

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/232660193>

# Ecological Criteria and Indicators for Tropical Forest Landscapes: Challenges in the Search for Progress

Article in *ECOLOGY AND SOCIETY* · March 2004

DOI: 10.5751/ES-00638-090107 · Source: OAI

CITATIONS

73

READS

147

3 authors, including:



**Douglas Sheil**

Norwegian University of Life Sciences (NMBU)

433 PUBLICATIONS 17,411 CITATIONS

[SEE PROFILE](#)



**Robert Nasi**

Center for International Forestry Research

316 PUBLICATIONS 6,937 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



Borneo Futures [View project](#)



The Socioeconomic Impact of Industrial Tree Plantations in Developing Countries [View project](#)

*Synthesis*

# Ecological Criteria and Indicators for Tropical Forest Landscapes: Challenges in the Search for Progress

[Douglas Sheil](#)<sup>1</sup>, [Robert Nasi](#)<sup>1</sup>, and [Brook Johnson](#)<sup>2</sup>

---

**ABSTRACT.** In the quest for global standards, “Criteria and Indicators” (C&I) are among the foremost mechanisms for defining and promoting sustainable tropical forest management. Here we examine some challenges posed by this approach, focusing on examples that reflect the ecological aspects of tropical forests at a management-unit level and assessments such as those required in timber certification.

C&I can foster better forest management. However, there are confusions and tensions to reconcile between general and local applications, between the ideal and the pragmatic, and between the scientific and the democratic. To overcome this requires a sober appraisal of what can realistically be achieved in each location and how this can best be promoted. Good judgment remains the foundation of competent management. Data can inform this judgment, but an over-reliance on data collection and top-down bureaucratic interventions can add to problems rather than solving them.

Our arguments stress compromise, planning, guided implementation, and threat preparedness. Importance is also placed on skills and institutions: the building blocks of effective forest management. We suggest some options for improving forest management. Although a wider discussion of these issues is necessary, procrastination is harmful. Action is needed.

---

## INTRODUCTION

*“A confusion of the real with the ideal never goes unpunished.”* —Johann Wolfgang von Goethe

Management of tropical forests for timber is a politicized and often divisive subject (Rice et al. 1997, 1998, Struhsaker 1997, Bawa and Seidler 1998, Bowles et al. 1998, Cannon et al. 1998, Salafsky et al. 1998, Lugo 1999, Pearce et al. 1999, Putz et al. 2000*b*). Although tropical deforestation is a global concern (Bowles et al. 1998, Achard et al. 2002), the potential for production forestry to halt this process, or to otherwise benefit conservation, is disputed (Bowles et al. 1998, Lugo 1999, Pearce et al. 1999, Putz et al. 2000*b*). The possibility of achieving sustainable forest management is itself distrusted (Bowles et al. 1998, Lugo 1999).

The concept of sustainable forestry now includes much more than conventional principles of sustained yield: that is, production (usually timber) at guaranteed levels in perpetuity (Dawkins and Philip 1998). The Ministerial Conference on the Protection of Forest in

Europe (Helsinki, 1993) states: “sustainable management means the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic, and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.” Sustainability has thus become a principle “that cannot be proven or measured but which serves to create a sense of community, connection and purpose” (McCool and Stankey 2001). Sustainability, in this modern, broad sense may be no easier to define than love, hope, and charity. Translating such concepts into practical guidance requires clear agreement concerning what to sustain. This is where Criteria and Indicators (C&I) enter.

In the early 1990s, several forums developed C&I for national-level reporting. The intention was to provide a “common understanding of what is meant by sustainable management” (Write et al. 2002). Interest in agreeing and applying such concepts to actual Forest Management Units (FMUs) emerged.

---

<sup>1</sup>CIFOR (Center for International Forestry Research); <sup>2</sup>NCBA (National Cooperative Business Association)

Compatibility with national-level C&I proved problematic (Castañeda 1998, FAO 2001) and FMU-scale demands were ultimately addressed in various ways (e.g., Wijewardana et al. 1997, Prabhu et al. 1999, McCool and Stankey 2001, Write et al. 2002). Examples are provided in Appendix 1 (see also FAO 2001).

C&I are “information tools in the service of forest management” (Prabhu et al. 2001). They are used to conceptualize, evaluate, and implement sustainable forest management. We use the definitions of Prabhu et al. (1999): *Criteria* “are the intermediate points to which the information provided by indicators can be integrated and where an interpretable assessment crystallizes”; *Indicators* “are any variables or components of a forest ecosystem or management system that are used to infer the status of a particular criterion”; and *Verifiers* “are data or information that enhances the specificity or the ease of a specific indicator.” Other definitions exist but remain contentious. D. Dykstra (*personal communication* 2003) suggests: “The extremely poor definitions upon which FMU-level C&I have been based is one of the important contributing factors that has resulted in useless C&I.” As we shall show, this difficulty is only the beginning.

Although sometimes viewed as a separate political process (Rametsteiner and Simula 2003), the idea of developing C&I was primarily to guide and facilitate certification (Elliot 2000). There are now over 50 different C&I schemes worldwide and more are in development (Canadian Wood Council 2003). Most standards reflect a multi-stakeholder approach. As Gullison (2003) notes “The range and balance of stakeholder groups represented during the standard setting process vary considerably. As a result, there are differences, sometimes large, in the conservation, social, and environmental standards that are considered to be sustainable.” Because continuous refinement is a recognized element in most schemes, tracking such diverse and divergent standards is increasingly difficult, although some commentators are optimistic about ultimate convergence (Rametsteiner and Simula 2003).

Case studies show that certification has achieved tangible conservation benefits in some concessions (Thorner et al. 1999, Gullison 2003). However, after 10 years, only 8% of certified production forests are tropical, with much of that being plantations (Eba’a

and Simula 2002). Yet producers are increasingly pressured to engage with certification programs to access the growing “green market.” This underlines both opportunities and challenges.

Our essay considers C&I in the context of opportunities to improve tropical forest management. The topic is vast. Many aspects are well covered in recent literature (e.g., Friedman 1999, Elliot 2000, Eba’a and Simula 2002, Mäntyranta 2002, Gullison 2003, Molner 2003). We assume, as given, that C&I are relevant to certification, and that conservation benefits should be achieved. We consider conceptual, practical, and ethical problems associated with C&I, particularly ecological C&I.

In considering the sets proposed by the Center for International Forestry Research (CIFOR), the International Tropical Timber Organization (ITTO), and others (See Appendix 1 for example lists of relevant published sets), our aim is to note more general concerns and challenges. Many issues concern balance, and can never be fully resolved. Nonetheless, *Conservation Ecology* [newly renamed *Ecology and Society*] provides a valuable forum for discussion.

## **Trials**

CIFOR conducted several C&I trials in the tropics: e.g., Brazil (Zweede et al. 1995), Cameroon (Prabhu et al. 1998), Central African Republic (Caballe 1999), Côte d’Ivoire (Mengin-Lecreulx et al. 1995), Gabon (Nasi et al. 1999), and Indonesia (Burgess et al. 1995). “Ecological” verifiers and indicators—those relating to biodiversity, soil, and water—proved especially unwieldy.

ITTO similarly evaluated their own FMU C&I in 32 countries and found that three-quarters had difficulties with nearly half of the indicators. Again, ecological verifiers were especially problematic (Johnson 2001).

McGinley and Finegan (2002) assessed two “management and ecology” C&I sets (the CIFOR and Costa Rican sets). They rejected 45% of verifiers. Of those accepted, 86% needed modification, and 91% required further documentation. Of the 45% rejected, equal numbers (17% each) were deemed redundant, conceptually weak, imprecise, or needing further research—the rest were judged inappropriate for assessments. Despite many initiatives, C&I are unready for application.

## CONCEPTUAL LIMITATIONS

McCool and Stankey (2001) suggested two pre-conditions for effective C&I. First, “scientists must agree on cause–effect relationships, in order to select indicators that are useful in providing reliable measures of progress toward achieving goals.” Second, “there needs to be a political agreement on what should be sustained.” Such conditions are rarely satisfied or compatible.

### Objectivity

The desire for replicable approaches to ecological C&I privileges scientific methods (Prabhu et al. 1999, McCool and Stankey 2001). Ecologists often equate indicators with their own “biological indicators” (e.g., Cairns 1986, Landers et al. 1988, Kremen 1992, 1994, Landers 1992, Lawton et al. 1998). However, to inform management, the relevant cause-and-effect relationships must be clear. Unfortunately, they rarely are.

Preference is given to finding indicators that are easily observed and identified (Kremen 1992, 1994, Beccaloni and Gaston 1995, Andersen 1997). For example, large butterflies are appealing candidates. Stork et al. (1997) propose “the number of large butterfly species maintained within natural variation [after harvesting]” as a verifier. However, there is no clear link between butterfly populations and desirable forest conditions (Ghazoul and Hellier 2000). Thus butterfly observations have little practical utility. Even if relationships were clear, simpler, more direct approaches will generally be much more sensible: e.g., reviewing management records, viewing the site, or talking to local people (Watt 1998).

How should data be interpreted? Stork et al. (1997) propose setting “threshold levels” using probability values derived from verifier data. Scrutiny of this example reveals problems. Stork et al. suggest that measurements from managed areas be compared to those from pristine areas; acceptable sites will “reveal no significant difference.” For a normal (frequentist) statistical interpretation, this significance is “the likelihood of obtaining these verifier data, given a true null hypothesis (i.e., equivalent forests), is less than some arbitrary level.”

Such approaches are flawed. First, “significance” is a probability concerning only the detection of

differences (not their nature, magnitudes, or practical implications). Second, the ability to *detect* differences is determined by study design, data quantity, and data quality. Third, detection (power) varies with the *analytical procedures* used and the *decisions* made in applying them (e.g., inclusion or elimination of outliers). Fourth, results depend on the “choice” of pristine *comparison* forest(s), if such areas truly exist. Fifth, the appropriateness of any comparison between any two pieces of forest is undermined by the fact that we are not concerned with whether the two forests are different—they always are (Hurlbert 1984, Nester 1996, Crome 1997)—but whether the differing conditions are detrimental to sustainability. In any case, such comparisons imply that any difference with a pristine forest is bad—a paradoxical view if it is already agreed that the area can be logged. Detection is irrelevant (Crome 1997). Managers should be focusing on the *nature* and *consequences* of change, its underlying causes, and management implications.

Are other approaches acceptable? For example, rather than the “silly null hypothesis” of no difference (Nester 1996), we could develop some scoring of levels and types of change and a more flexible means of statistical inference about their tolerability. These goals appear worthy, but remain plausible research themes rather than ready-to-use concepts: the development and application of standards that reflect local ecologies will not be trivial. Similarly, the use of alternative statistical approaches may offer some advantages. For example, Bayesian inference has useful properties in informed decision making (see, e.g., Crome et al. 1996, Ghazoul and McAllister 2003), although the implied subjectivity can be viewed both as a strength and as a weakness in the context of C&I. Crome (1997) has argued that probability values, and other standard methods, can all be viewed as a misleading basis for reasoning regarding forest change in real cases. Recent developments in fisheries indeed suggest that addressing uncertainty head-on can yield management and monitoring procedures that work (Harwood and Stokes 2003). However, there is no ready-made approach for forest C&I, where vastly more parameters appear to be of general concern.

The counter argument that “such statistical problems plague many modern scientific studies” may be true (J. Ghazoul, *personal communication*). But surely accepting what we know to be flawed science as our benchmark undermines our justification for being scientific. Even if efforts were made to apply every

verifier appropriately and consistently, the resulting interpretation and relevance to management must depend on contexts, value judgments, and assumptions.

## Biodiversity

Conservation comprises diverse aims and interests, most of which claim “scientific” support (Redford and Richter 1999). The term “biodiversity” provides an example. Many see this concept as roughly synonymous with species diversity and assume that high local species richness is desirable in itself (see Sheil et al. 1999). Hence, “species richness,” or “processes that maintain richness” are assumed to be management priorities (e.g., Stork et al. 1997). If challenged, most scientists will agree that this proposal is based on faith and vague value judgments. We cannot optimize biodiversity unless we agree on what it is, and what its importance is relative to other priorities. Some may suggest that all species should be counted equally, or weighted on their taxonomic “distinctiveness,” or vulnerability, or some such combination. Others might choose to weigh those with potential commercial values more highly, or according to their perceived public appeal. Yet others might take an ethics-oriented stance, placing intelligent species higher. Others may favor species named in religious texts, or those that serve as national or state symbols, represent local clan totems, or hold personal relevance. There is no correct answer. These alternatives cannot be resolved by appeals to science and are best addressed through informed consensus.

## Science or consensus?

“Sustainability” is not an all-or-nothing issue. It increasingly reflects a shift to more local and pragmatic concerns (e.g., Gale and Corday 1994, Wijewardana et al. 1997). Acceptance of *any* forest exploitation implies tolerance of *some* degree of change. Agreeing on what can change and what is to be sustained is, in reality, more of a societal problem than a scientific one. Science and technical ideas play a role, but choices require value judgments.

Forests have different management needs. Demands, contexts, and abilities vary. In a national forest estate, some forests may be managed for specific properties and services (conserving panda bears, protecting water catchments, scenery, or carbon storage, for example), whereas others are focused on production. It helps to

be precise, realistic, and selective about what needs to be maintained at what cost. Local needs must to be placed within the context of larger scale trade-offs. These aims are not facilitated by uniform prescriptive approaches.

Tropical forest stakeholders are diverse and are active on a range of scales, from the local to the national to the global. Disagreements arise both within and between groups. Indeed, in tropical forests, where rights and obligations are often tangled and unclear, many observers note that agreement is often more essential for action than is scientific insight (Thornber et al. 1999). However, building consensus is hard. Forums that facilitate action are hard to devise: participants who want to do nothing are usually in an inherently more powerful position than those seeking action. Even weak stakeholders find ways to undermine activities of which they disapprove (Scott 1985).

This situation argues either against participation or for the need to build trust and shared visions over long periods. In any case, the complexity of effectively accommodating the various stakeholders discourages donors from pursuing these challenges. Instead, they turn to science to provide easier solutions. But by doing so, a key local component is omitted: clear consensus on what should be sustained.

## Dilemma

What can science and politics offer to achieve sustainable forest management, and can they be combined? Individuals generally favor one or the other, leading to a “science versus politics” polarization. Bass (2001) notes this dilemma: “Do we consider sustainability to be nothing more than a technical constraint to development goals related to environmental limits—with the implication that this is primarily a matter of science; or do we consider sustainability, like liberty or justice, to be a social goal to which we aspire and therefore a matter of participation?”

Given the covertly normative nature of many “scientific” recommendations and the limited technical literacy of many stakeholders, tension between these factions seems justified and inevitable. In the concrete realm of the FMU, C&I are required to be both “ideal” and “real”; both “scientific” and “participatory.” Such tension encourages a debate with no potential

resolution, and which delays the improvement of forest management (Dykstra 1999).

## PRACTICAL LIMITATIONS

Aside from conceptual dysfunctions, there are practical limitations to C&I. Most C&I sets agree that there are certain “enabling conditions” required for success (ITTO 1998, Stortenbeker et al. 2000). These usually involve the following elements:

- 1) A manager who can be held responsible for what is under his/her control (and who is committed to the long-term objectives).
- 2) A well-implemented management system, which includes a plan for the harvest and management of all forest products.
- 3) Environmental vigilance (including monitoring).
- 4) An institutional structure able to support sustainable forest management.
- 5) Forest users who comply with conventions and codes ratified by local and national government.
- 6) The “rule of law.”

When these primary needs remain unmet, efforts to apply C&I are of questionable value and may distract attention from fulfilling them. We consider each in the following sections.

### Managers

The attributes of an effective manager include rationality, competence, motivation, and flexibility. C&I sets often emphasize outcomes. But is the manager responsible? Not always. El-Niño events, volcanic eruptions, upstream water quality problems, military activities, or invasions of exotic species from outside the area can severely undermine forest ecologies, but are not easily addressed by even the most competent managers. Such effects can be subtle and ambiguous.

Consider a scenario in which a well-managed forest borders on oil palm plantations: the plantations lead to local increases in rat and wild pig populations; the rats are then preyed upon by snakes, whose populations increase and affect the forest fauna (Ashton 1996); the increased pig population, in turn, impedes forest regeneration (Ickes et al. 2001; see also Curran et al. 1999). Management assessments must recognize the limits of control.

Although C&I are described as being “designed for

managers,” the manager's capacity, means, and priorities are seldom addressed. Current ecological C&I are rarely useful to managers. For their sake, indicators must be clear and ready for use. A verifier that “needs more work” *must* be set aside. Planning should start with clear management targets and limits, rather than a surfeit of complex response indicators.

C&I make demands that impinge on a manager's ability to fulfill other tasks. Many C&I sets provide substantial lists of indicators (Kneeshaw et al. 2000). Yet tracking 40–60 indicators is not trivial: is this a priority or a distraction? At its worst, an over-reliance on lists and data collection allows people to look busy while they avoid taking responsibility for action. Ultimately, C&I cannot replace skilled, committed professionals.

Approaches that *reduce* the bureaucratic burden on managers may allow sufficient time and resources for good forest management to take place. As Francis Bacon wrote, “truth arises more readily through error than from confusion.” For sustainable forest management to work, choice must remain squarely in the domain of human judgment.

### Management plans and objectives

In forest management, planning is an essential part of the process, but plans can be poorly designed, overly inflexible, or even ignored (Sayer 1995). Frequently, however, C&I require only the existence of “a management plan.”

In planning, we need to identify and promote approaches that best reflect local needs and conditions, while including only those “elements of sustainability” that genuinely apply. Ideally, management objectives are negotiated and agreed upon among the principal stakeholders. This does not lend itself to a “one-size-fits-all” prescription. Negotiations often require fudged wordings, but for management and assessment, clarity is essential. Despite these difficulties, some commentators are developing pragmatic guidelines (e.g., Gibson et al. 2000, Edmunds and Wollenberg 2001).

Each objective may require indicators of progress. These, too, must be practical, easily understood, and have the potential to influence management activities. “For indicators to serve as more than alarms, there must also be a management strategy in place for what

actions to take” (McCool and Stankey 2001).

Once a plan exists, implementation should be measured using two simple monitoring approaches:

*Implementation monitoring*, to determine if planned activities were undertaken as prescribed.

*Effectiveness monitoring*, to determine if the activities and interventions had the desired effect.

These should be developed to support and guide management. Indeed, they are part of management. Plans should provide a clear vision but be flexible enough to accommodate adjustments.

We advocate that forest management should be primarily evaluated on plans and on their implementation. A particular forest should not be judged on some globally determined notion of sustainability without first considering the degree to which management objectives reflect local trade-offs, and whether these have been implemented effectively.

Finding a balance between local and more general priorities remains a challenge, but the outcome of any such negotiation is more likely to have positive results if management systems adapt to local contexts. This may be unattractive to many stakeholders whose interests are defended by more general national regulatory systems and “fixed standards” certification systems. However, as we have seen, “command and control” C&I are consistent neither with local good practices nor with democratic views of good governance.

### Addressing threats

In addition to a well-balanced and realistic management plan, there must be a focus on defense: what precautions are to be taken against threats such as agricultural encroachment, fires, even machine wastes. Suitable monitoring systems are required. The case of invasive exotic species provides a good illustration.

Exotics, once established, tend to naturalize slowly and are often ignored until their presence is clearly damaging, and control measures become a major undertaking (Binggelli 1989, Cronk and Fuller 1994, Sheil 1994). Contrary to present practice, we propose working toward a management regime in which actors are aware of the potential threats and watch for invasive species. Once observed, exotics should be

eliminated quickly, before they become overwhelming. Because most stakeholders may have little initial interest in addressing such problems, the ability to proactively identify threats and summon an adequate response will be largely dependent on the presence of well-trained managers.

Such preventative activities are essential even when capacity and resources are extremely limited (Sheil 2001). It is also the cheap-but-necessary kind of activity that is often neglected in C&I assessments.

### Institutions

Effective planning, implementation, and monitoring require an institutional framework with elements that include broad participation in planning, administrative capacity, field presence, and effective knowledge management. In reality, institutional challenges are common: poor governance, short-term interests, weak enforcement, inappropriate incentives and penalties, inequity, vested interests and corruption, intersectoral conflicts, poor training, and weak motivation are all known to contribute to bad management (e.g., Karsenty 2000, Putz et al. 2000a). Solving such problems using technically demanding voluntary schemes with limited incentives will rarely be simple, because many vested interests have little to gain and much to lose.

### Participation

Broad participation has become a standard element of good practice (Edmunds and Wollenberg 2001). As Rasmussen et al. (2000) state, regarding their trials in Thailand, C&I will “only be able to change anything in reality if they are the outcome of a process involving all the present actors.” Yet, effective participation in tropical forest management remains difficult.

It is pragmatic to distinguish between *ideal* and *necessary* consent. That is, in building support for improved management, there needs to be some ranking of the stakeholders' concerns, with the necessary stakeholders being those whose cooperation is required to determine and implement management goals (e.g., managers, neighboring communities, legal enforcement agencies). There is also a need for decision processes that allow for the “least negative” alternative to be selected when necessary (Gibson et al. 2000). A pragmatic starting point is to simply

improve the integration of local stakeholders and their needs into the planning process.

The preferences of many stakeholders, like commercial enterprises, are likely to be clear and relatively simple to understand. However, this is not true for all stakeholders. Local communities generally recognize and value numerous goods and services, and may already possess institutions to protect these (McKean 2000). Such values often appear to be ad hoc to the outsider, and are not catered for by inflexible, centralized schemes (e.g., Chandrakanth and Romm 1991, Colfer et al. 1997, Scott 1998). For example, in studies in rugged forest landscapes of East Kalimantan, Indonesia, we learned that local communities have a history of crop failures and are often dependent on wild foods like the sago-producing palm *Eugeissona utilis*, which grows on forest ridge tops. "Good forestry practice" calls for forest roads and skid trails to be located on ridge tops because this reduces maintenance costs and limits soil erosion; however, skidding machinery and timber extraction destroy the palms. Either protecting this resource or finding alternative food security measures appear to be options (Sheil et al. 2003). Such priorities, although uncontroversial once elicited, were not being acknowledged in advance; they exemplify the critical local issues overlooked in top-down C&I.

The previous example also highlights how technical and bureaucratic generalities are insufficient to define good management with respect to local stakeholders; managers need local knowledge and understanding much more than any ability to track numerous pre-selected variables.

## Finance and capacity

Funding is an important factor in determining institutional and administrative capacity. Despite the massive wealth accruing from rapid, large-scale exploitation, most production forestry is viewed as only modestly profitable if sustainability is sought and investment-style discounting is factored in.

The direct costs of complete forest certification assessments vary from perhaps US\$0.5 to \$2 per ha (Williams 2001). Implementing verifiers alone may add 15% to 30% to total management costs (Foundation of the Peoples of the South Pacific International 1998). For smaller producers, like many community-run forests, such costs are prohibitive

(Thorner et al. 1999). Chapela and Madrid (2002 in Molner 2003) imply a cost of US\$12,000 per year for community enterprises in Mexico. The few communities that have gained certification have had significant external support (Molner 2003).

Certification costs depend on the C&I schemes employed, but the cost of reaching any standard will be high where operations are worst. Unfortunately, this applies to many tropical forest situations (Eba'a and Simula 2002). Certification is too expensive for most tropical concessions (Wibowo 2002).

Costs relate also to developing adequate technical capacity. In some cases, this is useful—but it is also debatable. C&I tend to emphasize high-tech approaches: for example, GIS are increasingly highlighted. Where capacity is available and other priorities are covered, this can be effective (Freycon et al. 1996, Pain-Orcet et al. 1998). However, a compulsory reliance on technology disadvantages those with the least to invest, and can be distracting (de Man and den Toorn 2002, Sheil 2002). MacKinnon (2002), discussing tropical conservation, disputes the belief that "GIS and other IT methods will solve management problems and lead to greater efficiency," noting that: "GIS is a very expensive way to create attractive wallpaper for the director's office. It is almost never used properly and rarely helps in planning or managing purposes. The most detailed satellite imagery is enormously costly and has a resolution of 4 m. A man on the ground is very cheap and has a resolution of 4 mm." Clearly, the reality depends on where you are, and many technologies are becoming more accessible and practical. Examples such as chain-of-custody log-tagging and satellite-based monitoring (de Miranda and John 2000, Global Forest Watch 2002) suggest that technological approaches can be valuable, but only when they match local priorities and capacities.

It may ultimately be more pragmatic, in terms of conservation outcomes, to lower certification standards if wider adoption results (Gullison 2003). An alternative is for donors to step in and cover the costs gap, but donors fear for their public image and few are willing to engage directly with commercial logging. Funding the development of standards is more politically acceptable than helping producers to achieve them.



## Knowledge

Few of the major failings seen in tropical forestry should be blamed on lack of knowledge. Generally, we know what needs to be done to improve timber harvesting (e.g., Dykstra and Heinrich 1996). Scientists, however, generally emphasize unknowns and demand additional information. C&I generally reflect this. But collecting new data is often inefficient. Sometimes guidance is already available, and much valuable knowledge remains unused (Sheil and van Heist 2000). Local knowledge, in particular, should be considered a valuable source of locally relevant insight that can enhance forest management (c.f. Posey 1992, 1997, Gadgil et al. 1993, Sheil et al. 2003).

Promoting better use of available information is valuable. Although the search for further information can be ongoing, it must be kept in control and not inhibit other important activities. Too often, assessments divert scarce funding, expertise, and time away from fundamental issues such as planning and threat monitoring (Sheil 2002). Effective sharing of expertise, on the other hand, offers great potential.

## Acceptance of conventions and laws

Incompatibility between legal settings and certification standards can be a serious problem (Eba'a and Simula 2002). Difficulties generally relate to ownership and usufruct rights, and conflicts between customary and legal regulation. Although not "ecological" in nature, such conflicts influence how topics like hunting and forest access can be addressed. Even with issues such as illegal logging, stakeholders will differ on what is, or should be, legal. Defining and implementing coherent conservation goals are impossible while such conflicts and ambiguities remain unresolved. It is no coincidence that small-scale tropical certification has been most successful in Mexico, where unambiguous communal tenure covers >80% of the country's forest estate (Chapela and Madrid 2002, quoted in Molnar 2003).

We have been emphasizing local interests and standards. Do laws and conventions have a place? External rules can be necessary. For example, the maintenance of forest cover in the Bangladesh Sundarbans appears to be essential, despite local land shortages, because these mangrove forests save lives during the storm floods that sweep the Bay of Bengal (Government of Bangladesh 1999). In many cases,

however, principles are less clear-cut and are better when agreed upon rather than simply imposed. For example, if local people can accept national hunting regulations or negotiate local arrangements, then these can help to limit hunting. Agreed-upon rules and clear enforcement can be more effective than complex monitoring schemes because they provide a platform for action rather than passive observation (Sheil 2002). In contrast, imposing rules, especially without "participatory feedback," can lead to ethical dilemmas and conflicts.

## ETHICAL LIMITATIONS

The conceptual and practical limitations of extending C&I to the Forest Management Units (FMU) are numerous, but ethical problems are the most difficult. C&I appear to give global priorities precedence over local needs. Stakeholders resent outsiders telling them "what matters," rather than listening (Louvet 2002; Philippe Guizol, *personal communication* 2001).

Donor agencies have supported C&I for tropical forestry. Such institutions have their own views as to what C&I should look like, because they have needs and priorities of their own. Technical monitoring is strongly supported because it appears to be low-risk, politically correct, and scientifically condoned (Sheil 2002). Donors require project accountability, which, in turn, justifies verifiers and indicators. Such accountability becomes paramount in a mind-set in which future funding hinges on the demonstration of success. Furthermore, because standards remain contested, donors willingly relinquish C&I design to outside consultants who have little to gain by challenging the validity and effectiveness of their terms of reference, but are, rather, encouraged to make authoritative assessments and proposals in a limited time and with limited stakeholder interaction.

As a result, C&I systems supported by outside donors are often absolute in their formulations, leading to standards that may be unrelated to local interests or managerial realities. Moreover, because these standards are often "scientific" in tone, they are considered "objective," and do not get adequate critical vetting. This undermines local inputs, especially on "technical" topics like biodiversity, and generates moral discrepancies. At worst, C&I might lead to a technical imperialism, in which local populations have little say. One of the reasons that FSC (Forest Stewardship Council) principles and

criteria were kept vague was, we believe, to allow concepts to be tailored to local conditions. Ironically, however, opportunities for local compromises are frequently disallowed by an over-zealous wielding of global standards.

## DISCUSSION

C&I have been developed with good intentions, but they continue to pose conceptual, practical, and ethical dilemmas. Asking if a forest is “sustainable” provokes debates in which many aspects will remain forever unresolved. Asking more simply “will the forest remain?” seems more practical, but fails to capture the many other goals and objectives that are inherent to modern forestry management. Ultimately, the agreement to and promotion of “better practices” seem to be a more realistic basis for forest production and conservation than the determination of sustainability (Wadsworth 1999). So, does science have a role?

Good science is concerned with identifying and clarifying uncertainties and with weighing competing hypotheses. As Stage (2003) notes, “A decision is ‘science-based’ to the extent that all relevant and acceptable hypotheses of effect have been used to display the consequences of the management actions. Verifying that the relevant hypotheses of effect have not been ignored is a crucial role for scientists in the decision process. That is very different from having scientists make the decision!”

One of the dangers of C&I, already touched upon, is the perception that it is an attempt to wrestle control from forest managers. Indicator lists grow as each interest has its say, and greater documentation is demanded. Centralized control can provide some benefits, but the costs also need to be recognized (Scott 1998). Bureaucratic reasoning cannot take account of all eventualities, and some circumstances will remain unanticipated, but is it desirable that C&I lists expand to address a universe of possible futures?

The assumption that “more information equals better management” should be mistrusted. Natural resources specialists increasingly recognize that data demands are potentially never-ending (Ludwig et al. 1993, Johannes 1998). More emphasis should be placed on halting problems than on merely trying to monitor them (Ludwig et al. 1993, Sheil 2001).

Common sense and flexibility are desirable in

management. In a science fiction satire (Adams 1980), a computer-operated spaceship is discovered on a now-barren planet; it is filled with aged passengers who have been waiting to launch for 900 years; the computer has been rigidly programmed not to take off until the “lemon-scented tissues” have been delivered. The logic of the computer when challenged about this is clear from its response: “The statistical likelihood is that other civilizations will arise. There will one day be lemon-soaked paper napkins. Till then there will be a short delay. Please return to your seat.” Common sense cannot be replaced by rule-based logic: are C&I just waiting for the right civilization to arise to make them workable?

We have argued that a key role for local stakeholders is to help define the aims of, and controls on, local management. We do not advocate the exclusion of national and global actors—only a better balance. Insofar as C&I certification is consumer-led, the politics of any scheme will need to be broadly acceptable.

This can be summed up in May’s (2001) words when discussing public health risk and UK government policy: “Often the questions [asked] are outside the envelope of known science, and the risks can only be guessed at. This is especially awkward for [those] that experience science as the certainties of established knowledge, not the unknown terrain at or beyond the frontiers. It is easy to say ‘let all voices be heard,’ but many will bring other agendas to the debate, and the resulting babble of voices is uncomfortable. However, these admitted and awkward costs of wide and open consultation, and of open admission of uncertainty, are outweighed by their trust-promoting benefits.”

His suggestions, too, seem apt: “Consult widely and get the best people, but also make sure dissenting voices are heard; recognize and admit uncertainty; and above all, be open and [share] all advice.”

## MANAGEMENT EXAMPLES: THE WAY FORWARD?

We have proposed that ecological goals and objectives be pragmatic, largely based on local priorities, and process oriented. In effect, we advocate an “informed democratic” approach with the creation of agreed-upon plans of action and “codes of conduct,” derived perhaps from a C&I-type checklist, but ultimately interpreted and defined at local levels. We now present

some illustrations of our ideas. These are not prescriptions, but suggestions that can be weighed in designing and implementing improved management practices.

## Wildlife

Hunting, especially market rather than small scale subsistence hunting, is often severe and threatening to forest biodiversity. Hunting generally increases in logging concessions due to the increased access and the demands of camp-based populations (Robinson et al. 1999, Bennett and Robinson 2000). Typical C&I-based approaches focus on counting population densities of wildlife and trying to determine critical thresholds. This approach is costly and does not necessarily help to identify management priorities. We suggest an initial emphasis on conventions, laws, and locally negotiated rules. The purpose of indicators should then be to check that these regulations are accepted and are implemented. A basis for local verifiers could include:

- 1) What are the current major threats in the vicinity? What are the most likely future threats? Are these reflected in pre-emptive monitoring?
- 2) What proportion of the responsible parties knows the agreed-upon rules and responsibilities?
- 3) How many times have rules been enforced, over time? What has happened as a result?
- 4) What are the estimated amounts of illegal hunting produce found by spot-checks in local areas (number of animals or kg/time unit)?
- 5) What is the percentage of forest workers who have affordable alternative sources of protein?
- 6) What are the numbers of tools, trophies, or other items associated with illegal hunting activities found in inappropriate locations per population?

We have tried to state these in quantifiable terms, although we suspect that more qualitative assessments (i.e., spot-checks) will often suffice to identify whether or not there is a serious problem.

Further development should consider the responses required to solve problems, not merely monitor them. These could involve the banning of nonselective hunting methods; provisioning licenses; establishing quotas for hunting and/or selling produce; and requiring logging companies to provide affordable alternative sources of protein to their local staff. In larger concessions, where wildlife is seen as an

important forest value, it would be possible to develop detailed wildlife management plans integrated within forest management plans. Again, the verifiers and milestones would relate to specific knowledge of the rules and agreements, evidence of capacity and efforts to enforce them, and a search for evidence regarding implementation.

There may be good reasons to monitor selected wildlife populations directly, as proposed in some C&I sets (e.g., Stork et al. 1997), but this needs to be the result of careful deliberation. Indirect monitoring may be more efficient. For example, when rodents constitute the major part of people's meat consumption in Central Africa, it suggests the depletion of larger game (Delvingt 1997, Jeanmart 1998).

## Landscape integrity and conservation value

In this example, we look at a conceptually complex set of options that address the spatial integrity of the landscape. This more holistic concern requires the weighing of many different requirements.

The *fragmentation* of forest cover has profound ecological significance, and is the subject of a considerable technical literature (Crome 1997, Gascon et al. 2000, Malcolm 2001). In brief: small populations in fragmented or heavily harvested landscapes run much greater risks of reduced reproduction, genetic deterioration, and extinction (Nason and Hamrick 1997). Furthermore, forest fragments are especially vulnerable to fire (Buechner and Dawkins 1961, Cochrane et al. 1999, Nepstad et al. 1999), invasion by weedy species, and other processes of habitat erosion (Laurance et al. 1997, Gascon et al. 2000, Malcolm and Ray 2000, Jackson et al. 2002). However, the impact of fragmentation on any given species usually remains hard to assess: some species are edge specialists, or benefit from an increased diversity of habitats, whereas others may not even cross open ground or approach a forest edge (Newmark 1991, Daily and Ehrlich 1996).

Although conservation priorities are usually directed toward more sensitive species, it is important to note that some stakeholders may perceive an improvement in composition following fragmentation. With this caveat in mind, we assume that one possible management aim, if it can be agreed upon, is the "persistence" of fragmentation-sensitive plants and animals.

Many references that address landscape monitoring emphasize the calculation of numerous indices using remote sensing and GIS. These appear in C&I (e.g., Stork et al. 1997). We noted earlier how GIS may be more useful to some managers than to others. We favor an emphasis on spatial planning in which different road and fragmentation alternatives are clearly anticipated, so that the consequences can be recognized and weighed appropriately. Planning should allow for remedial actions in degraded areas and a comprehensive consideration of neighboring lands and the threats that arise from them. For example, firebreaks may be considered to be more important in some locations than the edge effect that such breaks might create. In some cases, forest edges might be identified as a preferred niche for a specific valued species. All such factors would have to be considered and weighed. Such plans could then be assessed as having explicitly balanced spatial integrity against other local considerations, as well as the more generalized preferences of distant stakeholders. Once a plan is agreed upon, it becomes the statement of what can be verified. No abstract indices are necessary.

At a minimum, such a planning process should ensure that known rare, unusual, or sensitive habitats and species receive due attention. An assessment would identify who was involved in contributing information to the plan and whether key expertise, including local knowledge, was omitted. Additional management goals to balance with other demands might be to maintain forest connectivity, minimize road width and length, avoid undesirable edge creation, and maintain representative portions of all natural habitats. An assessment would also seek evidence that these concerns have influenced choices (e.g., “Given the choice of options A, B and C, C was selected because...”). Such specific and locally relevant statements lend themselves to direct assessment, as is already practiced at the operational scale in several millions of hectares of Congo Basin forests (Nasi and Forni 2003).

## CONCLUSIONS

In this article, we have touched on many questions: Can the C&I concept of “sustainability” be applied meaningfully? Can it be effective politically *and* scientifically? How can diverse views be reconciled? Who can or should establish C&I, and whose interests should count the most? What are the trade-offs between the various interests? Do most indicators

actually measure what they are supposed to? Are they cost-effective? Can they really contribute to better management in circumstances when capacity is lacking? How, ultimately, can better forest management be pursued?

Wholly satisfactory answers are elusive, and will remain so. It is not possible to agree on what constitutes ideal forest management or on a process to achieve it. However, endless debate must not be a distraction. Perfection is hard, but improvement is not so difficult.

C&I have troubling practical, conceptual, and ethical limitations. Many ecological indicators promoted by C&I sets are costly and of dubious value if their purpose is to cost-effectively improve management. Given the ecological and social complexity of tropical forests, low administrative capacities, poor planning, impressive rates of deforestation, and the limited success of certification, realistic objectives are needed.

To achieve this, firstly we suggest an emphasis in which assessments focus on the quality of management plans and their subsequent implementation. Current C&I might provide a “draft checklist” of considerations, but the plan itself should describe the actual goals—the practical reconciliation of diverse demands—against which management outcomes are assessed. Plans also need clear procedures to anticipate and respond to major threats.

Secondly, we question assessments that are based solely on external standards. Instead, we recommend verifiers based on a local “code of practice” and agreed-upon plan of execution. We emphasize input and process milestones, including greater attention to risks and threats, achieved through practical management-based monitoring. Managers should be assessed on their management, not on their luck.

Thirdly, we suggest a renewed focus on building institutional capacity, a key building block of effective forest management. Certification and related C&I ideas cannot achieve this alone. This will be neither simple nor quick, but it is essential. There is much to be said for developing a cadre of professional forest managers who work for long periods in a single forest and thus get to know it intimately (Dennis Dykstra, *personal communication* February 2003). Ideally, these managers would be well trained, paid a professional salary, given control, and sufficiently

motivated to interact with and represent local stakeholders. They would also have to be subject to outside review to ensure that they do not become overly ensnared in specific local interests, and that they perform their task in line with professional norms.

Good management can never be attained through bureaucratic procedures alone. Best practices require that able and motivated managers are available on site to address concerns on a day-to-day basis. Sound judgment remains the foundation of good management. Data can inform this judgment, but is not an end in itself. Capacity-building, education, and political processes must play major roles in improving tropical forest management.

We do not dispute the potential value of C&I. These concepts have promoted various key policy issues, and C&I approaches can give conservation benefits. But a realistic appraisal is required: what can be achieved with existing capacities? Improved management is achievable by focusing on one step at a time. Sufficient knowledge is already available; procrastination only increases the probability of

draconian actions (McCool and Stankey 2001) or disillusionment. Talking should continue, but more critical, by far, is the need for more action. A reasonable plan today is better than perfection tomorrow.

*Responses to this article can be read online at:*

<http://www.ecologyandsociety.org/vol9/iss1/art7/responses/index.html>

---

### **Acknowledgments:**

*We are very grateful for the help and feedback that we have received from Grahame Applegate, Jeff Sayer, Patricia Shanley, Ravi Prabhu, Lini Wollenberg, Carol Colfer, Agus Salim, and David Kaimowitz at CIFOR, and from e-mail colleagues Jaboury Ghazoul, Bryan Finegan, Mike Lawes, Christel Palmberg-Lerche, Jack Putz, and Dennis Dykstra. We are especially grateful to Jaboury Ghazoul and Dennis Dykstra for allowing us to quote their comments. We thank Margaret Shepard, Bill Faries, Sally Wellesley, Kim Wan, and Indah Susilanasari for help with the text.*

---

## **Appendix 1. Examples of criteria and indicators regarding biological diversity, ecological process, etc. (extracts from FAO 2001).**

### INTERNATIONAL TROPICAL TIMBER ORGANIZATION

#### *Criterion 5: Biological Diversity*

This Criterion relates to the conservation and maintenance of biological diversity, including ecosystem, species, and genetic diversity. At the species level, special attention should be given to the protection of endangered, rare, and threatened species. The establishment and management of a geographic system of protected areas of representative forest ecosystems can contribute to maintaining biodiversity. Biological diversity can also be conserved in forests managed for other purposes, such as for production, through the application of appropriate management practices.

#### **Species Diversity Indicators**

5.3 Existence and implementation of procedures to identify endangered, rare, and threatened species of forest flora and fauna.

5.4 Number of endangered, rare, and threatened forest-dependent species.

5.5 Percentage of original range occupied by selected endangered, rare, and threatened species.

#### **Genetic Diversity Indicators**

5.6 Existence and implementation of a strategy for *in situ* and/or *ex situ* conservation of the genetic variation within commercial, endangered, rare, and threatened species of forest flora and fauna.

### CENTRAL AMERICA/LEPATERIQUE PROCESS

#### *Criterion 4: Contribution of Forest Ecosystems to Environmental Services*

## Indicators

1. Number and area of protected areas with established management plans, working plans, and/or applied silviculture.
2. Area and percentage of forests managed for recreation and tourism in relation to the total national land area.
3. Number, area, and percentage of watersheds with a management plan.
4. Area and percentage of forest managed for soil and water conservation.
5. Relation between forest cover by watershed and frequency of flooding.
6. Estimates of biomass estimates forest ecosystems as a function of carbon sequestration and carbon sinks.

### *Criterion 5: Biological Diversity in Forest Ecosystems*

1. Percentage and area of forest types in the various categories of protected areas.
2. Number of endemic, threatened, and/or endangered species.
3. Estimates on wildlife species dependent on forest habitats.
4. Area and length of Biological Corridors per forest ecosystem.
5. Area and percentage of primary and secondary forests and of plantations.
6. Number of species conserved *ex situ* (e.g., in seed banks).

## TARAPOTO PROPOSALS (AMAZON COOPERATION TREATY COUNTRIES)

### *Criterion 10: Conservation of Forest Ecosystems*

## Indicators

- a. Proportion of area of permanent production in areas of environmental protection.
- b. Measures to protect, recuperate, and sustainably use wild populations of species in danger of extinction.
- c. Area and percentage of forest affected by processes or other natural agents (insect attack, disease, fire, etc.) and by human actions.
- d. Rates of regeneration and forest ecosystem structure.
- e. Soil conservation measures.
- f. Measures for protection of water courses from forest activities.

## CIFOR—PRINCIPLE 2. MAINTENANCE OF ECOSYSTEM INTEGRITY

### *Criterion 2.1: Processes that maintain biodiversity in managed forests (FMUs) are conserved*

## Indicators

I.2.1.1 *Landscape* pattern is maintained.

V.2.1.1.1 FMU compiles information on areal extent of each vegetation type in the *intervention area* compared to area of the vegetation type in the total FMU.

V.2.1.1.2 Number of *patches* of each vegetation type at the FMU is maintained within natural variation.

V.2.1.1.3 Largest *patch size* of each vegetation type is maintained within *critical limits*.

V.2.1.1.4 Area-weighted *patch size* is maintained within *critical limits*.

V.2.1.1.5 *Contagion index* of the degree to which vegetation types are aggregated is maintained within *critical limits*.

V.2.1.1.6 *Dominance* of patch structure does not show significant change as compared to unlogged site.

V.2.1.1.7 *Fractal dimension* of patch shape is maintained within *critical limits*.

V.2.1.1.8 Average, minimum, and maximum distances between two patches of the same *cover type* are maintained within natural variation.

V.2.1.1.9 *Percolation index*, specifying landscape “connectedness,” is maintained within *critical limits*.

V.2.1.1.10 Linear measures of the total amount of *edge* of each vegetation type exist.

V.2.1.1.11 Amount of *edge* around the largest *patch* does not show significant change as compared to undisturbed forest.

I.2.1.2 Change in diversity of habitat as a result of human interventions is maintained within critical limits as defined by natural variation and/or regional conservation objectives.

V.2.1.2.1 *Vertical structure* of the forest is maintained within natural variation.

- V.2.1.2.2 *Size class* distribution does not show significant change over natural variation.
  - V.2.1.2.3 *Frequency distributions* of leaf size and shape are maintained within natural variation.
  - V.2.1.2.4 *Frequency distribution* of phases of the *forest regeneration cycle* is maintained within *critical limits*.
  - V.2.1.2.5 *Canopy openness* in the forest *understory* is minimized.
  - V.2.1.2.6 *Other structural elements* do not show significant change.
  - V.2.1.2.7 The distribution of *aboveground biomass* does not show significant change as compared to undisturbed forest.
- I.2.1.3 Community guild structures do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds.
- V.2.1.3.1 Relative abundance of seedling, saplings, and *poles* of canopy tree species belonging to different regeneration guilds does not show significant change as compared to undisturbed forest.
  - V.2.1.3.2 The abundance of *selected avian guilds* is maintained within natural variation.
  - V.2.1.3.3 The abundance of nests of social *bees* is maintained within natural variation.
  - V.2.1.3.4 The abundance of seed in key plant species does not show significant change as compared to undisturbed forest.
  - V.2.1.3.5 Fruiting intensity in known bat-pollinated tree species does not show significant change as compared to undisturbed forest.
  - V.2.1.3.6 The abundance and activity of terrestrial *frugivorous mammals* is maintained within *critical limits*.
  - V.2.1.3.7 The diversity of forest floor *invertebrate* communities does not vary significantly between logged and undisturbed forest.
- I.2.1.4 The richness/diversity of selected groups show no significant change.
- V.2.1.4.1 *Species richness of prominent groups* is maintained or enhanced.
  - V.2.1.4.2 Number of different bird calls do not vary significantly as compared to unlogged site.
  - V.2.1.4.3 Number of large butterfly species is maintained within natural variation.
  - V.2.1.4.4 Numbers of species removed from the forest for sale in local markets.
  - V.2.1.4.5 Lists of selected groups of species, compiled by acknowledged experts, do not show significant change.
  - V.2.1.4.6 Temporal change in species richness is not significant.
  - V.2.1.4.7 Time series of the ratio of composition of mature-forest species to secondary-growth species shows no significant change.
  - V.2.1.4.8 The spatial diversity of selected groups is maintained within natural variation.
- I.2.1.5 Population sizes and demographic structures of selected species do not show significant change, and demographically and ecologically critical life cycle stages continue to be represented.
- V.2.1.5.1 The absolute population size of selected species is maintained within natural variation.
  - V.2.1.5.2 Temporal change in the population size is not significant.
  - V.2.1.5.3 Tree age or structure do not show significant change as compared to undisturbed forest.
  - V.2.1.5.4 Population growth rate does not show significant change as compared to undisturbed forest.
  - V.2.1.5.5 Spatial structure of the population is maintained within natural variation.
- I.2.1.6 The status of decomposition and nutrient cycling shows no significant change.
- V.2.1.6.1 Standing and fallen dead wood does not show significant change as compared to undisturbed forest.
  - V.2.1.6.2 State of *decay* of all dead wood does not show significant change as compared to undisturbed forest.
  - V.2.1.6.3 Abundance of small *woody debris* does not show significant change as compared to undisturbed forest.
  - V.2.1.6.4 Depth of litter/gradient of decomposition does not vary significantly between undisturbed and logged sites.
  - V.2.1.6.5 Abundance of *decomposer organisms* is maintained within natural variation.
  - V.2.1.6.6 *Decomposition* rate on the forest floor does not show significant change.
  - V.2.1.6.7 *Soil conductivity* and *pH* do not show significant change as compared to unlogged site.
  - V.2.1.6.8 *Soil nutrient levels* are maintained within *critical limits*.
- I.2.1.7 There is no significant change in the quality and quantity of water from the catchments.
- V.2.1.7.1 Abundance and diversity of *aquatic organisms* is maintained within critical limits.
  - V.2.1.7.2 *Chemical composition* of stream water does not show significant variation as compared to unlogged forest.
  - V.2.1.7.3 *Decomposition rate* of the stream water does not show significant change as compared to unlogged forest.
  - V.2.1.7.4 *Stream flow* does not show significant change as compared to the flow in the unlogged site.

*Criterion 2.2: Ecosystem function is maintained*

**Indicators**

- I.2.2.1 No chemical contamination to food chains and ecosystem.
- I.2.2.2 Ecologically sensitive areas, especially buffer zones along watercourses, are protected.
- I.2.2.3 Representative areas, especially sites of ecological importance, are protected and appropriately managed.
- I.2.2.4 Rare or endangered species are protected.
- I.2.2.5 Erosion and other forms of soil degradation are minimized.

---

**LITERATURE CITED**

**Achard, F., H. Eva, H. J. Stibig, P. Mayaux, J. Gallego, T. Richards, and J. P. Malingreau.** 2002. Determination of deforestation rates of the world's humid tropical forests. *Science* **297**:999–1002.

**Adams, D.** 1980. *The restaurant at the end of the universe. Part 2 of the hitchhiker's guide to the galaxy.* Pan Books, London, UK.

**Andersen, A. N.** 1997. Using ants as bioindicators: multiscale issues in ant community ecology. *Conservation Ecology* **1**(1):8. [Online, URL: <http://www.consecol.org/voll/iss1/art8>]

**Ashton, P.** 1996. *Stand level concepts and indicators for certification of forest management.* Paper for the UBC-UPM Conference on Certification: Economic, Social and Political Issues in Certification of Forest Management, 12–16 May 1996, Kuala Lumpur (Putrajaya, Kajang), Malaysia. [Online, URL: <http://www.forestry.ubc.ca/concert/ashton.html>]

**Bass, S.** 2001. Policy inflation, capacity constraints: can criteria and indicators bridge the gap? Pages 19–73 in R. J. Raison and A. Brown, editors. *Criteria and indicators for sustainable forest management.* IUFRO (International Union of Forest Research Organizations) Series Number 7. CAB International Publishing, Oxford, UK.

**Bawa, K. S., and R. Seidler.** 1998. Natural forest management and conservation of biodiversity in the tropics. *Conservation Biology* **12**(1):46–55.

**Beccaloni, G. W., and K. J. Gaston.** 1995. Predicting the species richness of neotropical forest butterflies—Ithomiinae (Lepidoptera, Nymphalidae) as indicators. *Biological Conservation* **71**:77–86.

**Bennett, E. L., and J. G. Robinson.** 2000. *Hunting of wildlife in tropical forests: implications for biodiversity and forest peoples.* WCS (Wildlife Conservation Society) and

World Bank Environment Department, Biodiversity Series, Impact Studies, Paper Number 76. World Bank, Washington, D.C., USA.

**Binggelli, P.** 1989. The ecology of *Maesopsis* invasion and dynamics of the evergreen forest of the East Usambaras and their implications for forest conservation and forestry practices. Pages 269–300 in A. Hamilton and R. Bensted-Smith, editors. *Forest conservation in the East Usambara Mountains, Tanzania.* World Conservation Union. Gland, Switzerland.

**Bowles, I. A., G. A. B. da Fonseca, R. A. Mittermeier, and R. E. Rice.** 1998. Logging and tropical forest conservation. *Science* **280**:1899–1900.

**Buechner, H. K., and H. C. Dawkins.** 1961. Vegetation change induced by elephants and fire in Murchison Falls National Park, Uganda. *Ecology* **42**:752–766.

**Burgess, P., with Elias, P. M. Laksono, R. J. Watling, and W. M. Wan Razali.** 1995. *Final report: Test Indonesia, March 5–April 2, 1995. CIFOR project on testing criteria and indicators for sustainable management of forests.* CIFOR Report. CIFOR (Center for International Forestry Research), Bogor, Indonesia.

**Caballe, G.** 1999. *Initiative pour les critères et indicateurs de l'OAB.* Rapport du Test en Centrafrique, Organisation Africaine du Bois, Libreville, Gabon.

**Cairns, J.** 1986. The myth of the most sensitive species. *BioScience* **36**(10):670–672.

**Canadian Wood Council.** 2003. [Online, URL: [http://www.cwc.ca/environmental/sustainable\\_buildings/certification/standards.html](http://www.cwc.ca/environmental/sustainable_buildings/certification/standards.html)]

**Cannon, C. H., D. R. Peart, and M. Leighton.** 1998. Tree species diversity in commercially logged Bornean rainforest. *Science* **281**:1366–1368.

**Castañeda, F.** 1998. *Linkages between national and forest*



- management unit levels criteria and indicators for sustainable forest management. CIFOR/FAO Fifth International Project Advisory Panel (IPAP) Meeting for CIFOR's (Center for International Forestry Research) Testing of Criteria and Indicators for the Sustainable Management of Forests, 25–27 March 1998. FAO, Rome, Italy.
- Chandrakanth, M. G., and J. Romm.** 1991. Sacred forests, secular forest policies and people's actions. *Natural Resources Journal* 31(4):741–756.
- Cochrane, M. A., A. Alencar, M. D. Schulze, C. M. Souza, D. C. Nepstad, P. Lefebvre, and E. A. Davidson.** 1999. Positive feedbacks in the fire dynamic of closed canopy tropical forests. *Science* 284:1834–1836.
- Colfer, C. J., N. Peluso, and C. S. Chung.** 1997. *Beyond slash and burn*. New York Botanical Garden, New York, New York, USA.
- Crome, F. H. J.** 1997. Researching tropical forest fragmentation: shall we keep on doing what we're doing? Pages 485–587 In W. F. Laurance and R. O. Bierregaard, editors. *Tropical forest remnants: ecology, management, and conservation of fragmented communities*. University of Chicago Press, Chicago, Illinois, USA.
- Crome, F. H. J., M. R. Thomas, and L. A. Moore.** 1996. A novel Bayesian approach to assessing impacts of rain forest logging. *Ecological Applications* 6(4):1104–1123.
- Cronk, Q. C. B., and J. L. Fuller.** 1994. *Invasive plants: the threat to natural ecosystems worldwide*. A World Wildlife Fund Handbook. Chapman and Hall, London, UK.
- Curran, L. M., I. Caniago, G. D. Paoli, D. Astianti, M. Kusneti, M. Leighton, C. E. Nirarita, and H. Haeruman.** 1999. Impact of El Niño and logging on canopy tree recruitment in Borneo. *Science* 286:2184–2188.
- Daily, G. C., and P. R. Ehrlich.** 1996. Nocturnality and species survival. *Proceedings of the National Academy of Sciences (USA)* 93(21):11709–11712.
- Dawkins, H. C., and M. S. Philip.** 1998. *Tropical moist forest silviculture and management: a history of success and failure*. CAB International, Oxon, UK.
- Delvingt, W.** 1997. *La Chasse Villageoise*. Rapport du Programme ECOFAC. Groupement AGRECO G.E.I.E – BDPA – SCETAGRI – SECA – CIRAD-Forêt (Centre de Coopération Internationale pour la Recherche en Développement), Bruxelles, Belgique.
- Dykstra, D.** 1999. *Technical consultation on management of the forest estate: issues and opportunities for international action by the World Bank and FAO— Meeting Report*. CIFOR (Center for International Forestry Research), Indonesia, and World Forestry Center, Portland, Oregon, USA.
- Dykstra, D. P., and R. Heinrich.** 1996. *FAO: model code of forest harvesting practice*. Food and Agriculture Organization of the United Nations, Rome, Italy (ISBN 92-5-103690-X). [Online, URL: <http://www.fao.org/forestry/include/frames/english.asp?section=http://www.fao.org/docrep/v6530e/v6530e00.htm>]
- Eba'a, A. R., and M. Simula.** 2002. *Forest certification: pending challenges for tropical timber*. ITTO Technical Series Number 19. ITTO (International Tropical Timber Organization), Yokohama, Japan.
- Edmunds, D., and E. Wollenberg.** 2001. A strategic approach to multi-stakeholder negotiations. *Development and Change* 32(2):231–253.
- Elliot, C.** 2000. *Forestry certification: a policy perspective*. CIFOR (Center for International Forestry Research), Bogor, Indonesia.
- FAO (Food and Agriculture Organization of the United Nations).** 2001. Criteria and indicators for sustainable forest management: a compendium paper compiled by F. Castañeda, C. Palmberg-Lerche, and P. Vuorinen, May 2001. *Forest Management Working Papers, Working Paper 5*. FAO, Rome [Online, URL: <http://www.fao.org/DOCREP/004/AC135E/AC135E00.HTM>]
- Freycon, V., N. Fauvet, C. Bernard, and J. P. Laclau.** 1996. Les SIG appliqués à la forêt. *Bois et Forêts des Tropiques* 250:63–70
- Gadgil, M., F. Berkes, and C. Folke.** 1993. Indigenous knowledge for biodiversity conservation. *Ambio* 22(2):151–156.
- Gale, R. P., and S. M. Corday.** 1994. Making sense of sustainability: nine answers to what should be sustained? *Rural Sociology* 59:314–332.
- Gascon, C., G. B. Williamson, and G. A. B. da Fonseca.** 2000. Receding forest edges and vanishing reserves. *Science* 288:1356–1358.
- Ghazoul, J., and A. Hellier.** 2000. Setting critical limits to ecological indicators of sustainable tropical forestry. *International Forestry Review* 2(4):243–253.
- Ghazoul, J., and M. McAllister.** 2003. Communicating

complexity and uncertainty in decision making contexts: Bayesian approaches to forest research. *International Forestry Review* 5(1):9–19.

**Gibson, C. C., M. A. McKean, and E. Ostrom.** 2000. *People and forests: communities, institutions, and governance*. MIT Press, Cambridge, Massachusetts, USA.

**Global Forest Watch.** 2002. *Forest Transparency Workshop Promoting Transparency in the Forest Sector: Best Practices for Detecting Illegal and Destructive Commercial Logging*. May 29–31, 2002, Washington, D.C., USA. [Online, URL: <http://www.globalforestwatch.org/english/index.htm>]

**Government of Bangladesh.** 1999. *Integrated coastal zone management: concepts and issues. Policy note*. [Online, URL: [http://www.iczmpbangladesh.org/pdf/policy\\_note\\_of\\_the\\_govt.pdf](http://www.iczmpbangladesh.org/pdf/policy_note_of_the_govt.pdf)]

**Gullison, R. E.** 2003. Does forest certification conserve biodiversity? *Oryx* 37:153–165.

**Harwood, J., and K. Stokes.** 2003. Coping with uncertainty in ecological advice: lessons from fisheries. *Trends in Ecology and Evolution* 18(12):617–622.

**Hurlbert, S. H.** 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54:187–211.

**Ickes, K., S. J. DeWalt, and S. Appanah.** 2001. Effects of native pigs (*Sus scrofa*) on woody understorey vegetation in a Malaysian lowland rain forest. *Journal of Tropical Ecology* 17:191–206.

**ITTO (International Tropical Timber Organization).** 1998. *Criteria and indicators for sustainable management of natural tropical forests*. ITTO Policy Development Series Number 7, Yokohama, Japan.

**Jackson, S. M., T. S. Fredericksen, and J. R. Malcolm.** 2002. Area disturbed and residual stand damage following logging in a Bolivian tropical forest. *Forest Ecology and Management* 166:271–283.

**Jeanmart, P.** 1998. *Tentative d'élaboration d'un plan de gestion de la chasse villageoise dans la réserve du Dja*. Programme ECOFAC– Composante Cameroun. Groupement AGRECO G.E.I.E – BDPA–SCETAGRI–SECA –CIRAD–Forêt (Centre de Coopération Internationale pour la Recherche en Développement), Bruxelles, Belgique.

**Johannes, R. E.** 1998. The case for data-less marine resource management: examples from tropical nearshore

fisheries. *Trends in Ecology and Evolution* 13:243–246.

**Johnson, S.** 2001. *ITTO's criteria and indicators: a tool for monitoring, assessing and reporting on SFM*. International Expert Meeting on Monitoring, Assessment and Reporting on the Progress Toward Sustainable Forest Management, 5 November 2001. Yokohama, Japan.

**Karsenty, A.** 2000. Les freins à l'adoption des meilleures pratiques d'exploitation en Afrique. *Bois et Forêts des Tropiques* 267:98–100.

**Kneeshaw, D. D., A. Leduc, P. Drapeau, S. Gauthier, D. Paré, R. Carignan, R. Doucet, L. Bouthillier, and C. Messier.** 2000. Development of integrated ecological standards of sustainable forest management at an operational scale. *Forestry Chronicle* 76(3):481–493.

**Kremen, C.** 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. *Ecological Applications* 2:203–217.

**Kremen, C.** 1994. Biological inventory using target taxa: a case study of the butterflies of Madagascar. *Ecological Applications* 4:407–422.

**Landers, P. B.** 1992. Ecological indicators: panacea or liability? Pages 1295–1318 in D. H. McKenzie, D. E. Hyatt, and V. J. McDonald, editors. *Ecological indicators*. Volume 2. Elsevier Science, London, UK.

**Landers, P. B., J. Verner, and J. W. Thomas.** 1988. Ecological uses of vertebrate indicator species: a critique. *Conservation Biology* 2(4):316–328.

**Laurance, W. F., S. G. Laurance, L. V. Ferreira, J. M. Rankin-de Merona, C. Gascon, and T. E. Lovejoy.** 1997. Biomass collapse in Amazonian forest fragments. *Science* 278:1117–1118.

**Lawton, J. H., D. E. Bignell, B. Bolton, G. F. Bloemers, P. Eggleton, P. M. Hammond, M. Hodda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stork, D. S. Srivastava, and A. D. Watt.** 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* 391:72–76.

**Louvet, S.** 2002. *Criteria and indicators for community forest management. Building-up criteria and indicators for sustainable forest management at community level: a case in Ghana*. Thesis. ENGREF-CIFOR (Ecole Nationale du Génie Rural et des Eaux et Forêts–Center for International Forestry Research), Montpellier, France.

**Ludwig, D., R. Hilborn, and C. Walters.** 1993. Uncertainty, resource exploitation, and conservation:

lessons from history. *Science* **262**:17 and 36.

**Lugo, A. E.** 1999. Will concern for biodiversity spell doom to tropical forest management? *Science of the Total Environment* **240**:123–131.

**MacKinnon, J.** 2002. *Avenues of futility in conservation*. Unpublished paper. Society for Conservation Biology 16th Annual Meeting, 14–19 July 2002, University of Kent, UK. Summarized in *The Babbler* **1**(4):7. [Online, URL: <http://home.pacbell.net/mjvande/scb5.htm>]

**Malcolm, J. R.** 2001. Unifying the study of fragmentation: external vs. internal forest fragmentation. Pages 136–138 in R. Fimbel, A. Grajal, and J. Robinson, editors. *The cutting edge: conserving wildlife in logged tropical forests*. Columbia University Press, New York, New York, USA.

**Malcolm, J. R., and J. C. Ray.** 2000. Influence of timber extraction routes on central African small mammal communities, forest structure, and tree diversity. *Conservation Biology* **14**:1623–1638.

**Man, W. H. E. de, and W. H. den Toorn.** 2002. Culture and the adoption and use of GIS within organizations. *International Journal of Applied Earth Observation and Geoinformation* **4**:51–63.

**May, R. M.** 2001. Science and society. *Science* **292**:1021.

**Mäntyranta, H.** 2002. *Forest certification: an ideal that become an absolute*. Kustannusosakeyhtiö Matsälehti, Helsinki, Finland.

**McCool, S., and G. Stankey.** 2001. Representing the future: a framework for evaluating the utility of indicators in the search for sustainable forest management. Pages 93–105 in R. J. Raison and A. Brown, editors. *Criteria and indicators for sustainable forest management*. IUFRO (International Union of Forest Research Organizations) Series Number 7. CAB International Publishing, Oxford, UK.

**McGinley, K., and B. Finegan.** 2002. *Evaluations for sustainable forest management*. Turrialba, Costa Rica, CATIE (Tropical Agricultural Centre for Research and Higher Education) and CIFOR (Center for International Forestry Research).

**McKean, M. A.** 2000. Common property: what is it, what is it good for, and what makes it work? Pages 27–55 in C. C. Gibson, M. A. McKean, and E. Ostrom, editors. *People and forests: communities, institutions, and governance*. MIT Press, Cambridge, Massachusetts, USA.

**Mengin-Lecreulx, P., A. Anvo, C. Huttel, H. van**

**Haafte, and N. K. Anatole.** 1995. *Final Report: Test Côte d'Ivoire June 2–30, 1995*. CIFOR project on testing criteria and indicators for sustainable management of forests. [English translation by Guy Ferlin.] CIFOR (Center for International Forestry Research), Bogor, Indonesia.

**Miranda, E. E. de, and L. John.** 2000. Ten years monitoring and mapping fires in Brazil: current products and information networks. *International Forest Fire News* **22**:15–18. [Online, URL: [http://www.fire.uni-freiburg.de/iffn/country/br/br\\_6.htm](http://www.fire.uni-freiburg.de/iffn/country/br/br_6.htm)]

**Molner, A.** 2003. *Forest certification and communities: looking forward to the next decade*. Forest Trends, Washington, D.C., USA. [Online, URL: <http://www.forest-trends.org>]

**Nasi, R., and E. Forni.** 2003. La gestion durable des forêts. *Le Flamboyant* **56**:39–40.

**Nasi, R., R. Ondo, N. Gami, S. Dondyas, and P. Hecketsweiler.** 1999. Initiative pour les critères et indicateurs de l'OAB. *Rapport du Test du Gabon*. Organisation Africaine du Bois, Libreville, Gabon.

**Nason, J. D., and J. L. Hamrick.** 1997. Reproductive and genetic consequences of forest fragmentation: two case studies of neotropical canopy trees. *Journal of Heredity* **88**:264–276.

**Nepstad, D. C., A. Veríssimo, A. Alencar, C. Nobre, E. Lima, P. Lefebvre, P. Schlesinger, C. Potter, P. Moutinho, E. Menzoza, M. Cochrane, and V. Brooks.** 1999. Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* **398**:505–508.

**Nester, M. R.** 1996. An applied statistician's creed. *Applied Statistics* **45**:401–410.

**Newmark, W. D.** 1991. Tropical forest fragmentation and the local extinction of understorey birds in the Eastern Usambara Mountains, Tanzania. *Conservation Biology* **5**:67–78.

**Pain-Orcet, M., D. Lo Seen, N. Fauvet, J. F. Trébuchon, and B. Dipapoundji.** 1998. *Les cartes, la télédétection et les SIG, des outils pour la gestion et l'aménagement des forêts tropicales d'Afrique Centrale*. Document FORAFRI (Capitalisation et transfert des résultats des recherches menées dans les forêts denses humides d'Afrique) Number 12, CIRAD-Forêt (Centre de Coopération Internationale pour la Recherche en Développement)/CIFOR (Center for International Forestry Research), Montpellier, France.

**Pearce, D., J. Putz, and J. K. Vanclay.** 1999. A

*sustainable forest future?* Natural Resources International, DFID (Department for International Development), London, UK.

**Posey, D. A.** 1992. Traditional knowledge, conservation, and 'the rain forest harvest'. Pages 46–50 in M. Plotkin and L. Famolare, editors. *Sustainable harvest and marketing of rain forest products*. Island Press, Washington, D.C., USA.

**Posey, D. A.** 1997. Indigenous knowledge, biodiversity, and international rights: learning about forests from the Kayapo Indians of the Brazilian Amazon. *Commonwealth Forestry Review* 76(1):53–60.

**Prabhu, R., C. J. P. Colfer, and R. G. Dudley.** 1999. *Guidelines for developing, testing, and selecting criteria and indicators for sustainable forest management*. The Criteria and Indicators Toolbox Series No. 1, Center for International Forestry Research, Bogor, Indonesia.

**Prabhu, R., W. M. Maynard, R. Eba'a Atyi, C. J. P. Colfer, G. Shepherd, P. Venkateswarlu, and F. Tiayon.** 1998. *Testing criteria and indicators for sustainable forest management in Cameroon: the Kribi Test*. Final Report. CIFOR (Center for International Forestry Research), Bogor, Indonesia. [Online, URL: [http://www.cifor.cgiar.org/publications/pdf\\_files/books/spubs/sp-kribi.pdf](http://www.cifor.cgiar.org/publications/pdf_files/books/spubs/sp-kribi.pdf)]

**Prabhu, R., J. H. Ruitenbeek, T. J. B. Boyle, and C. J. P. Colfer.** 2001. Between voodoo science and adaptive management: the role and research needs for indicators of sustainable forest management. Pages 39–66 in R. J. Raison, A. G. Brown, and D. W. Finn, editors. *Criteria and indicators for sustainable forest management*. CAB International-IUFRO (International Union of Forest Research Organizations).

**Putz, F., D. Dykstra, and R. Heinrich.** 2000a. Why do poor logging practices persist in the tropics? *Conservation Biology* 14(4):951–958.

**Putz, F. E., K. H. Redford, R. Fimbel, J. G. Robinson, and G. M. Blate.** 2000b. Biodiversity conservation in the context of tropical forest management. WCS (Wildlife Conservation Society) and World Bank Environment Department, Biodiversity Series, Impact Studies, Paper Number 75. World Bank, Washington, D.C., USA.

**Rametsteiner, E., and M. Simula.** 2003. Forest certification—an instrument to promote sustainable forest management? *Journal of Environmental Management* 67:87–9.

**Rasmussen, J. N., A. Kaosa-ard, T. Boon, M. Diaw, K.**

**Edwards, S. Kadyschuk, M. Kaosa-ard, T. Lang, P. Preechapanya, K. Rerkasem, and R. Flemming.** 2000. *For whom and what? Principles, criteria and indicators for sustainable forest resources management in Thailand*. Danish Center for Forest, Landscape and Planning. Planning Report Number 6, Horsholm, Denmark. [Online, URL: <http://www.fsl.dk/pub/Thailand>]

**Redford, K. H., and B. D. Richter.** 1999. Conservation of biodiversity in a world of use. *Conservation Biology* 13:1246–1256.

**Rice, R. E., R. E. Gullison, and J. W. Reid.** 1997. Can sustainable management save tropical forests? *Scientific American* 276:34–39.

**Rice, R., C. Sugal, and I. Bowles.** 1998. *Sustainable forest management: a review of the current conventional wisdom*. Conservation International, Washington, D.C., USA.

**Robinson, J. G., K. H. Redford, and E. L. Bennett.** 1999. Wildlife harvest in logged tropical forests. *Science* 284:595–596.

**Salafsky, N., M. Cordes, M. Leightone, W. Henderson, R. Watt, and R. Cherry.** 1998. *Chainsaws as a tool for conservation? A comparison of community-based timber production enterprises in Papua New Guinea and Indonesia*. Rural Development Forestry Network, Network Paper Number 22b. Overseas Development Institute, London, UK. [Online, URL: <http://www.odi.org.uk/fpeg/publications/rdfn/22/b.html>]

**Sayer, J. A.** 1995. *Science and international nature conservation*. Occasional Paper Number 4. CIFOR (Center for International Forestry Research), Bogor, Indonesia.

**Scott, J. C.** 1985. *Weapons of the weak: everyday forms of peasant resistance*. Yale University Press, New Haven, Connecticut, USA.

**Scott, J. C.** 1998. *Seeing like a state*. Yale University Press, New Haven, Connecticut, USA.

**Sheil, D.** 1994. Naturalized and invasive plant species in the evergreen forests of the East Usambara Mountains, Tanzania. *African Journal of Ecology* 32:66–71.

**Sheil, D.** 2001. Conservation and biodiversity monitoring in the tropics—realities, priorities and distractions. *Conservation Biology* 15:1179–1182.

**Sheil, D.** 2002. *Why doesn't biodiversity monitoring support conservation priorities in the tropics?* Unasylva. U.N. Food and Agriculture Organization, Rome, Italy. [Online, URL: <http://www.fao.org/DOCREP/004/Y3582E/y3582e11.htm>]

- Sheil, D., N. Liswanti, M. van Heist, I. Basuki, Syaefuddin, I. Samsodin, Rukmiyati, and M. Agung.** 2003. Local priorities and biodiversity in tropical forest landscapes: asking people what matters. *ITTO Tropical Forest Update* 13:1 [Online, URL: <http://www.itto.or.jp/live/PageDisplayHandler?pageld=245.html>]
- Sheil, D., J. A. Sayer, and T. O'Brien.** 1999. Tree diversity and conservation in logged rainforest. *Science* 284:1587.
- Sheil, D., and M. van Heist.** 2000. Ecology for tropical forest management. *International Forestry Review* 2:261–270.
- Stage, A. R.** 2003. How forest models are connected to reality: evaluation criteria for their use in decision support. *Canadian Journal of Forest Research* 33:410–421.
- Stork, N. E., T. J. B. Boyle, V. Dale, H. Eeley, B. Finegan, M. Lawes, N. Manokaran, R. Prabhu, and J. Soberon.** 1997. *Criteria and Indicators for assessing the sustainability of forest management: conservation of biodiversity*. CIFOR Working Paper Number 17, CIFOR (Center for International Forestry Research), Bogor, Indonesia. [Online, URL: <http://www.cifor.cgiar.org/docs/ref/publications/workingpapers.htm>]
- Stortenbeker, C. W., E. M. Blom, and L. van Bueren.** 2000. *Principles, criteria and examples of indicators for sustainable forest management classified according to the 'Tropenbos' hierarchical framework*. Tropenbos Foundation, Wageningen, The Netherlands.
- Struhsaker, T. T.** 1997. *Ecology of an African rain forest: logging in Kibale and the conflict between conservation and exploitation*. University Press of Florida, Gainesville, Florida, USA.
- Thorner, K., D. Plouvier, and S. Bass.** 1999. *Certification: barriers to benefits: a discussion of equity implications*. Discussion Paper 8, European Forest Institute, Joensuu, Finland.
- Wadsworth, F. H.** 1999. *La sostenibilidad y las prácticas silviculturales*. Paper presented at the IUFRO/CATIE/CIFOR/FAO International Conference and Workshop, Indicators for Sustainable Forest Management in the Neotropics. Fomenting multisectorial action in the development and implementation of scientifically-based indicators. Tropical Agricultural Centre for Research and Higher Education (CATIE), Turrialba, Costa Rica, 9–12 November 1999.
- Watt, A. D.** 1998. Measuring disturbance in tropical forests: a critique of the use of species–abundance models and indicator measures in general. *Journal of Applied Ecology* 35(3):467–469.
- Wibowo, D.** 2002. The challenge of growing certification. ITTO (International Tropical Timber Organization) *Tropical Forest Update* 12:9–10. [Online, URL: <http://www.itto.or.jp/live/PageDisplayHandler?pageld=245.html>]
- Wijewardana, D., S. J. Caswell, and C. Palmberg-Lerche.** 1997. Criteria and indicators for sustainable forest management. *Proceedings of the XI World Forestry Congress* 6:3–17. Antalya, Turkey.
- Williams, T.** 2001. *Certification cost analysis*. Profor Newsletter, March 2001. [Online, URL: <http://www.profor.info/pdf/March2.pdf>].
- Write, P. A., A. Gregory, T. Hoekstra, B. Tegler, and M. Turner.** 2002. *Monitoring for forest management unit scale sustainability*. Final Report of the Local Unit Criteria and Indicators Development (LUCID) Test: Executive Summary. USDA Forest Service IMI (Inventory and Monitoring Institute) Report 4, Fort Collins, Colorado, USA.
- Zweede, J., J. Kressin, R. Mesquita, J. N. M. Silva, V. M. Viana, and C. Colfer.** 1995. *Testing criteria and indicators for sustainable forest management*. Final Report: Test Brazil October 22–November 21, 1995. Unpublished text. CIFOR (Center for International Forestry Research), Bogor, Indonesia.