



# Critical need for new definitions of “forest” and “forest degradation” in global climate change agreements

Nophea Sasaki<sup>1,2</sup> & Francis E. Putz<sup>3</sup>

<sup>1</sup> Harvard Forest, Harvard University, Petersham, MA 01366, USA

<sup>2</sup> Graduate School of Applied Informatics, University of Hyogo, Kobe, Japan

<sup>3</sup> Department of Biology, University of Florida, Gainesville, FL 32611, USA

## Keywords

Carbon emissions; carbon stocks; conventional logging; definition of forest; forest degradation; illegal logging; REDD; RIL; tropical forestry, UNFCCC.

## Correspondence

Nophea Sasaki, Harvard Forest, Harvard University, 324 North Main Street, Petersham, MA 01366, USA. Tel: (978) 724-3302; fax: (978) 724-3595. E-mail: nsasaki@fas.harvard.edu

Received: 14 January 2009; accepted 15 June 2009.

doi: 10.1111/j.1755-263X.2009.00067.x

## Abstract

If global policies intended to promote forest conservation continue to use the definition of “forest” adopted in 2001 by the United Nations Framework Convention on Climate Change (an area of >0.05–1 ha with >10–30% cover of plants >2–5 m tall at maturity), great quantities of carbon and other environmental values will be lost when natural forests are severely degraded or replaced by plantations but technically remain “forests.” While a definition of “forest” that is globally acceptable and appropriate for monitoring using standard remote sensing options will necessarily be based on a small set of easily measured parameters, there are dangers when simple definitions are applied locally. At the very least, we recommend that natural forest be differentiated from plantations and that for defining “forest” the lower height limit defining “trees” be set at more than 5 m tall with the minimum cover of trees be set at more than 40%. These changes will help reduce greenhouse gas emissions from what is now termed forest “degradation” without increasing monitoring costs. Furthermore, these minor changes in the definition of “forest” will promote the switch from degradation to responsible forest management, which will help mitigate global warming while protecting biodiversity and contributing to sustainable development.

## Introduction

Forest degradation and deforestation are distinctly different processes. While deforestation involves the conversion of forests to another land cover types, degradation results when forests remain forests but lose their ability to provide ecosystem services or suffer major changes in species composition due to overexploitation, exotic species invasion, pollution, fires, or other factors (Millennium Ecosystem Assessment 2005). Over the past decade, tropical deforestation globally resulted in the release of an estimated 1.1–2.2 PgC/year (Houghton 2003; Achard *et al.* 2004; Gullison *et al.* 2007) (1 PgC =  $10^{15}$  gC); forest degradation is thought to have resulted in similar emissions (Gaston *et al.* 1998), but the data are more limited (but see Nepstad *et al.* 1999; Asner *et al.* 2005; Gibbs *et al.* 2007). Unfortunately, due to political instability and

governance failures, wildfires as well as the uncontrolled and often illegal logging that result in forest degradation continue unabated in much of the tropics (Hembery *et al.* 2007; Meyfroidt & Lambin 2008). Our concern is that while forest degradation is recognized as a major problem, it is mostly being disregarded by the United Nations Framework Convention on Climate Change (UNFCCC) partially because of the way they defined “forest.”

The possibility of compensating developing countries for reduced emissions from deforestation and degradation (REDD) was proposed in 2005 by the governments of Papua New Guinea and Costa Rica at the 11th Conference of Parties of the UNFCCC. As the roles of tropical forests in sustainable development and global warming become increasingly apparent, progress is being made toward including REDD in the post-Kyoto Protocol climate change

agreement (IISD 2008; Miles & Kapos 2008). Negotiations on this agreement are scheduled to be completed by December 2009 (UNFCCC 2008), which means that discussions about the broader issue of defining forests and debates over the inclusion of forest degradation need to be resolved very soon.

Here, we discuss the problems regarding the definition of "forest" adopted in 2001 under the Marrakesh Accord of the Clean Development Mechanism (CDM; see UNFCCC 2002), lack of a consensus definition of "forest degradation," and the potential exclusion of forest degradation in the post-Kyoto agreement (Neeff *et al.* 2006). We also provide explicit and readily implemented suggestions for addressing these problems so that the outcomes of the new agreement are more likely to include real carbon emission reductions while promoting sustainable forest management and contributing to the welfare of forest-dependent people.

## Current definition of "forest" and the need for a new or revised definition

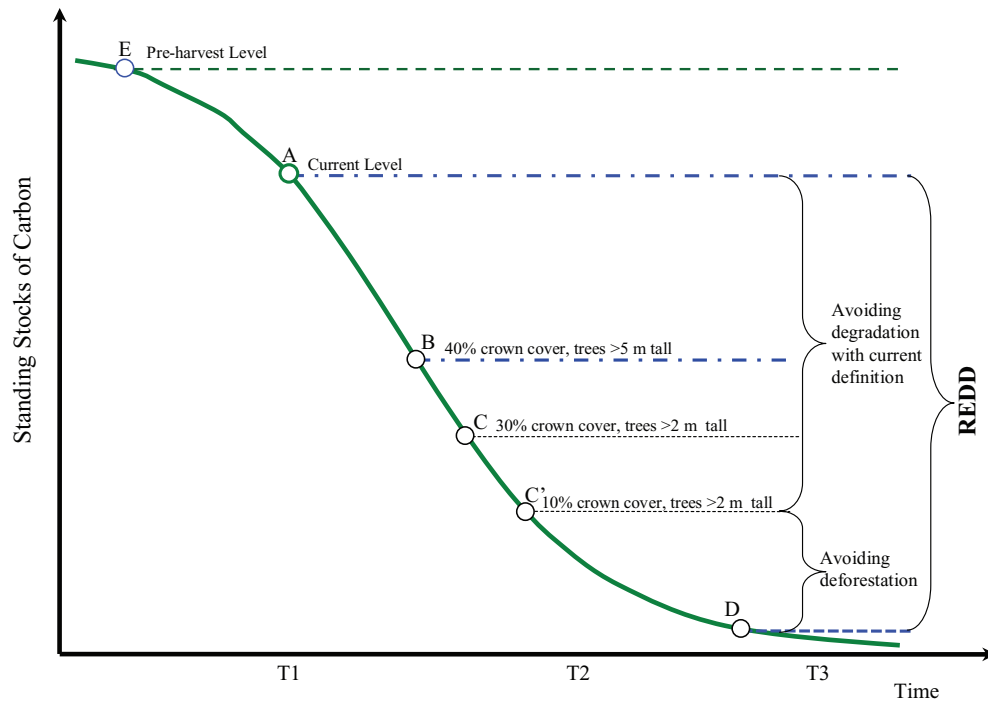
According to the CDM of the Kyoto Protocol, a "forest" is an area of more than 0.5–1.0 ha with a minimum "tree" crown cover of 10–30%, with "tree" defined as a plant with the capability of growing to be more than 2–5 m tall (UNFCCC 2002). Participating countries can choose from the specified ranges for a "forest" definition tailored to their needs. While we recognize that any definition suitable for global application will necessarily be composed of a very few easily measured parameters, we fear that continued use of this particular definition will jeopardize many forest values, including carbon. Furthermore, the CDM forest definition inadvertently allows continued unsustainable exploitation of forest resources principally because natural forests and plantations are not differentiated (about which we have no more to say) and because thresholds for crown cover are so low that the carbon consequences of continued indiscriminate extraction of commercially valuable tree species are not officially recognized (Figure 1).

By setting the lower limit of tree crown cover at 10 or even 30%, degradation leading to substantial reductions in standing stocks of carbon will be allowed to continue without causing deforestation (point A to points C and C' on Figure 1). The consequences are worse if the minimum height to which "trees" must grow is set at only 2 m rather than 5 m (Table 1), but in any case, the losses of both carbon and other forest values are substantial. These losses have attendant negative impacts on about 2.7 billion forest-dependent people (Koopmans

2005) as well as the rest of the planet. Furthermore, the permitted practices that lead to these losses (e.g., illegal, unsupervised, and unsustainable logging as well as rampant wildfires) also subvert the UNFCCC's goal of reducing net emissions from developed countries while promoting sustainable development in the rest of the world.

In defense of the UNFCCC negotiators' choice of tree crown cover as one of the principal parameters describing "forest," it is worth noting that this forest feature plays a vital role in biosphere and atmosphere interactions (Ozanne *et al.* 2003), that canopy cover can be readily monitored using standard remote sensing techniques, and, finally, that it is a major component of the definition of "forest" that has been used for decades by the Food and Agricultural Organization (FAO) of the United Nations. Nevertheless, it is important to note that whereas the FAO uses a minimum threshold of 40% tree crown cover to define "closed forest" (and 10–40% for "open forest"; FAO 2000), the UNFCCC left it to each country participating in the CDM to select a minimum threshold of only 10–30% (for the minimum canopy covers and tree heights selected to define "forest" by signatory countries see Table 1). Although by selecting the UNFCCC's higher minimum (i.e., 30%) to define "forest" a country would potentially have more land area eligible for reforestation or afforestation under the CDM (Verchot *et al.* 2007; Zomer *et al.* 2008), many chose a lower option. We suggest that in keeping with the FAO and in recognition of the fact that open forests (10–40% tree crown cover) are generally more fire-prone than more closed canopy forests (e.g., Cochrane *et al.* 1999) and are otherwise ecologically different, the UNFCCC should differentiate the two in the agreement being designed to replace the Kyoto Protocol during the second commitment period starting in 2012.

These changes in the "forest" definition used by the UNFCCC are critical because, unlike the first commitment period (2008–2012) during which compensation is only available for increased carbon stocks resulting from afforestation and reforestation, the post-Kyoto REDD approach is intended to provide compensation for the protection of forest carbon stocks. If REDD becomes a reality, then the question "what type of forest do we want as an outcome of the agreement?" remains to be addressed. If we want functioning forest ecosystems with their full complement of biodiversity, then forests should not be allowed to be converted into plantations or to otherwise lose large proportions of their carbon stocks or species. Avoiding these forms of degradation will be promoted by adopting a new definition of "forest."



**Figure 1** Differences in forest carbon stocks to be credited that result from different definitions of “forest.” Under the current definition of “forest” agreed upon in the Marrakesh Accords of the Kyoto Protocol, carbon stocks in the tropics could continue to decline without recognition from point A until a point corresponding to a crown cover of 10–30% (either C or C’), which defines the forest threshold. Depending on the adopted definition of a country, deforestation is likely to be credited by the REDD agreement only from point C or C’ onward. A REDD agreement based on 10 or 30% crown cover definitions would therefore halt deforestation and prevent carbon stock losses from dropping below C’ or C, respectively; carbon released above these limits would be from forest degradation. Forest

degradation losses would be much reduced (points A to B) if the “forest” definition is based on a higher canopy cover requirement (40%). Also, if improved forest management is also included in the agreement, healthy tropical forest as well as increased carbon stocks could be achieved (points A to E) as logging damage and wood waste are reduced. T1 to T2 is the next commitment period after 2012, and T2 to T3 is the “ensured” period for the post-Kyoto agreement. Carbon stored in the forest equivalent to point A (assuming that REDD is included in the post-Kyoto agreement) during the T2 to T3 period should not drop below that in the T1 to T2 period; otherwise, the forest would be logged or converted to other land uses shortly at the end of the next commitment period (T2).

### Current definition of “forest degradation” and the need for a consensus definition

Forest degradation greatly affects social, cultural, and ecological functions. It is a silent killer of sustainable development insofar as its consequences are often subtle and become apparent only slowly. Lack of a universally agreed-upon definition of forest degradation will cause complications when REDD projects are implemented. Unfortunately, the FAO, the International Tropical Timber Organization (ITTO), the United Nations Environmental Program (UNEP), and the Intergovernmental Panel on Climate Change (IPCC)—all define forest degradation differently (Schoene *et al.* 2007).

At the global level, a consensus definition of forest degradation is needed for sound implementation of

REDD as well as for the Convention on Biological Diversity, but that definition needs to take into account the full range of biophysical and social conditions under which forests develop and the variety of ways they can be degraded. This definition will necessarily continue to focus on readily monitored parameters (i.e., canopy cover and tree heights). In contrast, at the national level, implementation guidelines should consider other ecosystem services on which many poor people in developing countries depend (Koopmans 2005; Brauman *et al.* 2007). These other ecosystem services would include but not be limited to nontimber forest products, genetic resources, biogeochemical processes, recreation, and cultural practices. This detail in local policies is needed to avoid conflicts with efforts to protect biodiversity, to encourage sustainable forest use, and to promote regional development.

**Table 1** Forest definition parameters adopted by tropical countries<sup>a</sup> for participation in the UNFCCC

Country	Minimum tree crown cover (%)	Minimum area (ha)	Minimum tree height (m)	Forest area (2005) <sup>b</sup> ('000 ha)
Brazil	30	1.0	5	477,698
Indonesia	N/A	N/A	N/A	88,495
Peru	30	0.5	5	68,742
India	15	0.05	2	67,701
Mexico	30	1.0	4	64,238
Colombia	30	1.0	5	60,728
Malaysia	30	0.5	5	20,890
Paraguay	25	0.5	5	18,475
Thailand	30	0.16	3	14,520
Ethiopia	20	0.05	2	13,000
Viet Nam	30	0.5	3	12,931
Madagascar	30	1.0	5	12,838
Ecuador	30	1.0	5	10,853
Cambodia	10	0.5	5	10,447
South Africa	30	0.05	2	9,203
Ghana	15	0.1	2	5,517
Nicaragua	20	1.0	4	5,189
Honduras	30	1.0	5	4,648
Morocco	25	1.0	2	4,364
Panama	30	1.0	5	4,294
Uganda	30	1.0	5	3,627
Kenya	30	0.1	2	3,522
Costa Rica	30	1.0	5	2,391
Uruguay	30	0.25	3	1,506
Niger	30	1.0	4	1,266
El Salvador	30	0.5	5	298
Total				987,381

<sup>a</sup>Countries whose parameters of forest definitions are available on <http://cdm.unfccc.int/DNA/index.html>

<sup>b</sup>FAO (2005).

## Potential exclusion of forest degradation

The REDD program will involve developed countries (Annex I countries) compensating developing countries for activities that result in carbon retention in natural forests (Figure 1). REDD is attractive because it explicitly recognizes the value of natural forests, as opposed to plantations, and because the associated costs for project developers are expected to be low (Kindermann *et al.* 2008; Putz *et al.* 2008a; but see Potvin *et al.* 2008). Unfortunately, the frequent failure to consider forest degradation in several prominent recent studies (e.g., Gullison *et al.* 2007; Aldy & Robert 2008; Kindermann *et al.* 2008) causes concern that only deforestation avoidance credits will be allowed under the new protocol. Given that the uncontrolled selective logging by untrained and unsupervised crews commonly practiced in tropical natu-

ral forest doubles the amount of avoidable damage and wood waste relative to planned or reduced-impact logging (i.e., RIL; planned timber harvesting by trained and supervised crews; Table 2), the avoidable emissions from switching from exploitation to management are substantial (Asner *et al.* 2005; Putz *et al.* 2008b). Furthermore, given the rapid expansion of logging activities in central Africa (Laporte *et al.* 2007) and elsewhere in the tropics, carbon emissions resulting from forest degradation by uncontrolled logging are likely to increase.

If forest degradation is disregarded in the implementation of the REDD agreement, forests could lose much of their carbon, not to mention biodiversity and other ecosystem services, when valuable trees are harvested without regard to the ecological consequences (Broadbent *et al.* 2008). These losses will not be accounted for because the exploited areas still remain forest, as defined by the Marrakesh Accords of the UNFCCC. To illustrate this phenomenon, we use inventory data for trees more than 5 cm DBH (diameter at breast height) in 23 clusters of plots (each cluster contains nine plots of 20 × 60 m) collected in natural evergreen forest in central Cambodia. We estimate that this evergreen forest in this region holds average above-ground carbon stocks of 121.2 MgC/ha (see Supporting Information for calculation method), of which 71.4 MgC is in trees ≥45 cm DBH (Table S1). If all these large trees are harvested, the forest would still be categorized as “forest” by the UNFCCC definition. In Cambodia and other countries where loggers often operate without management plans or supervision, the highest valued timbers are exploited first (McKinney 2002; So 2004). Even the stumps and large roots of “luxury-grade” trees are used for manufacturing furniture. This sort of exploitative harvesting results in rapid disappearance of these highly valued tree species—a form of degradation by biodiversity loss. In fact, many species of Cambodian trees being illegally exploited for their luxury-grade timber (*Dalbergia oliveri*, *Aquilaria crassna*, *Dalbergia cochinchinensis*, *Gardenia ankorensis*, *Azelia xylocarpa*, *Pterocarpus marrocarpus*, *Dysoxylum loureiri*, *Diospyros cruenta*, *Lasianthus kamputensis*) are already classified as *critically endangered* on the International Union for Conservation of Nature’s “Red List” (So 2004; [www.iucnredlist.org](http://www.iucnredlist.org)). Technological capacities notwithstanding, at least some of these trees need to be protected to ensure the long-term sustainability of forest resource production as well as the maintenance of the ecosystem functions necessary for sustainable development.

Fortunately, with recent advancements in remote sensing technology, international concerns over the economic feasibility and monitoring costs of the REDD projects are declining rapidly. Remote sensors can already

**Table 2** Damage associated with conventional selective logging of tropical forests compared with similar intensities of timber harvesting by trained and supervised crews using RIL techniques

Variables	Locations	Uncontrolled logging	RIL	Sources
Logging damage to residual stands as percentage of commercial stem density	Sarawak, Malaysia	54.0 (DBH $\geq$ 10 cm)	28.0 (DBH $\geq$ 10 cm)	FAO (2001)
	Sabah, Malaysia	60.0 (DBH $\geq$ 1 cm)	30.0 (DBH $\geq$ 1 cm)	Tay <i>et al.</i> (2002)
	East Kalimantan, Indonesia	48.4 (DBH $\geq$ 10 cm)	30.5 (DBH $\geq$ 10 cm)	Bertault & Sist (1997)
Logging damage to residual stands per one commercial tree harvested	Eastern Amazon	50.9 trees (DBH $\geq$ 10 cm)	34.7 trees (DBH $\geq$ 10 cm)	Johns <i>et al.</i> (1996)
Waste as percentage of harvested wood	Sarawak, Malaysia	20.0	0.0	FAO (2001)
	East Kalimantan, Indonesia	46.2	26.2	Sist & Saridan (1999)
	Easter Amazon	24.0	8.0	Holmes <i>et al.</i> (2002)
Vulnerability to forest fires	Brazilian Amazon, Indonesia	Yes, due to large logging gaps, huge wood wastes, and forest drying. <sup>1,4</sup> About 5.2 million ha burned in 1997–1998 in Indonesia, <sup>2</sup> 27 million ha burned in 1998 in Brazilian Amazon <sup>3</sup>	Unlikely because of less logging gaps and less wood waste	<sup>1</sup> Holdsworth & Uhl (1997) <sup>2</sup> Siegert <i>et al.</i> (2001) <sup>3</sup> Nepstad <i>et al.</i> (1999)
Selective logging leads to deforestation and carbon emissions	Brazilian Amazon	More than 32% of logged areas were deforested within 4 years <sup>4</sup>	Unlikely because of well-planned logging and well-trained personnel	<sup>4</sup> Asner <i>et al.</i> (2006)
Carbon retention	Tropical	0	0.16 PgC/year	Putz <i>et al.</i> (2008b)

detect and monitor minor changes in forest canopy cover (Asner *et al.* 2006), which makes it possible to monitor forest degradation by illegal and unplanned logging operations.

## Conclusion and recommendations

To ensure that biologically rich natural forests are not severely degraded in ways that remain unrecognized, in addition to differentiating natural forests and plantations, the new and improved definitions of “forest” and “forest degradation” should set the minimum crown cover at 40% and the minimum height for a “tree” at 5 m. These changes will help reduce greenhouse gas emissions from what is now termed forest “degradation” without increasing monitoring costs. Furthermore, these changes will promote the switch from degradation to responsible forest management, which will help mitigate global warming while protecting biodiversity and contributing to sustainable development. We also recommend that to avoid conflicts between conservation goals, global agreements that pertain to the fates of forests include requirements for more detailed definitions of “forest” in national-level implementation guidelines. Given the variety of ways that forests are perceived and valued, the adopted definitions are likely to vary among countries and could include a variety of components, but explicit and appropriate definitions are nonetheless of paramount importance at the

country level. At least in regard to standing stocks of forest carbon, recent advances in remote sensing technology that allow cost-effective monitoring of forest degradation coupled with the substantial and increasing emissions from poor logging and forest fires, continued disregard of the second “D” in REDD is not justified. Including forest degradation in the new climate change agreements will help ensure the sustainability of ecosystem services and protect the livelihoods of forest-dependent people while providing a low-cost option for reducing carbon emissions.

## Acknowledgments

This work was funded by a Harvard Forest’s Charles Bullard Fellowship and benefited from insights from A.M. Ellison, S.J. Davies, W. Knorr, B.B. Eav, G. Asner, and S. Weiler.

## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1** Average stem density, basal area, stand volume, and carbon stocks in natural evergreen forest in Cambodia

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

## References

- Achard, F., Eva H.D., Mayaux P., Stibig H.J., Belward A. (2004) Improved estimates of net carbon emissions from land cover change in the tropics for the 1990s. *Global Biogeochem Cycles* **18**, GB2008, doi:10.1029/2003GB002142.
- Aldy, J.E., Robert S.N. (2008) Designing the Post-Kyoto climate regime: lessons from the Harvard project on international climate agreements. An interim progress report for the 14th Conference of the Parties, Framework Convention on Climate Change, Poznan, Poland, December 2008. Cambridge, MA.: Harvard Project on International Climate Agreements, November 24, 2008.
- Asner, G.P., Knapp D.E., Broadbent E.N., Oliveira P.J., Keller M., Silva J.N. (2005) Selective logging in the Brazilian Amazon. *Science* **310**, 480–482.
- Asner, G.P., Broadbent E.N., Oliveira P.J., Keller M., Knapp D.E., Silva J.N. (2006) Condition and fate of logged forests in the Brazilian Amazon. *Proc Natl Acad Sci USA* **103**, 12947–2950.
- Bertault, J.-G., Sist P. (1997) An experimental comparison of different harvesting intensities with reduced-impact and conventional logging in East Kalimantan, Indonesia. *Forest Ecol Manage* **94**, 209–218.
- Brauman, K.A., Daily G.C., Duarte T.K., Mooney H.A. (2007) The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annu Rev Environ Resour* **32**, 67–98.
- Broadbent, E.N., Asner G.P., Oliveira P.J.C., Knapp D.E., Keller M., Silva J.N. (2008) Forest fragmentation from deforestation and selective logging in the Brazilian Amazon. *Biol Cons* **141**, 1745–1757.
- Cochrane, M.A., Alencar A., Schulze M.D. *et al.* (1999) Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* **284**, 1832–1835.
- FAO (2000) *FAO global forest resource assessment 2000*. Forestry Paper 140. FAO, Rome.
- FAO (2001) *Financial and economic assessment of timber harvesting operations in Sarawak, Malaysia*. Forest Harvesting Case Studies 17. FAO, Rome.
- FAO (2005) *Global forest resources assessment 2005*. Progress towards sustainable forest management. FAO Forestry Paper 147, Rome.
- Gaston, G.S., Brown S., Lorenzini M., Singh K.D. (1998) State and change in carbon pools in the forests of tropical Africa. *Glob Change Biol* **4**, 97–114.
- Gibbs, H.K., Brown S., Niles J.O., Foley J.A. (2007) Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environ Res Letters* **2**, 045023.
- Gullison, F.R., Frumhoff C.P., Canadell G.J. *et al.* (2007) Tropical forests and climate policy. *Science* **316**, 985–986.
- Hembery, R., Jenkins A., White G., Richards B. (2007) *Illegal logging cut it out! The UK's role in the trade in illegal timber and wood products*. WWF-UK, Surrey.
- Holdsworth, A.R., Uhl C. (1997) Fire in Amazonian selectively logged rain forest and the potential for fire reduction. *Ecol Applic* **7**, 713–725.
- Holmes, T.P., Blate M.G., Zweede C.J. *et al.* (2002) Financial and ecological indicators of reduced impact logging performance in the eastern Amazon. *Forest Ecol Manage* **163**, 93–110.
- Houghton, R.A. (2003) Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850–2000. *Tellus* **55B**, 378–390.
- IISD (International Institute for Sustainable Development) (2008) Summary of the fourteenth conference of the parties to the UNFCCC and fourteenth meeting of the Kyoto Protocol: 1–12 December 2008. *Earth Negotiations Bulletin* **12**, 395.
- John, J.S., Barreto P., Uhl C. (1996) Logging damages during planned and unplanned logging operations in the eastern Amazon. *Forest Ecol Manage* **89**, 59–77.
- Kindermann, G., Obersteiner M., Sohngen B. *et al.* (2008) Global cost estimates of reducing carbon emissions through avoided deforestation. *Proc Natl Acad Sci USA* **105**, 10302–10307.
- Koopmans, A. (2005) Biomass energy demand and supply for South and South-East Asia—assessing the resource base. *Biomass Bioenergy* **28**, 133–150.
- Laporte, N.T., Stabach J.A., Grosch R., Lin T.S., Goetz S.J. (2007) Expansion of industrial logging in central Africa. *Science* **316**, 1451.
- McKinney, M. (2002) Protecting Mondolokiri's forest from illegal loggers is a military-style operation. The Cambodia Daily, Weekend Saturday, August 24–25, 2002.
- Meyfroidt, P., Lambin E.F. (2008) Forest transition in Vietnam and its environmental impacts. *Glob Change Biol* **14**, 1–8.
- Miles, L., Kapos V. (2008) Reducing greenhouse gas emissions from deforestation and forest degradation: global land-use implications. *Science* **320**, 1454–1455.
- Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: synthesis*. Island Press, Washington, DC.
- Neff, T., von Luepke H., Schoene D. (2006) *Choosing a forest definition for the Clean Development Mechanism*. Forests and Climate Change Working Paper 4. FAO, Rome.
- Nepstad, D., Verissimo A., Alencar A. *et al.* (1999) Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* **398**, 505–508.
- Ozanne, C.M.P., Anhof D., Boulter S.L. *et al.* (2003) Biodiversity meets the atmosphere: a global view of forest canopies. *Science* **301**, 183–186.
- Potvin, C., Guay B., Pedroni L. (2008) Is reducing emissions from deforestation financially feasible? A Panamanian case study. *Clim Policy* **8**, 23–40.

- Putz, F.E., Sist P., Fredericksen T.S., Dykstra D. (2008a) Reduced-impact logging: challenges and opportunities. *Forest Ecol Manage* **256**, 1427–1433.
- Putz, F.E., Zuidema P.A., Pinard M.A. *et al.* (2008b) Improved tropical forest management for carbon retention. *PLoS Biol* **6**, e166 doi:10.1371/journal.pbio.0060166
- Schoene, D., Killmann W., von Lüpke H., Loyche-Wilkie M. (2007) *Definitional issues related to reducing emissions from deforestation in developing countries*. FAO Forests and Climate Change Working Paper 5. FAO, Rome.
- Siegert, F., Ruecker G., Hinrichs A., Hoffmann A.A. (2001) Increased damage from fires in logged forests during droughts caused by El Niño. *Nature* **414**, 437–440.
- Sist, P., Saridan A. (1999) Stand structure and floristic composition of a primary lowland dipterocarp forest in East Kalimantan. *J Trop For Sci* **11**, 704–722.
- So, T. (2004) Status of forest genetic resources conservation and management in Cambodia. Pages 150–163 in T. Luoma-aho, L.T. Hong, V.R. Ramanatha, H.C. Sim, editors. *Forest genetic resources conservation and management*. Proceedings of the Asia Pacific Forest Genetic Resources Programme Inception Workshop, Kepong, Kuala Lumpur, Malaysia, 15–18 July 2003.
- Tay, J., Healey J., Price C. (2002) Financial assessment of reduced impact logging techniques in Sabah, Malaysia. Pages 125–140 in T. Enters, P.B. Durst, G.B. Applegate, P.C.S. Kho, G. Man, editors. *Applying reduced impact logging to advance sustainable forest management*. FAO, RAP Publication 2002/15, Bangkok.
- UNFCCC (2002) Report of the Conference of the Parties on its seventh session, held at Marrakesh from 29 October to 10 November 2001 (FCCC/CP/2001/13/Add.1, UNFCCC, Marrakesh, Morocco, 2001). [WWW document]. URL <http://unfccc.int/resource/docs/cop7/13a01.pdf>. Accessed December 1, 2008.
- UNFCCC (2008) Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 (FCCC/CP/2007/6/Add.1, UNFCCC, Bali, Indonesia, 2008). [WWW document]. URL <http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf>. Accessed December 1, 2008.
- Verchot, L.V., Zomer R., van Straaten O., Muys B. (2007) Implications of country-level decisions on the specification of crown cover in the definition of forests for the land area eligible for afforestation and reforestation in the CDM. *Clim Change* **81**, 415–430.
- Zomer, R.J., Trabucco A., Verchot L.V., Muys B. (2008) Land area eligible for afforestation and reforestation within the Clean Development Mechanism: a global analysis of the impact of forest definition. *Mitig Adapt Strat Global Change* **13**, 219–239.

**Editor:** Dr. Jos Barlow