The global impact of Indonesian forest fires

Uncontrolled fires across Indonesia burn large areas of peatland and create vast palls of smoke on an almost annual basis. This has devastating effects on wildlife, human health, the economy and climate. Yet, more than 10 years after the massive fires of 1997-98 grabbed international headlines, the problem is still far from solved.

Mark E Harrison[1], Susan E Page[2] Suwido H Limin[3]

Universities of [1]Cambridge and [2]Leicester, UK, and [3]University of Palangka Raya, Indonesia

Title Image. A scene of devastation following a peat-swamp forest fire in a logged area of Indonesia. Photo courtesy OuTrop.

Earlier this year, forest fires were once again in the media spotlight as devastating forest fires in Southern Australia killed over 180 people and razed around 0.5Mha of land. Forest fires are also a major problem in Indonesia where, though not a new phenomenon, their frequency and severity are increasing; indeed, the uncontrolled burning of large areas of land and the associated haze are now an almost annual problem. Most of these fires occur in Kalimantan and Sumatra, which have the world's largest areas of tropical peatland. These fires are a man-made disaster: the effects on wildlife, human health, the region's economy, and local and global climate are immense. Despite this, local people's awareness of the impact of the fires remains low, water-management policies are frequently inappropriate and local expertise in fire control is often ignored by government and donors. Meanwhile, international awareness of the problem, pressure on the Indonesian government and aid are insufficient.

The fires

Fires occur on Indonesian peatlands and peat-swamp forest (PSF) in the dry season and, unsurprisingly, are worse in drier years. The Indonesian climate is strongly influenced by the El Niño Southern Oscillation (ENSO): in El Niño years, dry-season rainfall can be less than half of normal and severe El Niño events have long been associated with fire (e.g. 1972-73, 1982-83, 1987, 1991-92, 1994, 1997-98, 2002, 2006). The Indian Ocean Dipole may also influence drought in Indonesia and, hence, fire frequency and severity (Field *et al*, 2009). The high carbon content of peat means peat fires release vast amounts of smoke (Figure 1) and carbon: tropical peatland fires emit ≥300Mg (megagrams, 10^6 g) C per hectare, compared to 7.5-70MgC ha^{-1} from other habitat types (Cochrane, 2003). During the severe 1997 El Niño, fires destroyed millions of hectares of PSF and released 810-2,570 Mt (10^6 tonnes) of carbon into the atmosphere (Page *et al*, 2002). This is equivalent to between 13 and 40% of mean annual global carbon emissions from fossil fuels and contributed to the largest annual increase in atmospheric CO_2 since records began. It is estimated that Bornean peat fires alone produced an average of 74MtC per year between 2000-06 (van der Werf *et al.*, 2008), making Indonesia one of the world's largest CO_2 emitters (Hooijer *et al*, 2006). Much evidence now indicates that the frequency and severity of peatland fires in Indonesia are increasing dramatically.

Figure 1. Smoke produced from peat-swamp fires. The railway leading to the Natural Laboratory of Peat-Swamp Forest (NLPSF) research site as seen from the jetty to the forest (ca. 1.5 km away), during the 2002 fires (1a) and during a smoke-free period in 2006 (1b). In the 2006 smoke season, smoke was of a similar thickness to 2002. Photographs by Helen Morrogh-Bernard (1a) and Claire Thompson (1b).

Causes

Tropical peatland fires in Indonesia are generally caused by illegal human activity, including:

- *Land clearing* – The area of PSF being allocated for plantations, and consequently being burned for land clearance, is increasing annually and these fires frequently get out of control. Indonesia is the world's largest palm-oil producer, and it is predicted that a further 6Mha of (primarily forested) land will be converted to oil-palm plantations by 2020, with half of this on peatland (Hooijer *et al*, 2006). Related causes include forest clearance associated with other forms of agricultural land conversion, for example the ill-fated Mega Rice Project (MRP, Box 1), and small-scale clearance by individual small farmers.
- *Use of fire as a weapon in land tenure/use disputes* – Uncertain land tenure and access rights with consequent conflicts can contribute to increased burning. Smallholders can become frustrated at being unable to have their claims heard in a fair and transparent judicial system and resort to the use of fire as a weapon to reclaim land for agriculture. Local people have no incentive to fight fires on land for which they are not directly responsible and, as a result, small fires spread, becoming uncontrollable and highly damaging.
- *Fire for resource extraction and other purposes* – This takes many guises (e.g. hunting, burning waste) but is generally of low importance.
- *Accidental fires* – These are often started by discarded cigarettes or unprotected cooking fires, following increased human access into peatland areas along newly-constructed logging tracks and canals.

Fires are a product of both climatic conditions and anthropogenic factors, e.g. transmigration projects (the probability of fire in transmigration areas is almost four times higher than in other areas in Jambi, Sumatra) and land use change (Stolle *et al*, 2003; Page *et al*, 2009). Consequently, by driving local land-use policies, national policy has a major influence on fire frequency and intensity.

In PSF, reduction in ground-water level by drainage is a major precursor to fire (Wösten *et al*, 2008). Undisturbed PSF is poorly drained and hence is waterlogged and flooded for much of the year. As a result, it is naturally fire resistant. Illegal loggers, unable to build roads on the soft peat, dig canals in which to float logs to the nearest river where they are processed and transported to points of sale. These canals rapidly drain the peat. Oil-palm and pulp-wood plantations on tropical peatland are also drained and the water table must be maintained at a fairly constant low level in order for the tree crops to grow. Once dry, the carbon-rich peat – which formed over thousands of years in wet, anoxic conditions – burns. Thus, peatland drainage is *the* principal cause of the recent increased frequency and severity of tropical peatland fires.

Of further concern is the positive-feedback loop for tropical forest fires, in which burning increases the ecosystem's susceptibility to fire, leading to more frequent and severe fires (Cochrane *et al*, 1999; Page *et al*, 2009). Fire does not normally spread in the moist, closed-canopy environment of undisturbed PSF, but when it does occur many trees die and large gaps occur in the canopy. This increases the rate of fuel drying and increases the fuel load, resulting in fires gaining hold more easily and burning more fiercely. Subsequent burning before the forest has recovered adds to this effect, with the likely end result being the complete destruction of the forest. Furthermore, due to increased fuel load, forest fires are more frequent in logged forests than natural PSF, further accentuating the positive-feedback loop. This is a major problem, considering the large areas of Indonesian PSF already burnt and/or logged, and the increase in size of these areas year on year (>2% of Bornean PSF is lost each year, Langner *et al*, 2007).

Figure 2. Peat fires in the NLPSF study area, 2006. Peat fires may not be dramatic to look at, often burning only below the surface (2a), but fires like this produce lots of smoke and burn away peat and stored carbon that took thousands of years to form. This leaves tree roots exposed and leads to mass tree falls (2b), and fires can reignite on the surface if left unattended. Photographs by Susan Cheyne (2a) and Marie Hamard (2b).

Effects of fires

Biological effects

Unlike many other fire-prone areas such as Australia, fire is not a natural event in tropical PSF. Consequently, the forest flora and fauna are not adapted to cope and are at great risk from fire events. The biological effects of fire in complex, highly diverse PSF are many, of which the following are examples:

- *Peat burning and consequent subsidence* (Figure 2) – Dry peat smoulders for long periods and burns down to the water table. When this happens, tree roots are exposed and both the peat and forest vegetation become unstable, resulting in peat subsidence, massive tree falls and the consequent loss of large areas of forest (Figure 3).
- *Effects on flora* – PSF trees are not adapted to fire (most have very thin bark), so tree mortality post-fire is high. Although fires are generally low intensity, their slow spread rate means fire is in contact with trees for long periods, heating up the bark. Fire can kill 23-44% of trees with >10cm DBH (diameter at breast height) and 95% of stems with >1cm DBH in the Amazon. They

alter species composition in the area with little regeneration even 15 years after burning (Cochrane *et al*, 1999; Cochrane, 2003). Tree mortality in severely burnt areas of PSF is virtually 100%, as most trees fall once the supporting peat is burnt away (Figure 2b).

- *Effects on fauna* – Animals dependent on intact PSF will clearly be impacted directly by fire, but other effects are also likely; for example, gibbons (*Hylobates albibarbis*) sing less frequently in smoky conditions, which could interfere with territorial spacing and, ultimately, reproduction (Cheyne, 2007).

Effects on human health

Following the 1997 fires, an estimated 20 million people in Indonesia suffered from respiratory problems, with 19,800-48,100 premature mortalities (Heil, 2007). In severely affected areas, > 90% of people had respiratory symptoms and elderly individuals suffered a serious deterioration in overall health (Kunii *et al*, 2002). The Indonesian National Standards Institute classifies concentrations of particulate matter with diameters $\leq 10\mu m$ in concentrations of over $200\mu g/m^3$ as 'very unhealthy' and above $300\ \mu g/m^3$ as 'dangerous'. These figures are regularly exceeded in smoky years; for example, in Palangka Raya, Central Kalimantan, air quality was rated as 'unhealthy/very unhealthy/dangerous' on 81% of days from September-November 2006 and, in October 2006, 30 of 31 days were 'dangerous' (Board for the Control of Environmental Impacts in Palangka Raya Area, 2006), representing a clear health threat (Figure 4). Additionally, thick smoke impairs visibility, causing an increase in traffic accidents, and a general lack of public health service and the high cost of health insurance means that treatment is not typically received for smoke-related ailments.

Effects on the economy

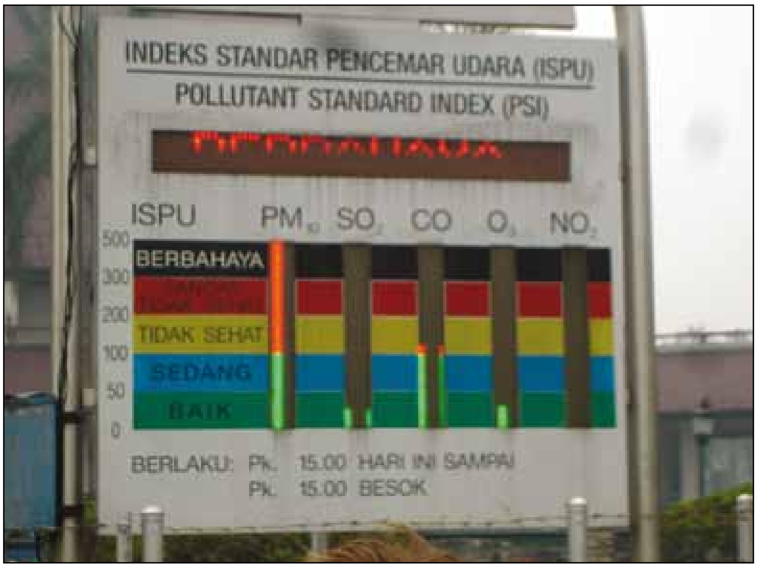
Estimates of the cost of uncontrolled fires to the Indonesian economy differ, but are invariably large. Varma (2003) analysed the costs and benefits of slash-and-burn to the Indonesian economy and concluded that during 1997-1998 Indonesia lost US$20.1 billion as a result of this practice. Economic losses in heavily-affected rural villages can amount to as much as 50% of township income. Haze from the fires can extend to Malaysia, Singapore and Thailand, shrouding them in smoke and affecting transport and economic activities for millions more people, resulting in billions more dollars of economic losses. Clearly, the economic losses associated with uncontrolled fires are contributing to poverty and restraining development in the region.

Figure 3. Burnt areas of forest in the NLPSF viewed from space. Areas of non-burnt forest are green and burnt areas (in the middle of the forest) are white/light brown. The black-red areas in between the forest and river are cleared areas of forest, which are highly degraded and burn almost annually. Image courtesy of www.googleearth.com.

Effects on climate

- *Global warming* – The massive carbon emissions from peat fires makes them a major contributor to the global increase in atmospheric CO_2. The Kyoto Protocol, to which Indonesia is a signatory, obliges ratifying countries to reduce CO_2 emissions by $\geq 5\%$ of 1990 levels by 2012. Based on the findings of Hooijer *et al* (2006), eliminating Indonesian peatland fires completely would

Figure 4. The Pollutant Standard Index Board in Palangka Raya, Central Kalimantan on 31st October 2006. Overall air quality and particulate matter levels are "dangerous" ("berbahaya") and carbon monoxide levels are "unhealthy" ("tidak sehat"). Photograph by Marie Hamard.



Box 1. Fires Within the Ex-Mega Rice Project Area

In 1995, the Indonesian government initiated the 'Mega Rice Project' – an attempt to make Indonesia self sufficient in rice production – which involved the reclamation of 1.5 Mha of peatland in Central Kalimantan for rice plantation and the transmigration of 100,000 families to the area. Over 4,000 km of deep drainage canals up to 20 m wide were dug (Figure 6). Peatland experts advised against this and correctly predicted the failure of the project, which dried the peat, leading to extensive annual burns and the near-complete destruction of the forest.

achieve this in one fell swoop.

- *Reduced temperatures and light intensity* – Smoke blocks out the sun, reducing light intensity and temperature. Photosynthetically-active radiation can decline by up to 92% under thick smoke conditions, negatively influencing plant photosynthesis rates (Davies and Unam, 1999) and possibly reducing food security in the region.
- *Potential influence on ENSO* – ENSO has far-reaching effects on world climate. The frequency of El Niño events is thought to have increased since the mid-1970s, due to global warming (Trenberth and Hoar, 1997). This could create a positive-feedback loop: increased burning increases atmospheric CO_2 concentrations, which raises temperatures, and increases the frequency and severity of ENSO events, thereby increasing the incidence and severity of future fires, etc.

Solving the problem

Numerous local and international organisations, as well as Indonesian and foreign governments, are taking action in an attempt to solve this problem (see example in Box 2). Fire-fighting teams have been established in many hotspot areas (Figure 5). These generally comprise local men, who protect land in their area of responsibility (be that an area of forest, farmland or an oil-palm plantation). Teams vary in their expertise and the resources available to them but are generally equipped with hoses and pumps to extract water from the nearest available source. Work is dangerous and tiring while wages are generally poor; hence, many people are unwilling to fight fires unless their property is immediately at risk. Due to limited resources, these teams are generally unable to attend all fires within their coverage area.

Prevention is always better than cure, however, and, as such, *retaining natural hydrology in intact forests, and blocking drainage channels in disturbed peatlands to restore natural hydrology is the only long-term solution in the battle to control tropical peatland fires* (Figure 6). This is particularly important in intact forest, to prevent the first burn and peat degradation from occurring, thereby preventing the positive-feedback loop from starting. Such projects are underway in some areas, but are hampered by a lack of resources.

Local education is also paramount as many fires are started accidentally or could be easily controlled if tended to immediately. Although education projects are underway, local people frequently remain unaware of simple fire-prevention and early-control methods. Clearing land by fire is illegal in Indonesia but insufficient

Figure 5. Fire fighting by the CIMTROP TSA in the NLPSF during 2006. When far from surface water, bores 16-24 m deep are dug into the peat to obtain water; this process continues both day and night (5a). Fire above and below the surface is then watered extensively (5b); when this picture was taken, flames on the surface had already been extinguished, but continued spraying was needed to extinguish the smouldering fires below the surface. Photographs by CIMTROP (5a) and Susan Cheyne (5b).

resources, lack of motivation and corruption within law-enforcement agencies result in hardly any successful prosecutions. Fire is also the cheapest, easiest and fastest method for clearing land and there is no monetary incentive to use alternative methods, ensuring a continuing propensity to flout laws.

Clearly, current actions are failing to eliminate the fire problem in Indonesia PSF. This is due to:

1. *The sheer size of areas involved and insufficient funds* – Massive areas of land (many of them remote) are threatened, huge numbers of canals require blocking, numerous dams are required to effectively block each canal and funds are severely limited. Thus, a huge increase in financial investment is required to make an impact on a grand scale. For example, in the 2000 United States fire season, over US$1.4 billion was spent on fire suppression in a 3.4Mha area, whereas in the 1997-98 Indonesian fires only US$25 million (including foreign aid) was available to combat fires over an 8Mha area (Cochrane, 2003). Extinguishing below-ground peat fires is also incredibly difficult (requiring 200-400 litres of water per sq metre), due to the peat itself burning beneath the surface.
2. *Inappropriate water-management policies in plantations* – The main objectives of these policies are generally to prevent wet-season flooding, but equal priority should be given to preventing water levels from falling too low in the dry season (Hooijer *et al*, 2006).
3. *Government policies* – While the Indonesian government is vocal about its intentions to combat fires, many of its policies (e.g. the MRP, oil-palm expansion) contribute to increased fire frequency.
4. *Poverty* – Poverty rates in peatland areas are much higher than elsewhere in Indonesia and without alternative sustainable-development options local communities will be forced to over-exploit remaining peatlands, increasing fire risk.
5. *Lack of local awareness* – Many people remain unaware of how their actions contribute to the problem and adequate preparations for early fire control are generally not in place.
6. *Insufficient international recognition, pressure and support* – The reduction targets agreed under the Kyoto Protocol exclude CO_2 emissions from soil, degraded vegetation and forest fires: yet these are huge causes of greenhouse gas emissions from tropical peatland. This must be remedied. Importantly, the magnitude of the funds needed to restore natural hydrology in disturbed areas and fight fires are such that they will probably never be attained solely from within Indonesia.

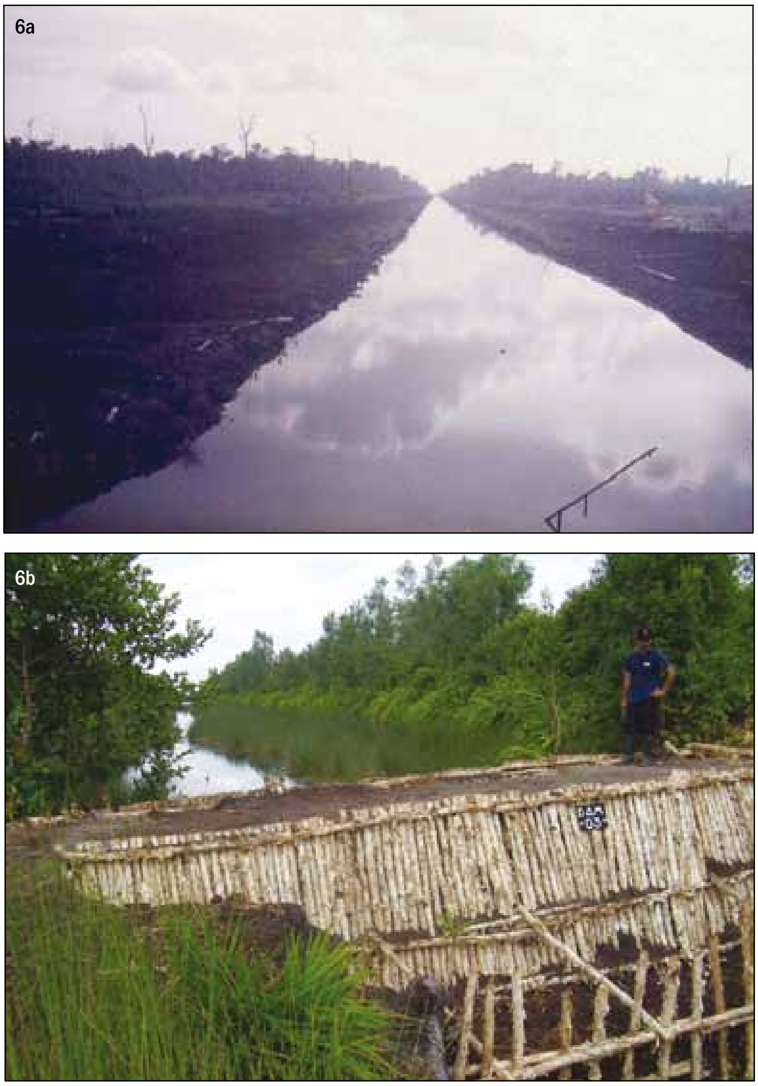


Figure 6. Large drainage canal in the ex-Mega Rice Project area when first dug in 1997 (a) and after (b) damming. Note the width of the canals and the difference in water level above and below the dam in Figure 6b. Photographs by CIMTROP.

There are a number of additional prerequisites that must be in place before there is any realistic hope of solving the problem:

1. Increased understanding and appreciation of the value of tropical peatland and PSF. In particular, translating the value of tropical peatlands as an internationally-important carbon store into a tangible economic value, such that the forest is worth more alive than dead. Hopefully, this can be achieved through schemes such as REDD (Reducing Emissions from Deforestation and Degradation), although international agreement on this hotly-debated topic is currently lacking.

Box 2. Case Study: Fire Prevention and Fighting Activities by CIMTROP

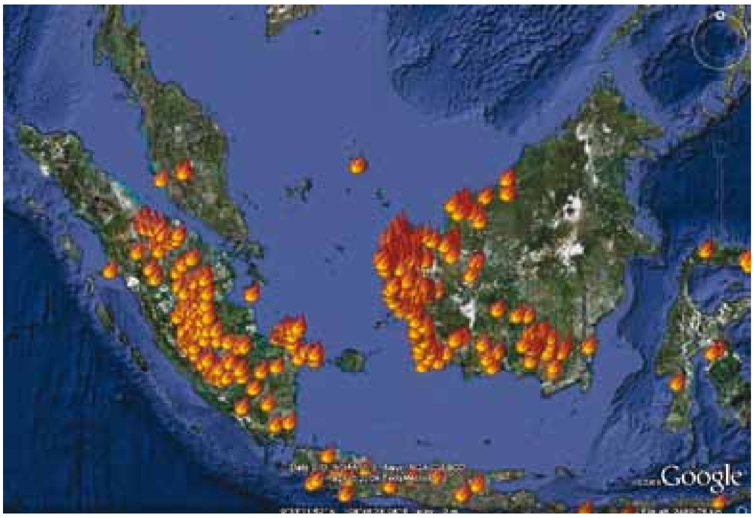
In 1997, CIMTROP (the Centre for International Cooperation in Management of Tropical Peatlands) established the Tim Serbu Api (TSA-KALTENG – Fire Attack Force of Central Kalimantan), with the aim of preventing and fighting forest fires around its two research sites: the Natural Laboratory of Peat-Swamp Forest, Sabangau (NLPSF) and Kalampangan, Block C of the Ex-MRP. Through working with the local community, TSA-KALTENG has made major strides in eradicating illegal logging and damming major canals within the NLPSF's boundaries. This will aid restoration of the forest's natural hydrology, hopefully preventing/reducing the frequency and severity of future fires. Further efforts and significant funding are needed, however, as effective damming requires numerous dams along each canal and funds are severely limited. During the dry season, TSA-KALTENG is on constant fire-fighting duty.

TSA-KALTENG's effectiveness is highlighted by their tackling of a recent fire near the NLPSF research base. At 1000 h on 29th October 2006, fire was discovered 600 m from the research camp, in an area of degraded forest about 1 km from the nearest above-ground water source. On the night of the 29th, the fire came within 300 m of camp but, by digging wells into the peat, watering flames, soaking peat in front of the fire to create fire blocks and working round-the-clock for the first 48 hours, the team stopped the fire's spread and extinguished it within just four days. TSA-KALTENG is the only team in Central Kalimantan that digs wells, meaning that they can extinguish fires in areas without nearby surface water, where other teams cannot work. The team has installed permanent wells in the NLPSF and Kalampangan, so future fires can be dealt with even more efficiently.

CIMTROP also have a grass-roots education programme, in which people are taught about fire prevention and making water bombs, which can be made using "dirty" water, stored indefinitely and used to extinguish small fires before they become uncontrollable. Despite the clear importance of this work, CIMTROP receives no support from the Indonesian government and, consequently, a lack of resources means that many fires are not prevented/left unattended.

2. Increased media exposure outside Indonesia, to create sustained international pressure and aid to Indonesia to prevent and fight fires.
3. Increased pressure on oil-palm and other plantation companies to act more responsibly and not burn areas or convert semi/pristine forest into plantations. Until this happens, use of palm oil, particularly as a biofuel, should be discouraged. Palm oil grown on peatland is not a carbon-saving biofuel: it would take 840 years of reduced emissions through oil-palm combustion to repay the carbon debt created through the conversion of PSF to oil palm (Fargione et al, 2008).
4. Increased education in affected areas on the effects of fire as well as the need for fire prevention and early control. Increased aid is needed to provide local people with fire-control devices (e.g. water bombs). This could be achieved through teaching in schools and mass-media campaigns.
5. Increased consultation by central government with local and international experts, and support for local fire-fighting teams.

Figure 7. Ten-day fire hotspot satellite image for period 7-17 July 2009 showing hotspots throughout much of Sumatra and Kalimantan. Red dots indicate fire hotspots. This image was taken at the beginning of this year's El Niño dry season; it is likely that substantially more hotspots will be detected as this dry season progresses. Image courtesy of NASA/GSFC MODIS Rapid Response.



Conclusions

The effects of uncontrolled fires on Indonesia's wildlife, economy and public health, and on local and global climate, are serious and cannot be understated. Current remedial actions have met with little success because of the sheer scale of the problem, inappropriate water-management and government policies, poverty and insufficient international pressure or support to solve the problem. It is therefore imperative that international attention is drawn to this problem, a commitment to change is made and resources are made available to implement these changes. At the time this article went to press, the National Oceanic and Atmospheric Administration (NOAA) had just confirmed the arrival of a new El Niño event in 2009, which is expected to persist throughout the winter. The full effects of this on peatland fires in Indonesia will not be apparent until then, but early reports of low rainfall in Indonesia, high numbers of hotspots detected by MODIS satellites (Figure 7) and rampant peatland fires in Riau, Sumatra, suggest that extensive peatland fires are likely to occur throughout the region again this winter, providing a potent reminder of the urgency of this problem.

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Further reading

Further information can be found in a special issue of *Mitigation and Adaptation*

Strategies for Global Change dedicated to South-east Asian fire (Volume 12, Issue 1) and on the Carbopeat project website (www.geog.le.ac.uk/carbopeat/index.html). Current fire hotspots can be viewed through the MODIS Rapid Response System website (http://rapidfire.sci.gsfc.nasa.gov).

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Mark E. Harrison (corresponding author) is a post-doctoral associate of the Wildlife Research Group, University of Cambridge and the Orang-utan Tropical Peatland Project (OuTrop). Email: harrison_me@hotmail.com. His research includes studies of wild orang-utans and forest ecology in PSF, flying-fox bushmeat surveys throughout Kalimantan, and PSF conservation. **Susan E Page** is a Senior Lecturer in the Department of Geography, University of Leicester. Her research interests include the ecology and management of tropical peatlands, with a particular focus on their role in the global carbon cycle. **Suwido H. Limin** is Director of the Centre for the International Cooperation in Management of Tropical Peatland, University of Palangka Raya, Indonesia. His research covers all aspects of PSF ecology. He is also Director of TSA-KALTENG and the CIMTROP Education Division.

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