Natural forest management as a conservation tool in the tropics: divergent views on possibilities and alternatives

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SUMMARY

A round table discussion was convened to explore divergent views on the potential for natural forest management (NFM) for timber to contribute to wide-scale maintenance of forest cover and biological diversity in tropical forests. The general argument for NFM for timber is that, by conferring relatively more economic value on forests than alternative forest uses, NFM for timber is a necessary, though imperfect, means by which extensive areas of forest cover and a large measure of their biological diversity would be maintained outside nature reserves. The discussion centred on five topics: the biological-diversity-related benefits and drawbacks of instituting NFM for timber, the biological and economic constraints on successful NFM for timber, the alternatives to NFM for timber, and the relative merits of community versus industrial concessions as mechanisms by which to institute NFM for timber. Both proponents and critics of NFM for timber should recognise that, first, NFM for timber can be carried out in ways that mitigate the negative effects on biological diversity and, second, there is a common set of conditions necessary to maintain forest cover for any use, including NFM for timber or nature reserves.

Keywords: biological diversity, community forestry, deforestation, natural forest management, non-timber forest products.

INTRODUCTION

The irony is striking - while tropical forests are being degraded and destroyed at alarming rates members of the international conservation community forcefully propound and pursue different and often incompatible solutions to the problem.

The exchanges recorded here were precipitated by differing perspectives on how best to integrate forest conservation and economic development in internationally-funded projects at two sites. These were the 265,000 ha suitable for forestry in the multiple-use zone of the Maya Biosphere Reserve, Petén, Guatemala (Santiso 1993) and the 450,000 ha Chimanes Permanent Timber Production Forest (Bosque Chimanes) in Bolivia (see Gullison 1995).

These different views prompted the Tropical Forest Management Trust to arrange a discussion among proponents of different strategies that would promote maintenance of forest cover, conservation of biological diversity, and economic development. The meeting was held in Washington D.C. on November 21, 1994 (see appendix for a list of participants). Participants work in the fields of ecology, forestry, economics and geography.

The debate was centred on six main questions:

1. Is NFM for timber always necessary or advisable as a means of maintaining forest cover?
2. What are the consequences of the forest 'domestication' required to produce timber?
3. What are the biological barriers to NFM for timber?
4. Under what conditions, if ever, is NFM for timber likely to be widely adopted given the much higher short-term gains associated with unsustainable logging?
5. What are the potential alternatives to the widespread promotion of NFM for timber and are they viable as means of ensuring the maintenance of forest cover and biological diversity?
6. In implementing NFM for timber, are community or industrial concessions more likely to be successful?

The debate has been ongoing and this paper is an attempt to summarise the various arguments and place them into a logical framework; however it is not a comprehensive review of the issues. We hope that this paper will stimulate and inform further debate about solutions to the problems of maintenance of forest cover and conservation of biological diversity.

DEFINITIONS

We follow the Biodiversity Convention in including three components in the definition of biological diversity (from Boyle and Sayer 1995): genetic variability within species,

the variety of species living in a given region (species richness), and the variety of ecosystems. We use the term nature reserve to mean a protected area for which the primary purpose is the maintenance of biological diversity (e.g. core areas of biosphere reserves and national parks).

We use natural forest management (NFM) to mean management of primary or secondary forests for sustained production of timber or other products or both in which forest cover is maintained indefinitely (Putz 1993; see review in Johnson and Cabarle 1993). The level of timber harvest in a previously unlogged forest is likely to be much higher than that in subsequent harvests. To qualify as NFM, some form of management is necessary, simply *ad hoc* logging does not count. Following Poore *et al.* (1989), we note that management ranges from low to high intensity (e.g. from light, selective-logging with long cutting cycles to enrichment planting on cleared lines). NFM may sustain biologically diverse forests or create highly simplified forests depending on the intensity of logging and the management approach. By definition, NFM maintains forest cover and certain ecosystem processes. Unsustainable logging would be logging in which the forest's ability to produce saleable timber is severely reduced, through, for example, severe soil and canopy disturbance or lack of sufficient regeneration of valuable species.

In the debate presented in this paper, some participants argued that NFM for timber should sustain the yield of individual species and not just a given volume of timber regardless of species. Accordingly, we use 'liquidation logging' to mean the elimination of a logged species from a forest due to either high rates of logging of the species or its failure to regenerate in the logged forest, or both.

NATURAL FOREST MANAGEMENT AS A CONSERVATION TOOL

Timber and other forest products have fuelled development for millennia (Perlin 1989) and continue to do so today (Vincent 1995). The fate of forests, though, has often been destruction or serious degradation (Perlin 1989, WRI 1996). Obviously, people value forests for provision of ecological services such as carbon sequestration and watershed protection (Holdgate 1993). Also, there is significant concern that a large proportion of tropical species will become extinct (see reviews in Whitmore and Sayer 1992) given that less than 5% of tropical forests are protected in nature reserves (Groombridge 1992) and that rates of forest loss and degradation are high (WRI 1996).

Forests outside nature reserves are becoming increasingly important for the opportunities they provide for conservation of biological diversity (Sayer and Whitmore 1991, McNeely 1994, Dickinson 1995, O'Connell 1996). It is proposed that the worst thing that could happen to a forest from a biological-diversity perspective is that it be converted to a non-forest use such as pasture, permanent agriculture, or plantation. Somewhat less damaging, though not trivial, is the widespread forest degradation caused by shortfallow agriculture, intensive fuelwood collection, fragmentation, and uncontrolled burning. Also, at its worst, heavy logging in timber-rich forests disrupts ecosystem processes, impedes the forest's ability to regenerate (Pinard *et al.* 1996), and degrades habitats for wildlife. For these reasons, heavy logging has been equated with deforestation (Myers 1993a, cf. Sayer and Whitmore 1991). It is argued that NFM for timber, even if intensive, is preferable to these alternatives (Boyle and Sayer 1995).

In the 'use it or lose it' principle (Johnson and Cabarle 1993) it is posited that forests not generating adequate income or other benefits recognised by society will be converted or degraded since there is no economic incentive for their maintenance as productive forest ecosystems. If forest conversion or severe degradation is imminent, some contend that the best conservation tool is pre-emptive NFM for timber because economic returns are likely to be much higher for timber than for other forest uses (Putz 1992, Browder 1992). In the following sections, we explore the arguments for and against the central importance of NFM for timber as a tool for maintenance of forest cover and conservation of biological diversity outside of nature reserves.

THE VALIDITY OF THE 'USE IT OR LOSE IT' PRINCIPLE

According to the 'use it or lose it' principle, if efforts to promote NFM for timber fail, and unsustainable logging results, the logical result will be conversion or further degradation of the forest after the valuable timber has been removed. As such, the 'use it or lose it' principle might well be renamed the 'use it well or lose it' principle. Because timber produced under conditions that can be called NFM accounts for such a small proportion of total timber production (Johnson and Cabarle 1993, Poore *et al.* 1989), many conservationists are not convinced that NFM for timber can play much of a role in widespread and long-term conservation of tropical forests and their biological diversity.

Also, it is argued that the 'use it or lose it' principle only applies in regions where the forest is currently being converted or degraded or is in imminent risk of such a fate. Promoting NFM where deforestation is not imminent risks creating conditions conducive to deforestation where they did not previously exist, as by access provided along logging roads. Where there is little or no immediate threat of deforestation, doing nothing instead of promoting NFM for timber may be the most defensible option from a conservation perspective.

FOREST DOMESTICATION AND LOSS OF BIOLOGICAL DIVERSITY

Even if NFM for timber were successful, it is argued that certain tree (Robinson 1993, Boot and Gullison 1995) and wildlife (Frumhoff 1995) species will fare poorly in forests

managed for timber alone. In intensive forest management, the goal is 'forest domestication,' a process that often eliminates or reduces the abundance of certain species (particularly low value tree species and vines) and changes the age and size distributions of tree populations. The effect on wildlife species of these changes depends on the wildlife species of interest (see review in Frumhoff 1995). Given the relatively small area of forests in nature reserves, it is argued that widespread NFM for timber must be accompanied by activities designed to mitigate the effects of logging on species sensitive to logging (for examples of management approaches see Frumhoff 1995, Roberts and Gilliam 1995, Hansen *et al.* 1991).

Against this, it can be it argued that the relevant comparison is not between NFM for timber versus maintenance of pristine forest but between NFM for timber and alternative land uses (Putz and Viana 1996). Compared with pristine forest (Boot and Gullison 1995) no significant extractive use of a forest will appear to be compatible with maintenance of biological diversity. Although NFM for timber will generally lead to the loss of species (Robinson 1993, Boot and Gullison 1995, Boyle and Sayer 1995), even the most intensive forms of NFM look good compared to pastures and short-fallow or permanent agriculture.

From an ecosystem perspective, rather than at the level of species richness, NFM for timber may be more appealing as a conservation tool. Highly simplified forests (such as plantations) maintain critical ecosystem processes such as soil protection, watershed protection, nutrient cycling and carbon sequestration (Sayer and Whitmore 1991). This suggests that there is species redundancy in the perpetuation of ecosystem processes, though contrary data exist, as noted in Gitay *et al.* (1996). Even if a plantation or otherwise simplified forest does not perpetuate ecosystem processes as well as a natural and more species-rich forest, it may do so adequately, and much better than it maintains species richness. Also, improvements in logging practices through better planning and appropriate technology can reduce the ecosystem-level impacts of logging (Gullison and Hardner 1993, Heinrich 1995, Pinard *et al.* 1995).

In support of the notion that tropical ecosystems can be managed without irreversible ecosystem-level consequences, it is recognised that many tropical ecosystems are not as fragile as has often been asserted and that, if disturbed beyond their inherent ability to regenerate, can often be re-established (Lugo 1995). A long history of both natural and human induced forest change, destruction and rejuvenation seems to bear this out (McNeely 1994). Lugo (1995) advocates an 'ecosystem management' approach (see review in Grumbine 1994) that fosters and maintains productive landscapes which contain a variety of forested ecosystems (spanning the range from plantations to nature reserves) providing multiple benefits. Though it is a decided improvement over past approaches, a danger of this ecosystem-level approach to management, in which perpetuating ecosystem processes is the objective, is that successful management of certain ecosystem processes may not prevent extinctions if unaccompanied by species-specific management action (Soule 1993).

BIOLOGICAL BARRIERS TO NFM FOR TIMBER

An important assumption of the 'use it or lose it' principle is that harvests subsequent to the first provide adequate economic returns. There are a number of biological constraints on the success of NFM for timber in mixed tropical forests. These constraints include the following: regeneration failures among shade intolerant species following light selective logging (Boot and Gullison 1995, Lowe 1995); the need to minimise damage to advance growth of shade tolerant trees (ter Steege *et al.* 1995); low abundances of many timber species and thus low potential marketable yields (Robinson 1993); generally low growth rates among timber species (Caughley and Gunn 1995); little or no increase in population growth rates at low densities (Boot and Gullison 1995); restricted dispersal ability and little propensity to coppice among some species (Martini *et al.* 1994); and inherently low-quality wood in many species of trees that reach sizes adequate for sawing. Many do not view these constraints as particularly serious (Poore *et al.* 1989) and foresters might claim that there are no technical barriers to overcoming some of these biological problems (Johnson and Cabarle 1993). However, the silvicultural solutions are often not practical economically under current market conditions (Asabere 1987).

ECONOMIC ARGUMENTS AGAINST NFM FOR TIMBER

There are a number of economic circumstances that lead some to argue that NFM for timber is a poor candidate as a tool for maintenance of forest cover and conservation of biological diversity. First, the short-term returns from liquidation logging are higher than those which could be derived from NFM for timber. Second, the boom-and-bust pattern, where valuable timber is logged with no view to subsequent harvests, is widespread with the income from timber often being profitably invested in activities other than NFM (Vincent 1992, Barbier 1995). Third, the most rational short-term economic choice is often to convert the forest to other uses, particularly when the policy is to encourage this (Southgate 1992). Fourth, in order to maximise profit, some argue that a dominant-use strategy should be pursued whereby timber production should be maximised in portions of the landscape where it is appropriate and other objectives (such as biological diversity maintenance) should be pursued elsewhere (Vincent 1995).

The conclusion that some draw from the above is that there rarely exist conditions under which NFM for timber will be practised and, as a result, NFM for timber will never contribute much to the maintenance of tropical forests or their biological diversity.

Market-based incentives, such as timber certification (Upton and Bass 1996), are often advocated as a means of improving the economic prospect of NFM for timber. It is argued that certification will allow higher prices to be charged for timber and wood products and would lead to higher

market share for certified timber. Others argue that the increased timber prices expected from certified timber are not adequate to prevent liquidation logging because the increase in income is unlikely to offset the expense of instituting NFM for timber (Gullison 1995). Also, some consider that there will not be enough demand for certified timber to make much of a difference anyway and, because of swifter progress, temperate timber will capture the certified-timber market at the expense of tropical timber (Kiekens 1995).

There are other ways, besides timber certification, in which the costs of instituting NFM for timber may be offset. International technical and financial support for NFM for timber covers some costs of instituting NFM for timber. Also, payment for carbon storage and sequestration services in logged forests is promising as a way of offsetting the costs of NFM for timber (Pinard *et al.* 1995). Forests also provide other benefits, including non-timber forest products and ecosystem services (such as watershed protection, local climate regulation, nutrient cycling, etc.), which may make forests more valuable than the timber they produce (Myers 1988, Panayotou and Ashton 1992). Not including these and other benefits of NFM for timber (and arbitrary valuation of costs and benefits) is a flaw of 'the standard analysis' that often shows NFM for timber to be a poor option from the financial standpoint (Leslie 1987).

Proponents of NFM for timber concede that NFM for timber does not compete well with the short-term gains derived from liquidating stocks of valuable timber. However, NFM for timber becomes possible when the option to convert a forest to some other use is removed through enforcement of strict forest policies. Effective enforcement becomes more likely when certain conditions hold. These conditions include the following (see reviews in Poore *et al.* 1989, Palmer and Synnott 1992): government resolve to implement NFM as a legitimate use of the land on a par with agriculture, creation and maintenance of a permanent forest estate, social and political support for the permanent forest estate, a suitable forestry policy setting, a good information base, an adequate system for planning and controlling the forests' management (and funds to carry it out), and the will by all involved to effectively control use of the forests. These conditions are more likely to hold when broader issues are resolved, such as high population growth rates, little access to education, high foreign debt, and high levels of corruption, etc.

Fortunately, creating the conditions for NFM is often a rational move for governments, communities and the international development-assistance community. Intergenerational equity and the values of forests beyond those of the merchantable timber are being considered more now than in the past (Poore 1995). While there are benefits to national economies from liquidation or otherwise unsustainable logging (Vincent 1992), they must be discounted to the extent that markets are distorted, logging is inefficient, and returns do not accrue to the nation in which the logging occurs (Barbier 1995).

ALTERNATIVES TO NFM FOR TIMBER

If NFM for timber is not an ideal solution to the problem of maintaining forest cover and conserving biological diversity outside of nature reserves, what are the alternatives and where are they appropriate? Apart from establishing nature reserves or otherwise leaving the forest alone, a forest can be used for such activities as timber management, non-timber forest product (NTFP) extraction, recreation, and eco-tourism (Dickinson 1995). If some economic use must be made of a forest (that is, if the 'use it or lose it' principle applies) then how viable are non-timber forest uses? Most debate has centred on NTFP versus timber extraction because, arguably, the amount of forest outside nature reserves needed for eco-tourism would not be enough to serve as sufficient incentive for maintenance of large areas of forest cover.

Some participants at the discussion strongly objected to the view that NTFP extraction alone is a viable strategy for maintaining forests on a large scale because of limited markets for non-timber forest products, problems with sustained-yield analogous to those of logging, the relatively high value of timber per unit area, and the poverty of an existence based on non-timber forest products (for views moderating initial enthusiasm about NTFP production, see Dove 1993, Richards 1993, Godoy and Bawa 1993, Browder 1992, Dobson and Absher 1991).

Furthermore, NTFP extraction and NFM for timber are not necessarily mutually exclusive (Panayotou and Ashton 1992, Putz 1992). For instance, chicle (*Manilkara zapota*), honey, wild game, construction materials and other products have been harvested from the logged forests in Quintana Roo, Mexico for decades (see Johnson and Cabarle 1993, Snook *et al.* 1994). Salick *et al.* (1995) found that NTFP production from a long list of species in Nicaraguan lowland forests can be compatible with certain, though not all, silvicultural systems. Furthermore, harvesting NTFP's in timber producing forests produces a steady stream of income that make it more likely for silvicultural treatments to be continued over the long term (Panayotou and Ashton 1993). Though there are often opportunity costs in loss of NTFP production (Panayotou and Ashton 1993), timber and NTFP production are not always incompatible and debate on this issue seems to be unnecessarily polarised (Putz 1992).

NFM for timber is not always the best means of promoting conservation. First, as discussed above, if there is no threat of degradation or conversion, instituting NFM for timber as a means of maintaining forest cover and biological diversity makes little sense, though it may make sense from an economic development perspective. Second, it is argued that highly selective and profitable liquidation logging (such as for mahogany in the Americas) could serve as a means to fund the establishment and maintenance of nature reserves. Even if the funds derived thereby were not used to establish a nature reserve, the liquidation of valuable species, such as mahogany, would considerably reduce the pressure for logging and enhance the prospects for maintenance of the area as inviolate nature reserve in the future. Logging before

nature reserve establishment is not without precedent, for instance, the Calakmul Biosphere Reserve in the Mexican Yucatan and the Great Smoky National Park in the USA have been logged in the past. Allowing liquidation logging could fuel economic development (Vincent 1995) and, if certain guidelines were followed, would result in an acceptably intact forest (Gullison 1995).

The third circumstance under which NFM for timber is not likely to be the best option for conservation is when a region has very little forest left. Loss of the remaining natural forests would probably have the most negative effects on global species richness (Sayer and Whitmore 1991). Pursuing other options for producing timber (such as reforestation using plantations) and maintaining the remaining natural forests would be more defensible from a conservation point of view than the institution of NFM for timber.

There is concern that implementing NFM for timber is accompanied by substantial opportunity costs. At some level, funds used for NFM for timber will not be available for other endeavours. In particular, funding for the establishment of nature reserves might be decreased. Also, reduced funding would be available for resolving broad societal problems that make maintenance of forest cover difficult (see below).

COMMUNITY VERSUS INDUSTRIAL CONCESSIONS

Whether industrial or community concessions would be more likely to ensure the maintenance of forests and their biological diversity figured importantly in the debate concerning the Maya Biosphere Reserve in the Petén of Guatemala. An important function of establishing concessions in the region was to discourage uncontrolled colonisation of the forests of the multiple-use zone by immigrants, including returning refugees from the Guatemalan civil war.

In support of industrial concessions, it was suggested that (assuming the presence of adequate incentives, appropriate tenure policies and enforcement) industrial enterprises can quickly begin forest management because they have organisational capability and access to capital. A well educated, successful entrepeneur who is attuned to appropriate policies, incentives and markets may be best able to profitably manage a large area of forest in an ecologically acceptable manner.

On the other hand, it is recognised that a drawback of relying on industries as forest stewards is that an industrial enterprise can be as efficient in converting a forest or degrading its potential to produce timber as in bringing one under management. Industrial forest enterprises are generally run by people who are economically and politically powerful, which may make them relatively immune to government regulation and NGO pressures. They are generally engaged in more than one business and have multiple economic options. Poor historical performance of industrial concessions (see Poore *et al.* 1989) makes many sceptical that industrial operations can be counted on to practise NFM.

The alternative in the Maya Biosphere Reserve was community concessions (for discussion of failures, successes and prospects of such community-level management see Cox and Elmqvist 1991, Singh and Khare 1993, Wells and Brandon 1993, Mallik *et al.* 1995). It was generally agreed that communities should be given concessions on nearby forests. However, some proponents of community concessions argued that forests remote from established communities should come under the control of new immigrants. Others argue that there is little prospect that poorly organised groups of recent immigrants could effectively prevent conversion of the forest to pasture and cropland (see Arnold 1993 for a similar view). It seems to be an unstated assumption that communities with control over a forest will automatically practise sustainable NFM for timber or other products; however, this view has been challenged (Browder 1992, Paulson 1994).

COOPERATION AMONG PROPONENTS AND CRITICS OF NFM FOR TIMBER

A narrow debate about NFM for timber may miss more fundamental issues. Even massive assistance to establish NFM for timber, or any other forest-based land use, may not ultimately succeed if there is strong pressure to convert forests to agricultural land or otherwise degrade them. Though understanding of the ultimate causes of forest conversion and degradation is often uncertain (see, for a review of efforts at quantitative modelling, Machlis and Forester 1996) and there are differences of opinion about who is to blame in any give case (Dauvergne 1994), problems larger than the technical aspects of NFM for timber derail efforts to maintain forest cover and prevent forest degradation (Pearce and Brown 1994). Larger issues, such as population pressure (Meffe and Ehrlich 1993, Myers 1993b),increased food demand (WRI 1996), market and policy failures (Southgate 1992), foreign debt (Rowe *et al.* 1992), corruption, ill-advised development projects (Dauvergne 1994), and the desire for capital derived from timber (Vincent 1995), must be confronted if forests are to be maintained for any use.

Another area for resolution concerns the technical problem of integrating NFM for timber and conservation of biological diversity. There are methods by which the effects of NFM for timber on biological diversity can be mitigated. Assuming that the 'use it or lose it' principle is broadly applicable and given that NFM for timber is better than deforestation or severe forest degradation, conservationists must 'get down off the fence,' as one participant at the discussion urged, and support NFM for timber, if not in all forms or circumstances. Debate of the sort described in this paper is needed to develop arguments, consider alternatives, and arrive at solutions to the problem of maintaining forest cover and conserving biological diversity.

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REFERENCES

ARNOLD, J.E.M. 1993 Management of forest resources as common property. *Commonwealth Forestry Review* **72**:157-161.

ASABERE, P.K. 1987 Attempts at sustained yield management in the tropical high forests of Ghana. *In*: Mergen, F. and Vincent, J.R. (eds.) *Natural management of tropical moist forests*. Yale University, School of Forestry and Environmental Studies, New Haven.

BARBIER, E.B. 1995 The economics of forestry and conservation: economic values and policies. *Commonwealth Forestry Review* **74**:26-34.

BOOT, R.G.A. and GULLISON, R.E. 1995 Approaches to developing sustainable extraction systems for tropical forest products. *Ecological Applications* **5**:896-903.

BOYLE, T.J.B. and SAYER, J.A. 1995 Measuring, monitoring and conserving biodiversity in managed tropical forests. *Commonwealth Forestry Review* **74**:20-25

BROWDER, J. 1992 The limits of extraction. *BioScience* **42**:174-182.

CAUGHLEY, G. and GUNN, A. 1995 *Conservation biology in theory and practice*. Blackwell Scientific, Cambridge, Massachusetts, USA.

COX, P.A. and ELMQVIST, T. 1991 Indigenous control of tropical rain-forest reserves: an alternative strategy for conservation. *Ambio* **20**:317-321.

DAUVERGNE, P. 1994 The politics of deforestation in Indonesia. *Pacific Affairs* **66**:497-518.

DICKINSON, J.C. III. 1995. The need and potential for private biodiversity conservation. *In*: Saunier, R. E., and Meganck, R. A. (eds.) *Conservation of biodiversity and the new regional planning*. Organization of American States, Washington, D.C., USA.

DOBSON, A. and Absher, R. 1991 How to pay for tropical rain forests. *Trends in Ecology and Evolution* **6**:348-351.

DOVE, M.R. 1993 A revisionist view of tropical deforestation and development. *Environmental Conservation* **20**:17-24.

FRUMHOFF, P.C. 1995 Conserving wildlife in tropical forests managed for timber to provide a more viable complement to protected areas. *BioScience* **45**:456-464.

GITAY, H., WILSON, J.B. and LEE, W.G. 1996 Species redundancy: a redundant concept? *Journal of Ecology* **84**: 121-124.

GODOY, R.A. and BAWA, K.S. 1993 The economic value and sustainable harvest of plants and animals from the tropical forest: assumptions, hypotheses, and methods. *Economic Botany* **47**:215-219.

GROOMBRIDGE, B. 1992 *Global biodiversity: status of the earth's living resources*. Chapman and Hall, London.

GRUMBINE, E.F. 1994 What is ecosystem management? *Conservation Biology* **8**:27-38.

GULLISON, R.E. 1995 *Conservation of tropical forests through the sustainable production of forest products: the case of mahogany* (Swietenia macrophylla *King*) *in the Chimanes Forest, Beni, Bolivia*. Unpublished dissertation.

GULLISON, R.E. and HARDNER, J.J. 1993 The effects of road design and harvest intensity on forest damage caused by selective logging: empirical results and a simulation model from the Bosque Chimanes, Bolivia. *Forest Ecology and Management* **59**:1-14.

HANSEN, A.J., SPIES, T.A., SWANSON, F.J. and OHMANN, J.L. 1991 Conserving biodiversity in managed forests: lessons from natural forests. *BioScience* **41**:382-392.

HEINRICH, R. 1995 Environmentally sound harvesting to sustain tropical forests. *Commonwealth Forestry Review* **74**:198-203.

HOLDGATE, M. 1993 Sustainability in the forests. *Commonwealth Forestry Review* **72**:217-225.

JOHNSON, N and CABARLE, B. 1993 *Surviving the cut: natural forest management in the humid tropics*. World Resources Institute, Washington D.C.

KIEKENS, J.P. 1995 Timber certification: a critique. *Unasylva* **46**:27-28.

LESLIE, A.J. 1987 The economic feasibility of natural management of tropical forests. *In*: Mergen, F. and Vincent, J.R. (eds.) *Natural management of tropical moist forests*. Yale University, School of Forestry and Environmental Studies, New Haven.

LOWE, R.G. 1995 How can ecology contribute to the silviculture of natural tropical high forest and its regeneration? *Commonwealth Forestry Review* **74**:162-163.

LUGO, A.E. 1995 Management of tropical biodiversity. *Ecological Applications* 5:956-961.

MACHLIS, G.E. and FORESTER, D.J. 1996 The relationship between socio-economic factors and the loss of biodiversity: first efforts at theoretical and quantitative models. *In*: Szaro, R.C. and Johnson, D.W. (eds.) *Biodiversity in managed landscapes: theory and practice*. Oxford University Press, Oxford.

MALLIK, A.U., RAHMAN, H. and PARK, Y.G. 1995 Community forestry: revitalizing an age-old practice of sustainable development. *Journal of the Korean Forestry Society* **84**:525-535.

MARTINI, A.M.Z., ROSA, N. de A. and UHL, C. 1994 An attempt to predict which Amazonian tree species may be threatened by logging activities. *Environmental Conservation* **21**:152-162.

MCNEELY, J.A. 1994 Lessons from the past: forests and biodiversity. *Biodiversity and Conservation* **3**:3-20.

MEFFE, G.K. and EHRLICH, A.H. 1993 Human population control: the missing agenda. *Conservation Biology* 7:1-3.

MYERS, N. 1988 Tropical forests: much more than stocks of wood. *Journal of Tropical Ecology* **4**:209-221

MYERS, N. 1993a Tropical forests: the main deforestation fronts. *Environmental Conservation* **20**:9-15.

MYERS, N. 1993b Population, environment, and development. *Environmental Conservation* **20**:205-215.

O'CONNELL, M.A. 1996 Managing biodiversity on private lands. *In*: Szaro, R.C. and Johnson, W.D. (eds.) *Biodiversity in managed landscapes: theory and practice*. Oxford University Press, Oxford.

PALMER, J., and Synnott, T.J. 1992 The management of tropical forests. *In*: Sharma, N.P. (ed.) *Managing the world's forests: looking for a balance between conservation and development*. Kendall Hunt Publishing Company, Dubuque, Iowa, USA.

PANAYOTOU, T. and Ashton, P.S. 1992 *Not by timber alone: economics and ecology for sustaining tropical forests*. Island Press, Washington, D. C.

PAULSON, D.D. 1994 Understanding tropical deforestation: the case of Western Samoa. *Environmental Conservation* **21**:326-332.

PEARCE, D. and BROWN, K. 1994 Saving the world's forests. *In*: Brown, K. and Pearce, D.W. (eds.) *The causes of tropical deforestation: the economic and statistical analysis of factors giving rise to the loss of the tropical forests.* University of British Columbia Press, Vancouver.

PERLIN, J. 1989 *A forest journey: the role of wood in the development of civilization.* Harvard University Press, Cambridge, Massachusetts, USA.

PINARD, M., HOWLETT, B. and DAVIDSON, D. 1996 Site conditions limit pioneer tree recruitment after logging of dipterocarp forests in Sabah, Malaysia. *Biotropica* **28**:2-12.

PINARD, M.A., PUTZ, F.E., TAY, J. and SULLIVAN, T.E. 1995 Creating timber harvest guidelines for a reduced-impact logging project in Malaysia. *Journal of Forestry* **93**:41-45.

POORE, D. 1995 Forestry and nature conservation: changing perspectives. *Commonwealth Forestry Review* **74**:5-19.

POORE, D., BURGESS, P., PALMER, J., RIETBERGEN, S. and SYNNOTT, T. 1989 *No timber without trees: sustainability in the tropical forest.* Earthscan Publications, Ltd., London.

PUTZ, F.E. 1992 Unnecessary rifts. *Conservation Biology* **6**:301-302.

PUTZ, F.E. 1993 *Considerations of the ecological foundation of natural forest management in the American tropics.* Center for Tropical Conservation, Duke University.

PUTZ, F.E. and VIANA, V. 1996 Biological challenges of certification of tropical timber. *Biotropica.* In press.

RICHARDS, M. 1993 The potential of non-timber forest products in sustainable natural forest management in Amazonia. *Commonwealth Forestry Review* **72**:21-27.

ROBERTS, M.R. and GILLIAM, F.S. 1995 Patterns and mechanisms of plant diversity in forested ecosystems: implications for forest management. *Ecological Applications* **5**:969-977.

ROBINSON, J.G. 1993 The limits to caring: sustainable living and the loss of biodiversity. *Conservation Biology* **7**:20-28.

ROWE, R., SHARMA, N. and BROWDER, J. 1992 Deforestation: problems, causes, and concerns. *In*: Sharma, N.P.(ed.) *Managing the world's forests: looking for a balance between conservation and development.* Kendall Hunt Publishing Company, Dubuque, Iowa, USA.

SALICK, J., MEJIA, A. and ANDERSON,T. 1995 Non-timber forest products integrated with natural forest management, Rio San Juan, Nicaragua. *Ecological Applications* **5**:878-895.

SANTISO, C. 1993 The Maya Biosphere Reserve: an alternative for the sustainable use of resources. *Nature and Resources* **29**:6-11.

SINGH, S. and KHARE, A. 1993 People's participation in forest management. *Commonwealth Forestry Review* **72**:279-283.

SAYER, J.A. and WHITMORE, T.C. 1991 Tropical moist forests: destruction and species extinction. *Biological Conservation* **55**:199-213.

SNOOK, L.K., NEGREROS-CASTILLO, P. and BARRERA DE JORGENSON, A. 1994 Reflexiones sobre la informacion, la investigacion y el manejo de las selvas de Quintana Roo. *In*: Snook, L.K. and Barrera de Jorgenson, A. (eds.) *Madera, chicle, caza y milpa: contribuciones al manejo integral de las selvas de Quintana Roo, Mexico.* PROAFT, INIFAP, USAID and WWF-USA.

SOULE, M. 1993 Normative conflicts and obscurantism in the definition of ecosystem management. *In*: *Sustainable ecological systems: implementing an ecological approach to land management*, United States Department of Agriculture, General Technical Report RM-247.

SOUTHGATE, D. 1992 Policies contributing to agricultural colonization of Latin America's tropical forests. *In*: Sharma, N. P. (ed.) *Managing the world's forests: looking for a balance between conservation and development.* Kendall Hunt Publishing Co., Dubuque, Iowa, USA.

TER STEEGE, H., BOOT, R., BROUWER, L., HAMMOND, D., VAN DER HOUT, P. JETTEN, V.G., KHAN, Z., PULAK, A.M., RAAIMAKERS, D. and ZAGT, R. 1995. Basic and applied research for sound rain forest management in Guyana. *Ecological Applications* **5**:904-910.

UPTON, C. and BASS, S. 1996 *The forest certification handbook.* St. Lucie Press, Delray Beach, Florida.

VINCENT, J.R. 1992 The tropical timber trade and sustainable development. *Science* **256**:1651-1655.

VINCENT, J.R. 1995 Timber trade, economics, and tropical forest management. *In*: Primack, B.R. and Lovejoy, T.E. (eds.) *Ecology, conservation, and management of Southeast Asian rainforests.* Yale University Press, New Haven, Connecticut, USA.

WELLS, M. P. and BRANDON, K.E. 1993 The principles and practice of buffer zones and local participation in biodiversity conservation. *Ambio* **22**:157-162.

WHITMORE, T.C. and SAYER, J.A. 1992 *Tropical deforestation and species extinction.* Chapman and Hall, London.

WORLD RESOURCES INSTITUTE. 1996 *World resources: a guide to the global environment: 1996-97.* Oxford University Press, Oxford, Great Britain.

APPENDIX

Participants in the meeting included J. C. Dickinson (geographer, Tropical Forest Management Trust), J. K. Parker (forester, The Oriskany Institute), B. Cabarle (forester, WRI), N. Sizer (ecologist, WRI), T. J. Synnott (forester, Forest Stewardship Council), M. Kiernan (forester, World Wildlife Fund), R. Rice (economist, Conservation International), J. Laarman (economist, North Carolina State University), P. Frumhoff (ecologist, University of Maryland), D. Gibson (forester, Chemonix Inc.), F. E. Putz (ecologist, CIFOR) and M. B. Dickinson (ecologist, Florida State University).