoring in environmental management, and is attached to the Laboratory of Ecology and Planning. Since 2002, his work has taken him to various parts of Malaysia, notably the peat swamp forests of Sarawak, where he conducted research on primates, birds and bats. He now conducts wildlife surveys in production (logging concessions and planted) forests to document the use of key natural resources, such as salt licks, by wildlife and to determine the best management measures for the conservation of wildlife and its habitat.