THE ROLE OF FIRE IN THE DEGRADATION OF TROPICAL PEATLANDS: A CASE STUDY FROM CENTRAL KALIMANTAN

A. Hoscilo, S.E. Page and K. Tansey

Department of Geography, University of Leicester, Leicester, UK
Email: ah165@le.ac.uk,

SUMMARY

Tropical peatlands in Central Kalimantan have been exposed to both extensive and intensive degradation as a result of unsustainable land management practices, which have led to widespread fires over the last three decades. Results from remote sensing analyses reveal that over the last 10 years fire frequency has increased and has now reached a yearly cycle. As a consequence of large scale, repeated fires, natural regeneration back to peat swamp forest has been replaced by retrogressive succession towards low biodiversity vegetation dominated by fire prone bushes and ferns. In a case study area of 450,000 ha, satellite images were used to determine land cover change and fire history and to assess the vegetation re-growth process.

Keywords: peatlands, deforestation, fire, remote sensing, Borneo.

INTRODUCTION

Tropical ecosystems annually process about six times as much carbon through photosynthesis as humans release into the atmosphere through fossil fuel combustion (Malhi & Grace, 2000; Malhi *et al.*, 2002). Therefore, even relatively small perturbations within tropical forest ecosystems could produce significant changes in global carbon flux, the rate of climate change, biodiversity and, ultimately, human welfare (Lewis *et al.*, 2004). Peat swamp forest in Central Kalimantan (in the Indonesian part of Borneo) have been subjected to both extensive and intensive degradation owing to unsustainable land management practices, which have led to land cover change and widespread fires over the last three decades. Implementation of the Mega-Rice Project (MRP) in 1996-1998 led to substantial damage in a short time period when almost 80% of this area of approximately one million hectares, comprising mainly over-drained peatland, was heavily affected by fire during the prolonged dry season associated with the 1997/98 El Niño event. This led to loss of biodiversity, carbon and natural wetland ecological functions. The weaker El Nino event of 2002 caused further degradation of the remaining peat swamp forest and further significant loss of carbon as a result of combustion of both above ground biomass and peat. Our investigations reveal that until 2002 widespread and intensive fires were, in most cases, related to cyclical El Niño phenomena. Since 2003, however, fire has become an abnormal "natural" phenomenon in this tropical environment and the cause of wide-ranging environmental, social and health problems at both local and global scales (Davies & Unam, 1999; Rieley & Page, 2005).

In order to quantify the scale of peatland degradation arising from this repeated and continuous fire activity, satellite imagery ware used to investigate a project study area of nearly half a million hectares comprising Block C of the ex MRP in Central Kalimantan.

MATERIALS AND METHODS

The fire history and land cover maps for the last three decades were derived from satellite earth observation data. We have used a time-series of images obtained from several sensors, including Landsat MSS, TM, ETM+, Aster/Terra and the Digital Monitoring

Constellation (DMC) covering a 32 year period (1973-2005). An analysis of more then 20 satellite images was undertaken to derive land cover maps for 1973, 1991, 1993, 1996, 2000, 2003 and 2005 as well as to obtain the spatial and temporal distribution of burn scars.

Maps showing the location of burn scars were derived by using a spatial index threshold approach combining the NDVI (Normalized Difference Vegetation Index) and dNBR (Difference Normalized Burned Ratio) (Chuvieco *et al.*, 2006; De Santis & Chuvieco, 2006). Land cover maps were based on manual segmentation of the data into 15 classes, one being recently burnt areas. A manual segmentation was shown to be the optimal approach because (i) the data were acquired from a number of sensors and at different periods of the year, covering both dry and wet seasons, (ii) pixel based automatic classification could not cope with separation of spectrally overlapping classes and specifically the heterogeneity of burned areas, and (iii) excessive haze and cloud cover further reduced the quality of the data.

RESULTS AND DISCUSSION

The classification results show that land cover alters dramatically over a 32 year period, largely as a consequence of land clearance and repeated fires. The first two decades of the study period are not so critical for land cover change, even though fire occurred in this region, especially during El Niño (ENSO) years. During ENSO-driven droughts in 1972/3, 1982/83 and 1991/2 (Aiken, 2004; Fuller & Murphy, 2006; Wyrtki, 1975) fire affected only 6.9% (~31,100 ha), 7.9% (~35,600 ha) and 7.5% (~33,600 ha) of Block C, respectively (Figure 1). The next El Niño event in 1997, however, caused devastation and was the most critical for the already disturbed peatlands of Central Kalimantan because of the MRP implementation. The fires that occurred in 1997 affected 33.5% (~150,500 ha) of Block C. This was one-and-a-half times more than was burned in total over the period 1973-1996. Peat swamp forest (PSF) removal made a major contribution (84%) to the total burnt area.

A further progressive degradation of peatlands took place during the weak El Niño dry season in 2002 when fires were widespread once more, affecting 24% (~106,500 ha) of Block C. The total PSF area affected by fire in relation to the total burnt area decreased from nearly 80% in 1997, to 18% in 2002, and 2% in 2005. This indicates that the location of the fires over this time period has shifted from forest into non-forest vegetation. Moreover our analysis of fire frequency and intensity reveals that, since 2002, fire has become an inherent factor affecting the tropical peatlands ecosystem of Central Kalimantan with annual occurrence. For example, during the dry seasons of 2003/2004 and 2005 fire affected 14.3 % and 12.4% of the study area, respectively, with the majority occurring in non-forest vegetation. In 2006, fire activity was again widespread across the region, associated with a moderate El Niño event. A detailed fire frequency map indicates that many parts of Block C have burned once, twice and even three and more times over the last three decades.

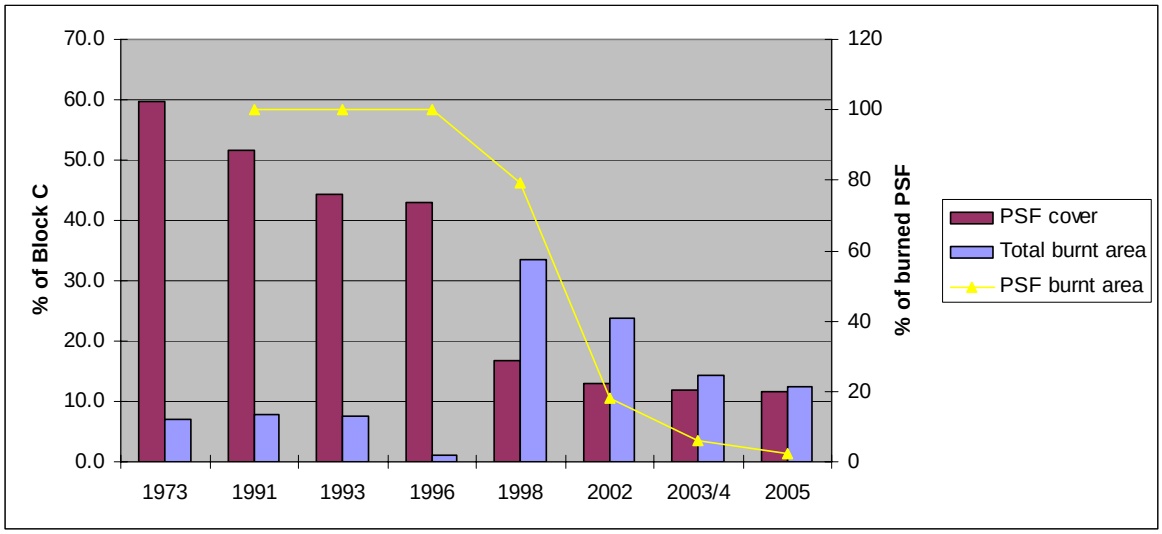

Figure1 Percentage of changes in Block C in a) cover of peat swamp forest (PSF) b) total burnt area and c) proportion of burned PSF within the total burnt area.

There is strong evidence that fire is the major factor that is driving land cover change in Central Kalimantan. After the El Niño of 1972/3, forest occupied 72% of Block C, 60% of which was defined as peat swamp forest (i.e. mixed swamp forest on peat up to 6m thick and low pole forest on peat >6m thick) (Page *et al.*, 1999). An additional 12% was freshwater swamp forest, mangrove and heath forest. Before the great fire of 1972/73, forest cover may have been nearer 80% of Block C. The rate of loss of peat swamp forest in relation to the initial year 1973 greatly increased from 26% in the first two decades up to 72%, owing to the fire of 1997 and reached 80% in 2005. Recent estimates indicate that 80% of the peat swamp forest has been lost over the last three decades.

Additional data obtained from the study area have revealed that the massively degraded peatlands in the MRP area are constantly being exposed to fire and are unable either to resist fire or to recover naturally. Forest is being replaced by more homogeneous, lower growing plant communities dominated by bushes, ferns and sedges with very few trees. These new post-fire peatlands are more susceptible, on the one hand, to fire during the dry season and, on the other, to flooding in the wet season (Wosten *et al.*, 2006).

REFERENCES

Aiken, S.R. (2004) Runaway fires, smoke-haze pollution, and unnatural disasters in Indonesia. *The Geographical Review*, 94, 55-79.

Chuvieco, E., Rian'o, D., Danson, F.M. and Martin, P. (2006) Use of a radiative transfer model to simulate the post fire spectral response to burn severity. *Journal of Geophysical Research-Biosciences*, 111, 1-15.

Davies, S.J. and Unam, L. (1999) Smoke-haze from the 1997 Indonesian forest fires: effects on pollution levels, local climate, atmospheric CO2 concentrations, and tree photosynthesis. *Forest Ecology and Management*, 124, 137-144.

De Santis, A. and Chuvieco, E. (2006) Burn severity estimation from remotely sensed data: Performance of simulation versus empirical models. *Remote Sensing of Environment*, 108, 422–435.

Fuller, D.O. and Murphy, K. (2006) The ENSO-fire dynamic in insular Southeast Asia. *Climatic Change*, 74, 435-455.

Lewis, S.L., Malhi, Y. and Phillips, O.L. (2004) Fingerprinting the impacts of global change on tropical forests. *Philosophical Transactions of the Royal Society of London*, Series B 359, 437-462.

Malhi, Y. and Grace, J. (2000) Tropical forests and atmospheric carbon dioxide. *TREE*, 15, 332-337.

Malhi, Y., Meir, P. and Brown, S. (2002) Forests, carbon and global climate. *Philosophical Transactions of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences*, 360, 1567-1591.

Page, S.E., Rieley, J.O., Shotyk, O.W. and Weiss, D. (1999) Interdependence of peat and vegetation in a tropical peat swamp forest. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, 354, 1885-1897.

Rieley, J.O. and Page, S.E. (Eds.) (2005) Wise Use of Tropical Peatlands: Focus on Southeast Asia. www.strapeat.alterra.nl

Wösten, J.H.M., van Denberg, J., van Eijk, P., Gevers, G.J.M., Giesen, W.B.J.T., Hooijer, A., Idrisi, A., Leenman, P.H., Rais, D.S., Siderius, C., Silvius, M.J., Suryadiputra, N. and Wibisono, I.T. (2006) Interrelationships between Hydrology and Ecology in Fire Degraded Tropical Peat Swamp Forests. *Water Resources Development*, 22, 157-174.

Wyrtki, K. (1975) El Niño-The Dynamic Response of the Equatorial Pacific Ocean to Atmospheric Forcing. *Journal of Physical Oceanography*, 5, 572–584.