Evaluations for sustainable forest management

Towards an adaptive standard for the evaluation of the ecological sustainability of forest management in Costa Rica

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Towards an adaptive standard for the evaluation of the ecological sustainability of forest management in Costa Rica

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Summary

The evaluation of the sustainability of forest management is an integral measure in the maintenance of production, and the ecological and socioeconomic functions of forest systems and should consider both the fulfillment of sound forest practices as well as the impacts and results of forest management, providing key information for the identification of aspects of negative impact that can be improved or modified within a system of adaptive management. This evaluation can be achieved through the use of practical and scientifically based sets of principles, criteria, indicators and, in specific cases, verifiers (PCI&V). Once developed, these sets of PCI&V should be tested and validated, and accompanied by the tools necessary for their implementation (e.g. documentation on their justification, their conceptual bases and guides for their application).

The research presented here was carried out with the general objectives of contributing to the definition of sustainable forest management in the region of Central America, determining guidelines for the ecological sustainability of forest management that include elements necessary for adaptive management and developing PCI&V for its reliable and efficient evaluation in Costa Rica. The process began with an initial set of PCI&V comprised of elements from the national standard for forest management in Costa Rica and the CIFOR generic template of C&I for adaptive management, and encompassed three phases of evaluation and analysis. The first phase consisted of office evaluations on the relative importance and priority of the initial set of PCI&V by a group of experts in forest management and ecology. The results of these evaluations served to indicate stronger and weaker PCI&V, but were not used to eliminate any element before field application and evaluation. The second phase, which served as a filter through which each element was either recommended, modified or rejected for the final set of PCI&V, included field testing and evaluation of the initial set of PCI&V by the expert group. The third and final phase consisted of a workshop with a larger group of experts in forest management, ecology and policy in which the results were presented and approved. The distribution of institutional responsibility associated with the implementation of the recommended elements was also discussed and evaluated.

Through this research, the strengths and weaknesses of the initial PCI&V were identified individually, as were the general strengths and weaknesses in the evaluated aspects of the original Costa Rican and CIFOR sets. Of the I&V from the initially proposed set of PCI&V, 55% were recommended for the final set, of these 86% were modified from their original wording before recommendation and 91% were judged to require supplementary documentation for implementation. Forty-five percent of the initial I&V were rejected for the following reasons: redundancy (17%), conceptual weakness (17%), poor precision (17%), need for further scientific development (17%) and recommendation for incorporation into a proposed code of forest practices (33%).

An adaptive set of PCI&V was developed on the basis of the work of the expert group and the evaluation results. This set consists of 3 principles, 5 criteria, 17 indicators and 10 verifiers. Of the final C&I, 2 criteria pertain to forest management inputs and 3 to forest management processes, and of the indicators, 2 are related to the evaluation of forest management inputs, 12 to the processes and 3 to the results of forest management. General recommendations regarding the current state of PCI&V development in Costa Rica included development of a manual for the implementation of the national PC&I, as well as a manual or a national code of practices for the implementation of sustainable forest management practices. Throughout the process of testing and validation there was a clear indication of the need for a realistic distribution of institutional responsibilities for PCI&V implementation which should include important actors such as forest operators, forest managers, regents, evaluators, research institutions and the Costa Rican State Forestry Administration.

Resumen

La evaluación de la sostenibilidad del manejo forestal es una medida integral del mantenimiento de la productividad y de las funciones ecológicas y socioeconómicas de los sistemas forestales; debe considerar el cumplimiento de la buena práctica forestal y los impactos y resultados del manejo, para facilitar información clave para la identificación de los aspectos de impacto negativo que se puedan mejorar o modificar dentro de un sistema de manejo adaptativo. Esta evaluación puede lograrse con el uso de un conjunto práctico y científicamente fundamentado de principios, criterios, indicadores y verificadores, en casos específicos (PCI&V). Dichos conjuntos de PCI&V deben ser probados y validados, y venir acompañados de las herramientas necesarias para la implementación (p. ej. documentación justificatoria, bases conceptuales y lineamientos de aplicación).

Esta investigación tuvo como objetivos contribuir a la definición del concepto del buen manejo forestal en la región, plantear estándares para la sostenibilidad ecológica que incluya elementos necesarios para un manejo adaptativo y aportar herramientas prácticas, científicamente bien fundamentadas y realistas para la evaluación de la sostenibilidad del manejo forestal en Costa Rica. El proceso inició con un conjunto de PCI&V compuesto por elementos provenientes de los estándares nacionales para el manejo forestal en Costa Rica y del conjunto genérico de C&I para el manejo adaptativo del CIFOR. Tuvo tres fases de evaluación y análisis. La primera consistió en una evaluación de oficina para determinar la importancia relativa y prioridad de los elementos del conjunto inicial de PCI&V. Esta fase fue desarrollada por un grupo de expertos en manejo y ecología forestal. Los resultados de esta evaluación se usaron para indicar los PCI&V más adecuados para la evaluación de la sostenibilidad ecológica, pero no para eliminar ningún PCI&V antes de la aplicación y evaluación de campo. La segunda fase se inició con la selección de un sitio para pruebas de campo y un ensayo preliminar de aplicación del conjunto inicial de PCI&V; luego, se realizó la prueba formal por parte del grupo de expertos, la cual sirvió como filtro para determinar el destino de cada elemento: recomendado, modificado o rechazado para integrar el conjunto final de PCI&V. La fase final fue un taller con un grupo mayor de expertos en manejo, ecología y política forestal, donde se presentaron y aprobaron los resultados. La determinación de responsabilidad institucional para la implementación de los elementos recomendados también se discutió y evaluó.

La investigación permitió identificar las debilidades y fortalezas del conjunto inicial de PCI&V, así como las fortalezas, debilidades y vacíos de información en los aspectos evaluados de los conjuntos de Costa Rica y del CIFOR. Del conjunto inicialmente propuesto, 55% fueron recomendados para integrar el conjunto final; de esos, 86% sufrieron modificaciones de redacción antes de ser recomendados y 91% requerían documentación complementaria para la implementación y evaluación. En cuanto a los elementos rechazados, el 45% se debió a las siguientes razones: redundancia (17%), de-

bilidad conceptual (17%), imprecisión (17%), necesidad de profundidad científica (17%) y recomendación para integrar el código de prácticas propuesto (33%).

A partir del trabajo de los expertos y de los resultados de las evaluaciones, se desarrolló un conjunto adaptativo de PCI&V para la evaluación de la sostenibilidad ecológica de bosques manejados en Costa Rica. Este conjunto está formado por tres principios, cinco criterios, 17 indicadores y diez verificadores. De los C&I finales, dos criterios pertenecen a los *insumos* del manejo forestal y tres a los *procesos*, y de los indicadores, dos están relacionados a la evaluación de los *insumos*, 12 a los *procesos* y tres a los *resultados* del manejo forestal. Entre las recomendaciones generales para el desarrollo de los PCI&V en Costa Rica están la necesidad de contar con un manual de implementación y un Código de Prácticas para la aplicación del manejo forestal sostenible. Durante todo el proceso fue evidente la necesidad de lograr una distribución realista de responsabilidades institucionales para la implementación de los PC&I. En Costa Rica, la distribución y designación de la responsabilidad debe incluir a actores claves como los administradores y operarios del bosque, regentes, evaluadores, instituciones de investigación y la Administración Forestal del Estado.

Introduction

Background

Framework for forest management standards[1]

Over the last decade, global awareness of the multiple benefits provided by forest ecosystems has increased while global forest coverage has continued to decrease. Subsequent demands for sustainable forest use have resulted in various initiatives to define guidelines for sustainable forest management at international, regional, national and forest management unit (FMU) levels (Higman *et al.* 1999). Some of these initiatives have led to the development of forest management standards, considered important tools for promoting sustainable forest management and for monitoring and evaluating forest management practices (Lammerts van Bueren and Blom 1997). Such standards, developed for varied purposes and at different scales, are generally based on a combination of principles, criteria, indicators and in certain cases, verifiers (PCI&V) that aim to define the elements and parameters of sustainable forest management (refer to Lammerts van Bueren and Blom 1997 for definitions).

Within the framework of forest management standards, criteria define the desired state or aspect of a forest system component in relation to principles. Indicators provide the parameters by which the actual state or aspect of the system can be assessed. Criteria and indicators (C&I) are developed in accordance with specific attributes of the forest ecosystem or associated social systems. These attributes can be used for classifying C&I. One system of classification groups C&I according to attributes associated with the inputs, processes and outcomes of forest management (see Lammerts van Bueren and Blom 1997, Prabhu *et al.* 1999). C&I associated with inputs take into account the objects introduced into the eco- or social system by human driven processes (e.g. the management plan). C&I associated with processes take into account intentions (e.g. silvicultural treatments planned in the management plan) or actions (e.g. harvesting) introduced into the related systems (Lammerts van Bueren and Blom 1997).

C&I based on the widely-accepted Forest Stewardship Council (FSC) principles and criteria (P&C) primarily take into account the inputs and processes of forest management. Such C&I sets principally define good management practices and seek to reduce negative impacts of management operations on the ecosystem and associated social systems (FSC 1999). C&I that evaluate inputs and processes are often easy to apply, measure and evaluate, but they do not provide a direct measure of forest man-

[1] Following Lammerts van Bueren and Blom (1997) we define "standard" as a set of PCI&V or at least some combinations of these hierarchical levels, that serves as a tool to promote sustainable forest management, as a basis for monitoring and reporting or as a reference for assessment of actual forest management.

agement impacts or outcomes on the affected system components (Lammerts van Bueren and Blom 1997, Prabhu *et al.* 1999).

On the other hand, C&I associated with the outcomes of forest management define the desired or actual results of the management process and provide measures for the impacts of forest management on the eco- and social systems. These C&I can be used to determine the state (e.g. habitat diversity) or capacity of the system component (e.g. change in nutrient cycling) in respect to management impacts. C&I that evaluate management outcomes should provide unambiguous information for monitoring, and identify aspects of the management system in which changes or improvements can be made within the context of adaptive management (Lammerts van Bueren and Blom 1997, Prabhu *et al.* 1999).

Prabhu *et al.*(1999) suggest another way for classifying C&I in association with the pressures that affect the states of forest systems and the responses that these systems demonstrate. Pressures are the external factors, forces or stimuli applied to the eco- or social system that can cause changes in the status of system components (e.g. silvicultural treatments). State is the desired condition or quality of a particular system component (e.g. status of decomposition and nutrient cycling), regardless of the pressures that act upon it. Response is the human- or ecosystem - related reaction to pressures or changes in the state of the system (e.g. diversity of selected groups show no significant change).

Making forest management adaptive

Many of the forest management standards in development and practice today consist primarily of input and process C&I[2] which define good management practices and often establish predefined standards or "best practice" for reducing management impacts[3]. These C&I can be used as effective tools for meeting the challenges of controlling the often destructive and wasteful nature of traditional forest harvesting activities that persist in many parts of the tropics today. Input and process C&I are, obviously, indispensable elements in the evaluation of sustainable forest management. However, the argument that forest management can not be sustainable if it is not adaptive is persuasive (Howard and Majid 1996, Raison and Flinn 2000) and sustainability assessments based only on the evaluation of inputs and process do not provide the information necessary for management to be adaptive. When assessment of management outcomes and results through monitoring and evaluation is incorporated into a standard, the associated C&I provide important information for adaptive management, as well as mechanisms for continuous learning (Howard and Majid 1996). An

[2] In this document "Input C&I refers to C&I that are used to assess the inputs associated with forest management. "Process C&I" refers to those that assess management processes and "Outcome C&I" refers to those that evaluate the results of forest management practices

[3] See the FSC's P&C (except for Principle 8: Monitoring) (1999), the ITTO C&I proposed for tropical forests (1998); for the neotropics in particular see the Tarapoto Proposal C&I (ACT 1995), the Lepaterique Process C&I (CCAD 1997) an the Costa Rican CNCF PC&I (1999).

adaptive set of PCI&V that evaluates the inputs, processes and outcomes of forest management provides the means not only to evaluate practice, but also to determine the actual state of the system and the system responses to management impacts and subsequently, identify pressures or aspects of management practices which can be adapted to reduce negative impacts and promote sustainability.

Currently, the capacity to implement programs for monitoring aspects of the forest related eco- and social systems, other than those which are of immediate and practical importance to the forest manager, is limited in the neotropics (Finegan and Campos 2000). Nonetheless, the complexity and dynamic nature of tropical forest systems result in a clear necessity to monitor the occurrence, magnitude, direction and significance of changes in key components of the eco- and social systems (Ferris-Kaan and Patterson 1992) and ultimately require a move towards adaptive management over the medium term (Finegan and Campos 2000). Adaptive management, defined by Baskerville (1985) as "management with a built-in learning process [that] uses well-defined feedback loops to design actions and track the effects resulting from actions", provides a means for managing dynamic and complex forest systems through monitoring and facilitated understanding, determination of system responses to management impacts and identification of the negative impacts and errors in management practices. Adaptive management encourages a cognitive approach to management that does not restrict the "creativity" that is needed in order to deal effectively with uncertainty and change, which are characteristic of tropical forests and their associated eco- and social systems (Taylor 1996).

Taking into account the complexity and dynamics of natural ecosystems, Johnson (1999) maintains that the overall goal of adaptive management is not to uphold an optimal condition of the resource, but to develop an optimal management capacity that can be used to manage within a range of acceptable outcomes while avoiding catastrophe or irreversible, negative impacts. In the development of adaptive forest management, evaluation tools which assess forest management inputs, processes and outcomes as well as system pressures, input and responses are important components in the basic steps of adaptive management identified by Taylor (1996): assessment, design, implementation, monitoring, evaluation and adjustment of management activities (Fig. 1).

Developing and testing forest management standards: CIFOR and CNCF

In 1994, the Center for International Forestry Research (CIFOR) began testing established sets of C&I in different test sites around the world. The goal of testing was the selection of a core set of PC&I that could be used as the basis for measuring sustainable forest management world-wide and at different levels of application (Prabhu *et al.* 1996). One of the general conclusions from CIFOR's testing process was the deficiency of local level ecological C&I. In response, an initiative was made to develop improved C&I for assessing the conservation of biodiversity in forest management (Stork *et al.* 1997). The resulting proposal of ecological CI&V was incorporated into the CIFOR C&I generic template which, at the time of this study, had not been tested nor

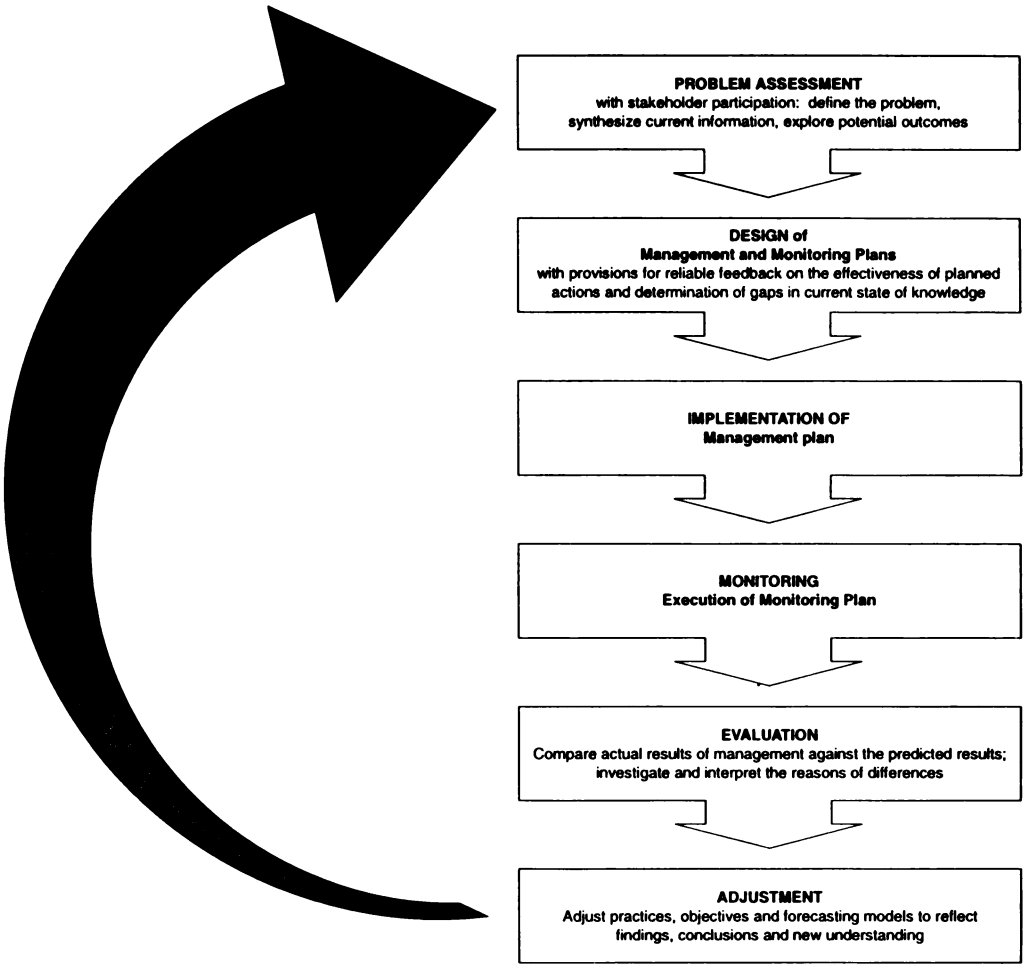


Figure 1. Framework for adaptive management (adapted from Taylor 1996)

validated in the field (CIFOR C&I Team 1999), two steps considered fundamental in the establishment and implementation of forest management guidelines and evaluation tools (Prabhu *et al.* 1996, 1999; Ghazali and Simula 1998).

In Costa Rica, initiatives to create a national forest management standard began in 1994 with the hopes of establishing an accepted and applicable mechanism for evaluation and certification of forest management at the FMU level (Campos and Müller 1999). The national set of PC&I was developed by the National Commission for Forestry Certification (CNCF) in cooperation with the public and private sectors (CNCF 1999). It was based on the P&C for sustainable forest management defined by the FSC, resulting in a strong emphasis on evaluating the fulfillment of sound forest practices with a comparatively minimal focus on monitoring the impacts of forest

management and use of adaptive elements. Since the development of the national standard and at the time of this study, the CNCF PC&I had not been tested and validated in the field, two steps considered fundamental in the establishment and implementation of forest management guidelines and evaluation tools (Prabhu *et al.* 1996, 1999; Ghazali and Simula 1998).

Justification

Over the past decade, beyond various initiatives and related advances in the development of forest management standards at the regional and national level in the neotropics (Castañeda 1999), there have been few experiences in the development of local and FMU level C&I. In Costa Rica, the development of FMU level PC&I for the evaluation and certification of forest management is a significant advance, however, field testing and validation was still lacking at the time of this study, as it was for the CIFOR CI&V (CNCF 1999; Prabhu *et al.* 1999). Of further note in regards to the CNCF standard is its limited focus on monitoring the impacts of forest management, which is a principal emphasis of the CIFOR proposal.

Integration of elements from the CNCF and CIFOR sets would provide the means to evaluate sound forest practices and the effects of forest management on the eco- and social systems, essentially providing a tool for increasing the adaptiveness of forest management in Costa Rica. Furthermore, a considerable amount of scientific and technical information exists on the ecology and management of forests in the Northern and Atlantic zones of Costa Rica, result of extensive research over the past two decades by institutions such as the Tropical Agricultural Center for Research and Higher Education (CATIE) and the Organization of Tropical Studies at La Selva Biological Research Station, that can be used as the basis for developing and justifying local level CI&V for the evaluation of the ecological sustainability of managed forests in the region.

Presentation

In 1999, a group of researchers from CATIE initiated a process for the development of an adaptive set of PCI&V for the reliable and efficient evaluation of the ecological impacts of forest management in the Northern and Atlantic regions of Costa Rica and the Southern Atlantic region of Nicaragua. The forests in these areas represent valuable timber, non-timber, biodiversity, water, soil, recreational and other forest resources, yet they are under continuous pressure from illegal harvesting practices as well as demands for land for settlement and agriculture (Campos and Müller 1999). The CATIE process is designed to contribute to the development of tools for assessing the sustainability of forest management and the maintenance of forest production and associated ecological and socioeconomic functions in the regions of focus. It represents one of the first neotropical initiatives to go beyond generic regional or national sets of PC&I and focus on the application of a large quantity of scientific and technical information in the development of site specific CI&V for the forests of a defined region.

Results from the process are expected to contribute to advances in sustainable management practices in these regions, to strengthen institutional capacity in the control and monitoring of forestry activities and to enhance the understanding of processes for developing local level CI&V for sustainability assessments of natural tropical forest management, using existing or generic sets of C&I as a starting point.

Specific objectives of the first phase of this work, carried out in Costa Rica, and described in the present paper, were:

- Assess the applicability, interpretability and efficiency of the generic principles, criteria, indicators and verifiers developed by the Costa Rican National Commission for Forestry Certification (CNCF) and by the Center for International Forestry Research (CIFOR) for the specific case of evaluation of ecological sustainability in managed forests in the Northern and Atlantic Zones of Costa Rica.

- Compare the applicability, interpretability and efficiency of the CNCF elements versus the CIFOR elements for the evaluation of ecological sustainability.

- Compare the applicability, interpretability and efficiency of input and process elements versus outcome elements for the evaluation of ecological sustainability.

- Compare the applicability, interpretability and efficiency of pressure, state and response elements for the evaluation of ecological sustainability.

- Having attained the previous objectives, propose a standard for evaluating the ecological sustainability of forest management in the Northern and Atlantic regions of Costa Rica, including elements necessary for their adaptive management.

Materials and methods

The process applied for the determination of an adaptive set of PCI&V comprised three phases of research and evaluation[4].

Phase 1: Initial evaluation

Office evaluations of the initial set of PCI&V

During Phase 1, the initial set of PCI&V[5] was assessed by a multi-disciplinary group of experts in forest ecology and management. This initial set consisted of PC&I from the CNCF national standard, and CI&V from the CIFOR C&I generic template, associated with the evaluation of ecological sustainability of forest management operations. Two office evaluations were carried out in order to make a preliminary assessment of the applicability, interpretability and efficiency of the initial elements and to determine their relative importance.

A multi-disciplinary group of experts was incorporated into the evaluation process to facilitate, as well as lend credibility to, the determination of an adaptive set of PCI&V. According to Mendoza *et al.* (1999), the strength of expert group evaluations depends on the experts' combined knowledge and experience in the field of study. Seven individuals were selected to participate as expert group members based on their area(s) of expertise and their extensive experience in the region of study[6].

The expert group was provided with the initial set of PCI&V (Appendix 1 Table 1A), documentation regarding the development and phases of evaluation of the research project and a draft manual documenting the justification and scientific basis for the initial set of PCI&V (Delgado *et al.* in prep.). Revision of these documents provided the expert group members with the background information necessary to com-

[4] The methodology used in this research was based on modifications of the methodology proposed by CIFOR for developing, testing and selecting criteria and indicators for sustainable forest management (Prabhu *et al.* 1999).

[5] In this document, "initial set of PCI&V" refers to the original elements selected from the CNCF forest management standard (1999) and the CIFOR Generic C&I Template (1999), the CIFOR Generic C&I Template (1999) and verifiers proposed to complement the CIFOR template (Aguilar 1999).

[6] The expert group included: a botanist from the National Institute of Biodiversity (INBio), a scientific researcher with the Natural Forest Management Unit of CATIE, the manager and director of Research and Development of FUNDECOR (Foundation for the Development of the Central Volcanic Chain), a public official for the Costa Rican System of Conservation Areas (SINAC), a representative of the Tirimbina Rainforest Center and M.Sc. in wildlife biology, a professor of the Forest Management with the Technology Institute of Costa Rica and a forestry engineer and regent from Osa Peninsula, Costa Rica.

plete the office evaluations. It should be noted that the office evaluations served not only as a medium for the preliminary evaluation of the applicability, efficiency and interpretability of the proposed PCI&V, but also as a means for familiarization with the proposed elements by the expert team members. It is also noted that the resulting scores were not used to eliminate any element from the intially proposed set of PCI&V before their evaluation in the field.

In the first office evaluation, each indicator or verifier was evaluated individually based on important attributes associated with the assessment of ecological sustainability in forest management operations (Table 1 shows a sample of the first office evaluation). The I&V were first scored on a scale of 1 – 5 (very poor – very good) according to their association with the assessment goal, applicability, efficiency and range of response. Based on the scores for these four important attributes, the evaluator then determined if the element was a "priority" or "not a priority" for further consideration and evaluation through field testing.

Table 1. Sample of Form 1a: Evaluation of I&V attributes and priority for further evaluation

Source: CIFOR CNCF	No. of I/V in source doc.	Class*: Mngt (M) Ecology (E)	Closely or ambiguously related to the assessment goal?	Easy to detect, record and interpret? (1-5)	Provides a summary or integrative measure? (1-5)	Adequate response range to changes in levels of stress? (1-5)	Selected as "priority"? 1- yes 0- no (1-5)

*Related to forest management practices or ecological impacts.

The methodology used for the second office evaluation was based on the multi-criteria analysis (MCA) techniques developed by CIFOR for selecting C&I (Mendoza *et al.* 1999). Multi-criteria analysis (MCA) is defined by Mendoza *et al.* (1999) as "a decision-making tool developed for complex multi-criteria problems that include qualitative and/or quantitative aspects of the problem in the decision-making process." The MCA approach simplifies the determination of order of importance which can become difficult in the frequently mixed sets of qualitative and quantitative indicators (or verifiers) found under the same criteria (or indicator). MCA was also chosen for its capacity to incorporate each expert opinion into the overall relative weight of importance of each I&V, which assisted in mitigating the difficulties that often arise when attempting to reach a general consensus in multi-disciplinary groups.

Relative importance was determined by considering the applicability, interpretability and efficiency of each I (orV) in relation to the other I (or V) under the same C (or I) and in relation to the C (or I) with which it is associated (e.g.: the elements

under CNCF C6.1 (I6.1.1, I6.1.2 and I6.1.3) were each evaluated according to their importance in association with each other as well as with C6.1). Two MCA techniques were applied in order to determine relative importance. The first technique was a "ranking" of the elements in which each I under the same C (or each V under the same I) was ranked on a 9-point scale of importance in association with its respective criterion or indicator. Regular ranking was used which allows for two elements to be evaluated with equal ranks of importance and does not force the expert to choose between elements. This technique provided the security that no element was eliminated due to forced decision making.

"Rating" was the second MCA technique applied. It required each expert to assign a rating or percentage score of importance to each element. This value was assigned to each indicator in relation to its respective criterion as well as in relation to the other indicators under the same criterion (the same was done for each verifier under the same indicator). Each I under the same C (or V under the same I) received a score of importance between 0-100 so that the sum of scores for all elements under the same C/I is equal to 100 (Table 2 shows a sample of the second office evaluation).

Table 2. Sample of Form 1b: Ranking & Rating of I associated with CNCF C6.1

P6, C6.1	Ranking[1]	Rating[2]	Relative Weights (filled out by results analyst)			REMARKS
Indicators		Total = 100	Ranking	Rating	Overall	
6.1.1						
6.1.2						
6.1.3						

1 Rank each I on a scale of importance from 1 – 9 where: 1 = weakly important, 3 = less important, 5= moderately important, 7 = more important, 9 = extremely important

2 Rate each I with a % score of 1–100 where the sum of all I under the same C = 100%

Integrating and analyzing the first phase evaluation results

The results from the office evaluations were tabulated, analyzed and consolidated for presentation to the expert group before the field test, during the second phase of evaluation. Elements receiving high scores were generally considered to be strong candidates for the final set of PCI&V. Those elements which received low scores were considered inadequate in at least one aspect of applicability, interpretability and efficiency and were brought to the attention of the experts for specific examination in the field test and careful consideration in group discussions.

Responses from each of the expert group members for the first office evaluation were tabulated to determine the average scores for each of the four attributes and the

percentage of priority for further consideration and evaluation, for each indicator and verifier. The average attribute scores indicated strengths and/or weaknesses according to the element's applicability, efficiency, range of response and association to the assessment goal. Scores of "priority" for further evaluation were then calculated from the proportion of positive responses to the final column in Form 1a. These scores were used to determine the preliminary, expert group assessment of the initial elements, higher scores indicating which elements should be included in the final set and lower scores indicating which elements might be modified or excluded.

Upon completion of the second office evaluation, individual scores from each expert were tabulated, then calculations were made to determine the relative weight or "importance" attributed to each element within each sub-group of indicators and verifiers (Table 3). These scores indicated which elements were preliminarily considered most important for inclusion in the final set of PCI&V, and which were initially considered less adequate and subsequently, allowed for the elements to be placed in order of importance.

Table 3. Example spreadsheet and calculations for ranking & rating of I under CNCF C6.1

I	Sum of Ranking Scores		Sum of Rating Scores		Relative Ranking Weight		Relative Rating Weight		Combined Weight	
	Calc.	Sum	Calc.	Sum	Calc.	Weight	Calc.	Weight	Calc.	Weight
6.1.1	E_1+E_2+ ...E_7*	W	E_1+E_2+ ...E_7	A	(W/Z) x100	15**	(A/D) x100	17	15+17 /2	16
6.1.2	E_1+E_2+ ...E_7	X	E_1+E_2+ ...E_7	B	(X/Z) x100	25	(B/D) x100	25	25+25 /2	25
6.1.3	E_1+E_2+ ...E_7	Y	E_1+E_2+ ...E_7	C	(Y/Z) x100	60	(C/D) x100	58	60+58 /2	59
		Σ=Z		Σ= D		Σ=100		Σ=100		Σ =100

* $E_{1,2,3}$ Ranking or rating assigned by Expert 1,2,...

** Arbitrary numbers to show example calculations.

Phase 2: Field application and evaluation

Site selection and field preparations

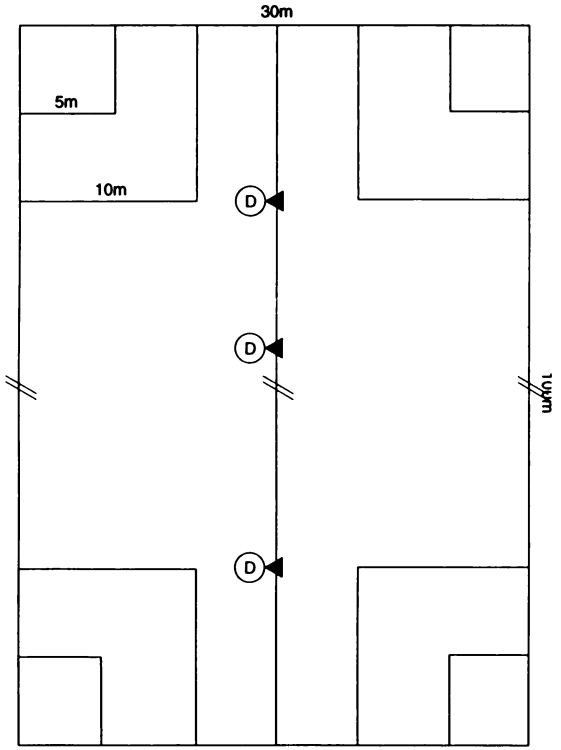
In the beginning of Phase 2, members of the research group carried out a preliminary field application of the I&V according to the methodologies proposed by CATIE for the evaluation of ecological sustainability through C&I (Delgado *et al.* in prep.). Figure 2 displays the sampling plot design developed for the application of specific I&V based on the methodologies proposed by CATIE (Delgado *et al.*, in prep.) which maximized use of the sampling infrastructure installed for the forest inventory. Following the preparations for the field application exercise and development of the respective field forms for data collection, a test site was selected based on characteristics such as forest composition, accessibility, FMU size, a legally approved forest management plan, and association with the Foundation for the Development of the Central Volcanic Mountain Chain (FUNDECOR), a local organization dedicated to forest management and certified by SGS under the group certification scheme (FUNDECOR 2000).

The site selected, owned by RAMAREMASEPRO Limited, is located in Sarapiquí, in the province of Heredia, in the northern zone of Costa Rica. It lies at an average elevation of 600 m above sea level. The total area comprises 262.7 ha of previously undisturbed primary forest, of which 127.9 ha are titled as area for conservation and 134.8 ha as production forest. Within the production forest, 70.4 ha are actually under effective management and 64.4 ha are described and conserved as area for protection purposes.

After site selection, preliminary field exercises for the application of I&V from the initial set of PCI&V were carried out by members of the research group (see Figure 2). During these field exercises, the respective sampling plots and transects were established and the corresponding data were collected. According to observations made in the preliminary exercises, all field forms and the frameworks for sampling and field activities were modified where necessary before the field test was carried out by the expert group.

Field test and evaluations

The second part of Phase 2 served as a platform for the testing and evaluation of the proposed PCI&V, both in the field and in discussion, by the group of experts. This phase functioned as a "filter" for the original PCI&V, through which each element was either recommended, revised or rejected according to its performance in the field test and observations made during group discussions. The field evaluations constituted an interdisciplinary implementation of the I&V in order to assess their performance and applicability in the field. The group discussions provided a means for interdisciplinary discourse on the practicality and efficiency of the elements tested.



- **Transects** (center, sides of 30x100 m plot)

Mammal abundance, activity (V2.1.3.6)
Butterfly groups (V2.1.4.3)
Dung beetle diversity (V2.1.4.X)*
*D - indicates beetle sampling

- **30x100 m Plot**

Decomposition and dead wood (V2.1.2.8, V2.1.6.1, B2.1.6.2), V2.1.6.3)
Above ground biomass (V2.1.2.7)
Tree sp. from different regeneration guilds (≥30 cm dbh) (V2.1.3.1)
Bird species (V2.1.3.2)

- **10x10 m Plot**

Vertical structure of forest (V2.1.2.1)
DBH class distribution (V2.1.2.2)
Regeneration phase (2.1.2.4)
Understory opening (V2.1.2.5)
Tree sp. from different regeneration guilds (10 - 29.9 cm dbh) (V2.1.3.1)
Abundance of large woody debris (V2.1.6.3)

- **5x5 m Plot**

Tree sp. from different regeneration guilds (5 - 9.9 cm dbh) (V2.1.3.1)
Abundance of small woody debris (V2.1.6.3)

* Complete sampling framework (nested plots and transects) serve for the application of CNCF I6.3.11 and I8.1.4.

Figure 2. Sampling framework for the application of select I&V (Delgado *et al.* in prep)

Phase 2 was organized as a workshop in which the expert group members spent four days located near the test site to facilitate field work and group interactions. The workshop opened with a discussion on the activities to be carried out and a presentation of the results from Phase 1. These results were presented to indicate the elements of particular consideration due to high or low scores associated with relative importance, priority for further consideration and evaluation, and the four attributes originally evaluated. The expert group was then divided into task-oriented teams of 2 – 3 people who were responsible for the evaluation of specific elements associated with their areas of expertise.

Field evaluations of the I&V by task oriented teams used the sampling protocols suggested by CATIE (Delgado *et al.* in prep., see Section "Site selection and field preparations). During the days dedicated to field work, group discussions were held both in the field as well as at home-base to review daily events and observations and allow all the experts the opportunity to discuss possible recommendations for each element.

Upon completion of the field work, each expert team evaluated their subset of I&V according to nine attributes concerning the applicability, interpretability and efficiency of the elements tested (see Table 4 for attribute description; for field form see Annex 1 Table 2A). Before recording their final recommendations, each team presented the experiences and perspectives associated with the evaluation of their sub-group of I&V

Table 4. Important C&I attributes and their descriptions

ATTRIBUTES	DESCRIPTION
Relevance	C&I should be "relevant" to the issues that define SFM
Closely and unambiguously related logically to the assessment goal	Each I must be directly related to a C, each C must be directly related to a P, all P have SFM as their goal. PC&I fit into a hierarchical framework with horizontal and vertical consistency
Precisely defined	Simple and unambiguous wording in the definition of C&I
Diagnostically specific	I should provide information that allows direct interpretation
Easy to detect, record and interpret	I should be selected in such a way as to result in minimal additional costs and contribute to cost-effectiveness
Reliability	Techniques for measuring C&I should be reliable and replicable
Adequate response range to changes in levels of stress on FM, eco- or social systems	C&I should be defined so that they provide meaningful gradual change in response to system changes. A useful indicator will provide meaningful information over a wide range of changes in the system.
Provide a summary or integrative measure over space &/or time	When possible, a single I will relate a quantity of information in relation to the system and tend towards cost-effectiveness
Appealing to users	Those who apply C&I will accept them as important, practical, legitimate measures

Source: Prabhu *et al.* 1999

and a final group discussion was held to approach group agreement on the individual team recommendations. Final team decisions were then made for the recommendation, modification (and subsequent recommendation) or rejection of each element in their subset of I&V. These final decisions or "recommendations" became the basis for the newly proposed, adaptive set of PCI&V for the evaluation of ecological sustainability of forest management operations in Costa Rica.

Analysis of Phase 2 results

Comparisons were made between the overall proportion of recommended and rejected I&V and between different groups of I&V using contingency tables and a chi-square test to determine whether groups or types of I&V (CNCF, CIFOR; input, process, outcome, pressure, state, responce, (see Annex Table 1A for I&V classification) differed with respect to the outcome of the evaluation (recommended, rejected; not modified, modified; CP required, CP not required; recommended for CP, redundant, conceptually weak, poor precision, need for further research). Of the I&V recommended for each group or type, further comparisons were made between elements recommended with or without need for modification. Comparisons were also made between elements recommended with or without need for supplementary documentation and/or provisions in the proposed Code of Practices. Of the I&V rejected for

each group, a five-way comparison was made between elements rejected due to (1) recommendation for incorporation into the proposed Code of Practices, (2) redundancy, (3) conceptual weakness (e.g. not related to the assessment goal), (4) poor precision for measurement or sampling or (5) need of further scientific development.

Phase 3: Final workshop

The third and final phase took place after analysis and review of the results from the first two phases of evaluation. A final workshop and meeting of experts was held with members of the original expert group, as well as with other experts in forest ecology, management and policy. The workshop opened with a presentation and discussion of the results and observations of the initial set of PCI&V from the first two phases of evaluation. Gaps in the C&I sets, detected by the research group after reviewing the recommended elements from Phase 2, were also presented and discussed, and ways in which to fill them were suggested by the expert group.

The workshop also served to evaluate and discuss the distribution of institutional responsibility for C&I implementation, classified by the aspects of (1) data and information collection, (2) data management and processing and (3) data interpretation (Table 5 shows a sample of evaluation). Evaluation results for institutional responsibility were analyzed and incorporated into the recommendations for the application and implementation of the newly proposed, adaptive set of PCI&V.

Table 5. Sample of Form 3: Assignment of institutional responsibility for C&I application

	COLLECTION							PROCESSING							INTERPRETATION						
CNCF	Op	M	O	S	R	C	RI	Op	M	O	S	R	C	RI	Op	M	O	S	R	C	RI
C6.1																					
I6.1.1		2			1							2							1	1	1
C6.2																					
I6.2.1	2				1				2			1								1	2
I6.2.2		2			1				2			1							2	1	1

1 = primary institutional responsibility and 2 = secondary institutional responsibility

Institutions assigned responsibility are: Op = Forest operator/technician, M = Forest manager, O = Forest owner/producer, S = State Forestry Administration, R = Regent, C = Certifier/Evaluator, RI = Research institutions

Aspects of C&I application are: Collection = data or information collection, Processing = information management (data entry and management through preparation and presentation of data results), Interpretation = determination of tendencies over time, comparison with reference or previous data and judgment of general state of management.

Results and discussion

Initial evaluation results – Phase 1

All results from Phase 1 office evaluation are displayed in the Appendix 1 (Table 3A) and a detailed discussion of the scores for attributes, priority for further evaluation and relative importance are found in the Appendix 2 (Discussion 1).

Taking into account the overall trends in scoring, it is interesting to note that all of the CNCF elements were considered average to above-average (≥ 3) in respect to all four attributes: closely or ambiguously related to the assessment goal; easy to detect, record and interpret; provides a summary or integrative measure; and adequate response range to changes in levels of stress, with the exception of three indicators which received a below-average score for one of the four attributes. I6.1.1 "The management plan establishes agreement to maintain impacts within the limits mentioned under this principle" was scored low for its sensitivity to stress (2) , I6.1.3 "Before harvesting there is an assessment of the impacts on run-off, soil and water that has been signed by the regent" was scored low in association with its ease of detection, recording and interpretation (2) and sub-indicator 7.1.3e "Viable alternatives for the commercialization of timber and respective market prices are indicated" was scored low for its relation to the assessment goal (2).

On the other hand, the CIFOR elements generally ranked somewhat lower (average = 3) in regards to the attributes assessed, with the exception of their relation to the assessment goal, for which 75% of the elements assessed were ranked above-average (4). In general, the attribute scores indicated that the CIFOR elements were considered more difficult to apply and assess, with more than one-third of the CIFOR elements receiving below-average scores (2) for the attribute related to ease of detection, recording and interpretation. Overall, it seems that the CIFOR elements were considered to be closely related to the assessment goal but difficult to use and interpret. Nonetheless, there was not a marked difference in the range and frequency of scores of priority for further evaluation between the CNCF and CIFOR sets, indicating that although the experts may not have considered the CIFOR elements as effective as the CNCF elements with regard to three of the four attributes assessed (the exception being relation to the assessment goal), they were not inclined to reject them any more than the higher scoring CNCF elements, before evaluation in the field.

Furthermore, regarding to the overall tendencies in the office evaluation results, it was noted that there was a general level of agreement in the order of elements derived from overall relative importance (office evaluation 1) and priority for further consideration and evaluation (office evaluation 2), indicating a general, direct relation between importance and priority (see Appendix 1 Table 3A). However, it should be noted that when larger subsets were considered (e.g. sub-group of indicators under CNCF C6.3, and the sub-indicators under CNCF I6.3.11), the scores for relative importance and pri-

ority for further evaluation were less congruent for the lower scoring elements, attributable to the increase in difficulty when evaluating larger and more detailed subsets of elements and in subjectivity when evaluating elements considered less important.

Variability among the experts' evaluations was also examined using the mean, standard deviation (SD) and coefficient of variation (CV) of the ranking and rating scores of importance (see Appendix 1 Table 4A). These statistics indicate when there is higher (lower SDs and CVs, ex. I6.2.1, V2.1.2.2) and lower (higher SDs and CVs, ex. I6.3.11a, V2.1.27) consensus among the experts in their assessments of the I&V. With respect to the overall results, it is noted that the CVs for rating were generally higher than the CVs for ranking. This can be attributed to the fact that rating was more subjective due to the determination of a percentage score (1-100) of importance by each expert which could indicate similar orders of importance but demonstrate differences between the individual scores assigned to each element, resulting in higher coefficients of variation among the expert evaluations. Ranking, on the other hand, was associated with verbal descriptions of levels of importance (Table 2) and thus lent to less subjectivity and lower CVs. Nonetheless, although rating may result in increased variation, it is still considered an important tool for its capacity to detect the degree of difference in importance assigned to grouped elements, which is not possible with ranking. As previously noted, the main objective for the selection of these MCA techniques was based on their capacity to incorporate each expert's opinion into an overall score of importance, considering the differences in opinion common to multi-disciplinary groups (Mendoza *et al.* 1999).

Recommendations after field evaluations- Phase 2

Chi-square tests showed that difference in groups or types of I&V in respect to evaluation outcome was significant ($p \leq 0.01$) for all tests except for that of CNCF vs. CIFOR and Input/Process vs. Outcome elements and their recommendation or rejection status (Table 6). A detailed discussion of these results continues.

Recommendation status at the end of Phase 2

Comparing the conditions of recommendation of all I&V evaluated [7]

Slightly more than half of all the I&V from the initial set were recommended (Fig. 3). Notably, almost all of the recommended I&V required modifications to the original wording and even more required supplementary documentation, which supports the general recommendation for documentation on C&I implementation. Of the rejected I&V, one third were recommended to be separated from the initially proposed set and incorporated into a Code of Practices. The remaining I&V were rejected in equal proportions due to redundancy, conceptual weakness, poor precision and need of further research and development (Fig. 3).

[7] See Appendix 2 Discussion 2 for a detailed discussion of specific recommendations and observations made by the expert group and Appendix 1 Table 5A for a summarization of all results and observations for the initial set of PCI&V after Phase 2.

Table 6. Overall results and comparison of recommendation status for groups of I&V

	TOTAL	CNCF	CIFOR	Inp/Proc	Outcome	Pressure	State	Response
Recommended	55% (22/40)	54% (13/24)	56% (9/16)	52% (12/23)	59% (10/17)	56% (10/18)	0% (0/3)	59% (10/17)
Rejected	45% (18/40)	46% (11/24)	44% (7/16)	48% (11/23)	41% (7/17)	44% (8/18)	100% (3/3)	41% (7/17)
		chi² = 2.08		**chi² = 3.40**		**Chi² = 104.68****		
Recommended								
Not modified	14% (3/22)	23% (3/13)	0% (0)	17% (2/12)	10% (1/10)	20% (2/10)	0% (0)	10% (1/10)
Modified	86% (19/22)	77% (10/13)	100% (9/9)	83% (10/12)	90% (9/10)	80% (8/10)	0% (0)	90% (9/10)
		chi² = 129.16**		**chi² = 107.56****		**Chi² = 200.00****		
Recommended								
CP required (10/10)	91% (20/22)	85% (11/13)	100% (9/9)	83% (10/12)	100% (10/10)	90% (9/10)	0% (0)	1 0 0 %
CP not required	9% (2/22)	15% (2/13)	0% (0)	17% (2/12)	0% (0)	10% (1/10)	0% (0)	0% (0)
		chi² = 149.00**		**chi² = 143.56****		**Chi² = 264.00****		
Rejected								
Move to CP	33% (6/18)	55% (6/11)	0% (0)	55% (6/11)	0% (0)	38% (3/8)	100% (3/3)	0% (0)
Redundant	17% (3/18)	27% (3/11)	0% (0)	27% (3/11)	0% (0)	38% (3/8)	0% (0)	0% (0)
Conceptually weak	17% (3/18)	18% (2/11)	43% (3/7)	18% (2/11)	43% (3/7)	24% (2/8)	0% (0)	43% (3/7)
Poor precision	17% (3/18)	0% (0)	43% (3/7)	0% (0)	43% (3/7)	0% (0)	0% (0)	43% (3/7)
Further research	17% (3/18)	0% (0)	14% (1/7)	0% (0)	14% (1/7)	0% (0)	0% (0)	14% (1/7)
		chi² = 198.60**		**chi² = 198.60****		**Chi² = 567.56****		

* Significant at $p \leq 0.05$

** Significant at $p \leq 0.01$. For 2x2 comparisons and 1 degree of freedom (d.f.), at $p \leq 0.05$: chi^2 = 3.841 and at $p \leq 0.01$: chi^2 =6.635. For 2x3 and 2 d.f, at $p \leq 0.05$: chi^2 = 5.991 and at $p \leq 0.01$: chi^2=9.21. For 5x2 and 4 d.f. at $p \leq 0.05$: chi^2 = 9.488 and at $p \leq 0.01$: chi^2 =13.277. For 5x3 and 8 d.f. at $p \leq 0.05$: chi^2 = 15.507 and at $p \leq 0.01$: chi^2 =20.090.

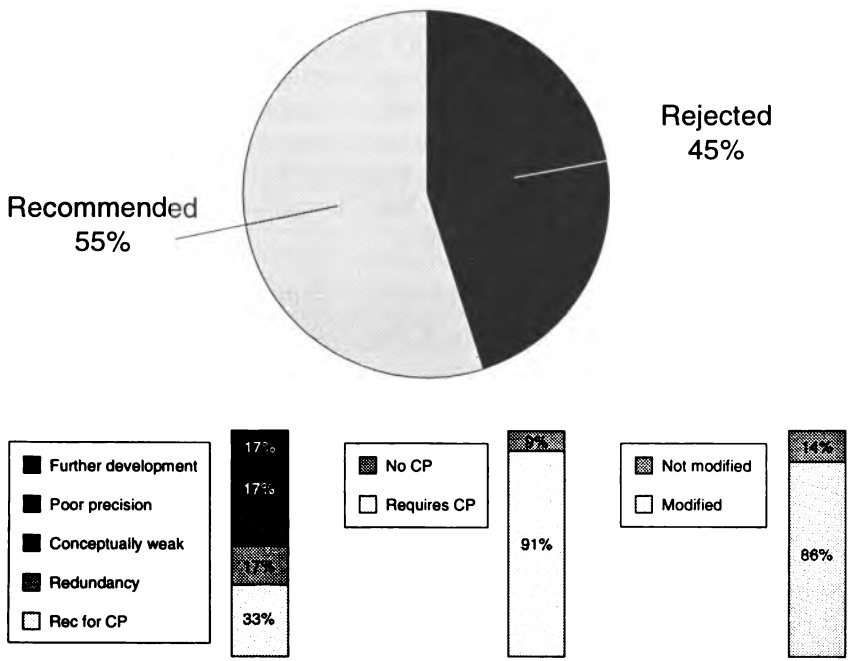


Figure 3. Final recommendation results for all I&V

Comparing the conditions of recommendation of CNCF Indicators and CIFOR Verifiers

There was no significant difference between the per cent of CNCF and CIFOR elements which were recommended and rejected (chi-square test, $p \leq 0.01$). Both groups resulted in high percentages of elements in need of modification and supplementary documentation. Notably, all of the verifiers recommended from the CIFOR group were modified from the original wording presented in the C&I Generic Template (CIFOR C&I Team 1999) which include predefined limits or ranges (e.g.: V2.1.2.4 *"Frequency distribution of phases of the regeneration cycle is maintained within critical limits"*, V2.1.3.2: *The abundance of selected avian guilds is maintained within natural variation"*, etc.). Such information is generally not available for forest systems in the region. Nonetheless, the recommended verifiers were considered very valuable in respect to forest management monitoring and evaluation, and so, were modified to wording representative of verifiers which define the source of information for a particular indicator (e.g. the accepted modified version in the final adaptive set of PCI&V: V2.1.2.4 *"Frequency distribution of phases of the forest regeneration cycle"*, V2.1.3.2 *"The abundance of select indicator groups of birds"*, etc.) (see Appendix Table 5A for details). It should also be noted that the associated CIFOR indicators were also later modified by the research coordinating group, for the same reasons (see I8.1.2, 8.1.3, 8.1.4 in Table 11 for modified versions). Furthermore, all of the recommended CIFOR elements require supplementary documentation in the proposed Code of Practices due to their increased complexity in both application and evaluation. In regards to the reasons for rejection there are, however, marked differences between the two groups (Table 7). The majority of elements rejected from the CNCF set were recommended for incorporation into a Code of Practices (Fig. 4a). The remaining CNCF elements were rejected because of redundancy and conceptual weakness (Fig. 4a). On the contrary, the majority of CIFOR elements were rejected in equal proportions for poor precision in measurement, or were considered relevant in regards to their ecological bases, but in need of further scientific development before being included in C&I sets (Fig. 4b). The remaining CIFOR elements were rejected due to conceptual weakness (Fig. 4b).

Comparing the conditions of recommendation of Input/Process and Outcome and Pressure, State and Response indicators and verifiers

The recommendation results for the input/process and outcome elements were very similar to those of the CNCF and CIFOR elements, respectively (see Table 6). This attributed to the dominance of input/process elements in the CNCF standard compared to the dominance of outcome elements in the CIFOR template.

With regard to the pressure, state and response recommendation results, it should be noted that this type of classification was not as readily applied as input, process, outcome. Particulary, pressure and state classification were more difficult to apply to the I&V, where several elements could be interpreted as

Table 7. Elements not recommended for final set of PCI&V and reasons for rejection

I or V	Wording in Source Documentation	Reason for rejection*
CNCF 1999		
I6.1.1	The management plan establishes agreement to maintain impacts within the limits mentioned under this principle.	Conceptually weak
I6.1.2	The management plan describes the means for controlling impacts and these are applied in the field.	Recommended for CP
I6.1.3	After harvesting there is an assessment of the impacts on run-off, soil and water that has been signed by the regent.	Recommended for CP
I6.3.7	Subsequent harvests are not carried out for at least 15 years since the last harvest in forests previously harvested.	Recommended for CP
I6.3.8	Species with an abundance of less than 3 trees per hectare (0.3 trees/hectare) according to the preliminary inventory of species with dap > 30cm, are considered to be rare within the ecosystem and cannot be harvested.	Redundant
I6.3.9	Banned or restricted tree species with a dap >60 dap should be marked in the field and located on a map. These complete the function of seed trees, but are not contemplated within the 40% of seed trees, reserved during harvesting.	Redundant
I7.1.2	The general plan contains the following aspects:	Recommended for CP
I7.1.3	The operational plans for harvesting or silvicultural treatments contain the following:	Recommended for CP
I7.1.4	The route of primary roads are marked in the field as well as the trees to be extracted and seed trees.	Recommended for CP
I8.1.2	Those in positions of responsibility must keep regency reports available with the certificates of receipt from the SFA (State Forestry Administration).	Recommended for CP
I8.1.3	Seed trees, infrequent, banned and endangered species are marked in the field. Their location and numbering correspond with their identification in the map.	Redundant
CIFOR C&I Team 1999		
V2.1.2.2	Class size distribution does not show a significant change from the natural variation.	Poor precision
V2.1.2.7	The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest.	Poor precision
V2.1.4.6	Temporal changes in species richness is not significant.	Poor precision
V2.1.5.4	The rates of population growth do not show significant changes in comparison with undisturbed forests.	Conceptually weak (in relation to ecol. sust.)
V2.1.6.1	Dead standing wood and on the ground does not show significant changes in comparison with undisturbed forests.	Needs further development
V2.1.6.2	The state of decomposition of all dead wood does not show significant changes in comparison with the undisturbed forest.	Needs further development
V2.1.6.3	The abundance of woody debris does not show significant changes in comparison with undisturbed forests.	Needs further development

* See Appendix 1 Table 5A for details.

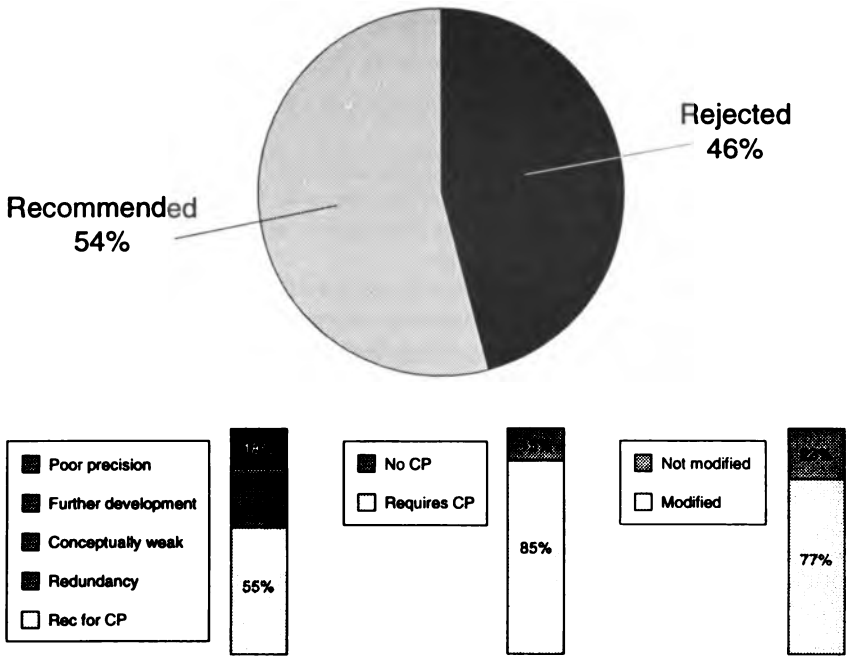


Figure 4a. Final recommendation results for CNCF indicators

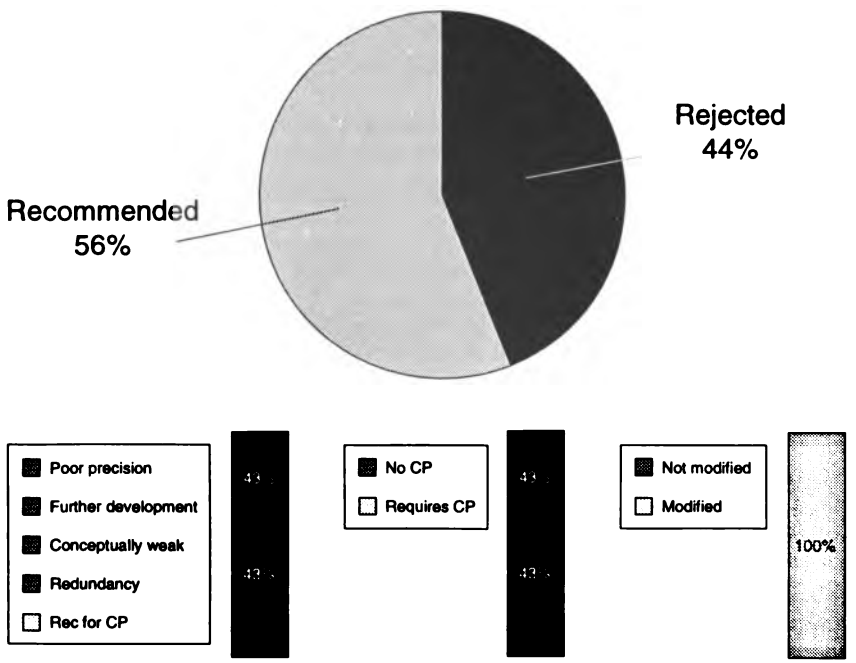


Figure 4b. Final recommendation results for CIFOR verifiers

either (see for example CNCF I7.1.1 *"The structure of the management plan includes a general plan and operacional plans"* which refers to the state of the management plan - a pressure on the system; see also CNCF I7.1.2, I7.1.3, I8.1.3) or simply were not applicable to the original format of the I&V (Appendix 1 Table 1A).

Again, there are similarities between the pressure, state results in this study and the CNCF (Input/Process) results, and between response results and the CIFOR outcome results. This is due to the majority of CNCF elements classified as pressure and state type elements, these same elements commonly classified as input and process and all CIFOR elements classified as outcome or response elements.

Comparability on results from Phase 1 and Phase 2

In relation to the scores for relative importance from Phase 1 (Appendix 1, Table 3A) for elements under CNCF P6 *"Management Impact"* there was both consistency and inconsistency with the results from Phase 2. Under C6.1 *"Forest management seeks to reduce the impact on the structure and composition of the forest, hydric erosion of the soil, water contamination due to erosion and sedimentation of natural drainage system"*, the scores from Phase 1 indicated I6.1.2 and I6.1.3 to be more important than I6.1.1, however all three were rejected after Phase 2 (see Table 7). Under C6.2 *"Infrecuent, threatened and endangered forest species are protect as well as their habitats. Hunting capturing and collecting floral and fauna species is controlled"*, I6.2.2 *"Measures exist to control hunting, capture and collection of plant and animal species"* received a much lower score for relative importance (39) than I6.2.1 *"Measures exist for the protection of infrequent, threatened, banned, restricted and endangered tree species, as well as for the protection of the characteristics of their habitats. Their location in the field and their identifying numeration corresponds with the map associated with tree location"* (61), nonetheless both were recommended after Phase 2. Under C6.3 *"Management should orient itself towards the maintenance of ecological funtions of the forest ecosystem. These include: a. Natural regeneration and succesion. b. Sufficient genetic diversity to maintain the production system. c. Natural process that affect the productivity of the forest ecosystem. d. Function and processes of the natural drainage system"*, it is noted that I6.3.7 (RI = 6) was not recommended after Phase 2, and was also one of the lowest scoring elements for relative importance in its sub-group in Phase 1. Indicator 6.3.10 *"Dead standing and fallen trees can be harvested if it is technically justified that their removal does not negatively affect the ecological functions of the forest"* (RI = 3) and I6.3.12 *"Mechanized extraction operations use only cables and the tractor or "skidder" does not go outside of the established trails"* (RI = 6) -the lowest scored elements for relative importance from Phase 1 for this sub-group of indicators- were recommended with modifications to their original wording at the end of Phase 2 after evaluations and testing in the field.

The elements under CNCF P7 *"Management plan"* underwent unusual recommendations, in that they were not rejected based on weaknesses but on the inappropiatess of their placement in the national standard, and therefore, Phase 1 and 2 results were

not compared. As for the elements under CNCF P8 *"Monitoring and evaluation"*, it was noted that all four indicators evaluated in Phase 1 were relatively similar in scores of importance. After Phase 2, two indicators were maintained (8.1.1 *"Records should exist of management activities, volume of production per species, and numbers of logs that are verifiable with the respective transportation guides. Records should also exist in the case of production of non-timer forest products"* and 8.1.4 *"In FMUs greater than 100 hectares and the case of certified forests, permanent sample plots should exist where monitoring of the dynamics of management areas take place. The intensity of sampling is not inferior to 1% of the total area. The variables to be analysed are: a. Annual increment in dbh (mm/year), b. Annual increment in basal area (m^2/ha/year), c. Mortality, regeneration and recruiment, d. Floristic composition"*). Of the two indicators which were rejected, one was due to recommendation for inclusion in the proposed Code of Practices (8.1.2) and the other due to redundancy (8.1.3).

When comparing the results for CIFOR elements after Phase 1 and Phase 2, again there are consistencies and inconsistencies. Under I2.1.2 *"Changes in diversity of habitat as result of human interventions are maintained within critical limits as defined by natural variation and/or regional conservation objectives"* the lowest scoring verifier (V2.1.2.7) was not recommended after Phase 2. However, the second and third lowest scoring verifiers in the same group (2.1.2.8 *"Dead standing wood and on the ground does not show significant changes in comparison with undisturbed forest"*, 2.1.2.5 *"Canopy openness in the forest understory is minimized"*) were both recommended with modifications for the final adaptive set of PCI&V. There was considerable consistency under CIFOR I2.1.3 *"Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds"*, the three verifiers evaluated (2.1.3.1 *"The relative abundance of seedlings, saplings and trees of canopy tree species pertaining to the different guilds of regeneration do not show significant changes in comparison with the undisturbed forest"*, 2.1.3.2 *"The abundance of select guilds of birds is maintained within the ranges of natural variation"*, 2.1.3.6 *"The abundance and activity of terrestrial frugivorous mammals is maintained within critical limit"*) were considered of almost equal importance in Phase 1 and notably, all three were recommended after Phase 2. Nonetheless there was definite inconsistency under I2.1.4 *"The richness/diversity of selected groups show no significant change"*, in which the lowest scoring verifier after Phase 1 (2.1.4.X) *"The richness/diversity and species composition of species the dung beetle guild (Scarabaeinae) do not show significant changes"* was recommended after Phase 2 and the highest scoring verifier (2.1.4.6 *"Temporal changes in species richness is not significant"*) was rejected after Phase 2. The three verifiers evaluate under I2.1.6 were scored with a relatively small range of difference in importance. Nonetheless, they were not recommended for the final adaptive set at the end of Phase 2.

When examining the consistencies and inconsistencies between Phase 1 and Phase 2 results, the inconsistencies in elements initially scored as important and later rejected do not have as serious implications as when elements are initially scored low for relative importance and then later recommended for the final set. Notably, some currently accepted methodologies for C&I selection, testing and development propose the use of relative importance scores from the office evaluations as initial filters which

reduce C&I sets before testing in the field (see Prabhu *et al.* 1999, Mendoza and Prabhu 2000). Nonetheless, in the present study scores of relative importance were not used to reject any element before field testing and by maintaining all original elements after Phase 1, it was observed that, in this case, many of the final recommended elements would have been rejected before the field evaluation, had previously used methodologies been applied. Consequently, precaution is recommended in the use of filters based on office – evaluation results for rejecting elements before field testing. Furthermore, with regard to these results, support is lent to the argument that C&I should be applied and assessed in the field as well as "on the table", in order to be reliably evaluated.

In the comparisons made between the attribute scores from Phase 1 and from Phase 2 definitive similarities or discernible correlations were not in evidence (Appendix 1 Table 6A). In the CNCF group, for example, the indicators under C6.1 generally scored higher in Phase 1 than in Phase 2 for their relation to the assessment goal, but generally scored lower for their provision of a summary and sensitivity to stress, and notably these three indicators were rejected. On the other hand, in the CIFOR group, the verifiers were generally rated higher for their relation to the assessment goal and for their sensitivity to stress in Phase 2 as compared to Phase 1. However, some were rated higher for ease of detection and recording in Phase 1 while others were rated higher in Phase 2, as was the case with the attribute associated with provision of summary. These differences may be attributed to the more detailed evaluation carried out in Phase 2 in which nine attributes were examined as opposed to only four in the first phase, thus resulting in both positive and negative changes in individual attribute scores. Furthermore, differences could be attributed in part to the fact that the scores from Phase 1 were based on averages of the individual scores submitted by each expert group member, while the attribute scores from Phase 2 were based on the consensus of the two to three person task-oriented teams.

General recommendations made by the expert group[8]

Phase 2 generated a series of general recommendations and observations associated with the originally proposed sets of PCI&V, the current state of development of a forest management standard in Costa Rica and the means for its implementation (Table 8). These recommendations and observations were considered to reflect the conditions necessary for sustainable forest management.

During group discussions and field evaluations in Phase 2, the need for an instruction manual for the use of the national forest management standard and its associated criteria and indicators was duly noted, as well as the need for up-to-date lists of banned, threatened and endangered species, based on the most current information available for Costa Rica. It was also recommended that the terms and methodologies associated with sustainable forest management (e.g. skid trails), implementation (e.g.

8 See Appendix 2 Discussion 2 for details of the specific recommendations and observations in Phase 2, and the Appendix 1 Table 5A for a summary of the results and observations in Phase 2.

directional felling) and monitoring (e.g. permanent sampling plots) be better defined, clarified and described. The importance of monitoring was noted, with the agreement that permanent sampling plots are essential for following changes in the vegetation as a result of forest management. Respectively, it was also recommended that guidelines for the establishment, maintenance and measurement of permanent sampling plots (PSP) should be developed and provided and that the variables to measure and analyze should be clearly identified. The classification of forest types based on compositional criteria relevant to forest management was considered crucial and, in effect, would provide the information necessary to establish the sustainable means and levels for minimizing management impact according to forest type as well as reference data for monitoring in different forest types. Furthermore, it was recommended that the appropriate personnel should be provided with the training necessary for PSP installation and management. It was also strongly recommended that inter-institutional relationships be established in order to facilitate the processes of C&I development as well as implementation and analysis (e.g.: CNCF and the National Commission of Forestry Research – a national NGO). Finally, it was noted that there exists the need for a Code of Practices for sustainable forest management in Costa Rica.

Table 8. Requirements identified as essential for the implementation of the CNCF national standard for forest management in Costa Rica

Instruction manual for the implementation and interpretation of CNCF forest management standard
Up-to-date lists of banned, threatened and endangered tree species
Clarification, definition and description of all terms and methodologies
Monitoring and a national system of permanent sampling plots
Classification of forest types
Development of inter-institutional relationships
Instruction manual for the implementation of forest management *Code of Practices*

Taking into account the need for a Code of Practices, it was recommended that sub-indicators associated with CNCF I6.3.11: "*Minimal impact is made on runoff, soil and water resources through management and harvesting which take into account the following aspects or applicable levels*" and the criteria, indicators and sub-indicators associated with CNCF Principle 7: "*Management plan*" be removed from the current standard and incorporated into a Code of Practices, legalized by a separate governmental decree. The inclusion of these elements in the standard was considered to be inefficient with regard to the overall objectives of the national standard for the evaluation of sustainable forest management. These elements were considered to be important by the expert group and were recommended to become the basis for a Code of Forest Practices. With the separation of these elements from the current standard and their incorporation into a national Code of Practices, the national standard for sustainable-

forest management and associated C&I should be developed and used to determine the fulfillment of the norms or performance standards described by the Code of Practices. Most notably, the experts felt it crucial that this Code of Practices be legally established, implemented and upheld before modifications are made to the current standard for sustainable forest management.

Final workshop results

The workshop held in Phase 3 was attended by a group of 11 experts, including 5 members of the Phase 2 expert group and 6 other experts in forest management, ecology and policy[9]. An important overall result of the workshop was the group acceptance and approval of the process for determining an adaptive set of PCI&V and the results to date, including the recommendations, modifications and rejections of the initial PCI&V.

Creating a Code of Practices

During group discussions in Phase 3 much consideration was given to the group of CNCF elements not recommended for the final set of PCI&V, but recommended for incorporation into a proposed national code of forest practices (Section "Recomendations after field evaluations, Phase 2"). Codes of forest practice are typically sets of guidelines or "regulations" developed to help critical actors in the forestry sector (e.g. forest managers, operators, government officials, etc.) apply and carry out forest management operations (Dykstra 1994). When forest management operations are carried out according to codes of practice, they should theoretically meet standards set for sustainable forest management (e.g. harvest limits for commercial timber according to area). Codes of practice should be developed and adapted according to local conditions and focus on practices rather than the desired outcome, resulting in guidelines and prescriptions which, if observed, should enable the goal of sustainable forest management to be met. It is also noted that codes of practice should not be "overly prescriptive" but should provide a sound basis for decision making and evaluation, permitting adaptability of actions so that standards and guidelines can be adapted as management results are detected and new, information relevant to the sustainability of the management system is discovered (Dykstra 1994).

Taking into account the basic fundamentals of codes of forest practices, similarities are detected with the hierarchical framework of forest management standards. In the Phase 3 workshop, correlation was drawn between the 'principles' and 'criteria' of forest management standards and the 'goals' of codes of practices, and between forest management standard 'indicators' and code of practices 'guidelines'. Based on these correlations, it was agreed that a national code of forest practices and a national stan-

[9] The 6 new members included CATIE's Latin American Chair of Diversified Management of Tropical Forests, a researcher with CATIE's Forest Management Unit, a professor of forest management at the Costa Rican Institute of Technology, a professor of forest studies at the Costa Rican National University, a representative of the College of Agronomy Engineers and a M.Sc. student in Conservation and Management of Forests and Biodiversity at CATIE.

dard for forest management should be developed and implemented in parallel with each other in Costa Rica. A list of potential users was then created for both documents which were then distinguished as primary or secondary users (Table 9).

Currently in Costa Rica there are several different "institutions" involved in the development and application of the national standard for forest management. According to La Gaceta (1996), the official journal in the country, these acting institutions include:

- the State Forestry Administration (SFA), responsible for the approval of forest management plans, establishment of guidelines for forest management, assertion that management plans are effectively executed, coordination of forest sector, control and approval of forest management certifiers (under the guidelines of the National System of Forestry Certification), among other responsibilities.
- Regents, responsible for the sound and effective execution of approved forest management plans, recognized by and reporting to the SFA.
- College of Agronomists, overseer of forest regents.
- CNCF, responsible for the recommendation of forest management PC&I to the SFA and the supervision and observation of forest management certifiers, among other responsibilities.
- SFA accredited certifiers, responsible for auditing and "certifying" the sustainability of forest management planning and execution.

Table 9. Primary and secondary users for the Costa Rican forest management standard and the proposed Code of Practices

USER*	Standard	CP
State Forestry Administration – forest management approval sector	P	P
State Forestry Administration – forest management control sector	P	P
Evaluators (Certifier, NGO, private, final product consumers)	P	S
Entity in-charge of monitoring	P	S
Auditors	P	S
Professional responsible for forest management	S	P
Regent	S	P
College of Agronomist (responsible for forest regents)	S	P
Forest Owner	S	S
Business Owner	NA	P
Forest Workers	NA	P
COVIRENAS (Commission of Independent Volunteers for Natural Resources)	NA	P

CP = Code of Practices, P = primary user, S = secundary user, NA = not applicable (not a user)
* See in Section 'Integrating and analyzing the first phase evaluation results, the description of users responsabilities'.

From this list it can be concluded that the forest management standard has similar primary users – including the SFA approval and control sectors, forest management evaluators and entities in-charge of forest monitoring. These users all have similar needs in regards to the information provided by the forest management standard, thus making it possible to develop a "universal" document for all primary users. On the contrary, the proposed Code of Practices has diverse primary users -the SFA control and approval sectors, professionals responsible for forest management, regents, the College of Agronomists, business owners, forest workers, and environmental organizations (e.g. COVIRENAS)- each with very different needs in regards to their use and application of a proposed Code of Practices. In consideration of such differences, it is suggested that the code of practices eventually be broken down into different volumes which would correspond to the different primary users and their needs (e.g. volumes referring to harvesting operations, protective measures for water and nutrient cycles, protective measures for species and associated lists, etc). At present, the principal recommendation is to develop a national forest management standard and a national code of forest practices that would result in two separate but complementary documents which would both be legally decreed and upheld and used for the implementation and evaluation of forest management in Costa Rica.

Determining the distribution of institutional responsibility for sustainability assessment

Taking into account the current actors involved and the distribution of institutional responsibility for the implementation of the forest management standard, three aspects of responsibility for C&I implementation were evaluated in Phase 3. Table 10 displays the overall results from this evaluation (see Appendix 1 Table 5A for details and description of the recommended I&V). It is noted that for the majority of CNCF elements, the general inclination of the expert group was to assign primary responsibility for data collection to the regent, while assigning the majority of secondary responsibility to forest operators and technicians. As well, the group assigned the regent primary responsibility for data processing for the majority of CNCF elements and secondary responsibility to the forest manager and the State Forestry Administration. The majority of primary responsibility for the interpretation of data associated with the CNCF elements was assigned to certifiers and secondary responsibility was divided among the SFA, regents and research institutions. It is noted that for the CNCF elements responsibility (primary or secondary) was seldom assigned to research institutions, which were only designated responsibility for aspects of interpretation of data related to forest management impacts and monitoring.

For the CIFOR elements, responsibility was assigned very differently, with a greater degree of designation to research institutions. Although primary responsibility for data collection was commonly assigned to the regent or the forest operator, secondary responsibility was distributed between the SFA, the forest manager and research institutions. Primary responsibility for data processing was mostly assigned to research institutions or regents, and secondary responsibility to the forest manager. Primary responsibility for the interpretation of data associated with the CIFOR ele-

ments was not directly assigned, instead it was distributed among certifiers, regents and research institutions.

An adaptive set of PCI&V for ecological sustainability assessment

Based on the results from the three phases of research, and the overall acceptance and recommendation of elements which evaluate the inputs, processes and results of forest management, an adaptive set of PCI&V was developed for the evaluation of ecological sustainability of forest management operations in the Northern and Atlantic zones of Costa Rica (Table 11). This final set integrates I&V from the recommended CIFOR elements with PC&I from the recommended CNCF elements into the existing framework of the CNCF forest management standard. In this adaptive set, means for evaluating good management practices, primarily derived from the recommended CNCF PC&I, are complemented by means for monitoring the changes and outcomes in the forest system through the I&V recommended from the CIFOR set. Integrating elements that define good management practices and ways for reducing negative impacts, with elements that evaluate and monitor the results and outcomes of forest management, resulted in a set of PCI&V which provides a tool for a continuous learning process in association with forest management as well as for the adaptability of the forest management system. It should be noted that this adaptive set of PCI&V was developed under the supposition that there existed a Code of Forest Practices and that the necessary, supplementary documentation was developed, up-to-date and available (Table 8). These PCI&V have been proposed for the evaluation of ecological sustainability, and should be adapted and updated in association with changes in local environmental, social and political conditions in the Northern and Atlantic regions of Costa Rica.

Closing discussion

With regard to the methodology used to determine an adaptive set of PCI&V, it was evident throughout this process that adaptiveness is essential. Processes for determining forest management standards and their associated C&I are still very new and have not been so widely applied, nor are they well enough understood to be mechanically implemented without room for modification. Furthermore, taking into account the dependence upon expert opinion, subjectivity is a considerable factor ever-present in this type of process. Although methodologies and techniques are incorporated so as to minimize subjectivity and maximize expert knowledge and experience, cut and dried methods for eliminating elements based on subjective opinions, which may be made before sufficient evaluation is carried out, can lead to the premature elimination of elements which may in fact be strong components for C&I sets. In regards to the present research, the scores from the office evaluations for relative importance did not prove to be reliable nor consistent enough to merit their use for eliminating elements before their application and observation in the field. Nonetheless, it should be noted that other studies have supported the use of these scores as a type of "filter" for eliminating elements from initial C&I sets before field testing (Mendoza and Prabhu 2000, Woodley *et al.* 1999).

Table 10. Recommendations for the distribution of responsibility for aspects of I&V implementation according to the expert group after Phase 3

SOURCE	COLLECTION		PROCESSING		INTERPRETATION	
CNCF	PR	SR	PR	SR	PR	SR
I6.1.3	R	-	R	C	S	R, C
I6.2.1	R	Op, S, C	R	M	C	S, R, RI
I6.2.2	R	Op	R	M	C	S, R, RI
I6.3.2	R	Op, S	R	M, S	C	S, R, RI
I6.3.3	R	Op, M	R	M, S	C	S, C
I6.3.4	R	Op	R	S	R	S
I6.3.5	R	Op, S	R	M, S	R	S
I6.3.6	R	Op, M	R	S	C	S, R, RI
I6.3.10	R	Op	R	M	R	S, C, RI
I6.3.11	R	Op	R	M, S	R	C
I6.3.12	R	Op	R	S	R	C
I7.1.1	R	M, S	R	M, S	C	S, R
I7.2.1	R	M	R	M, S	C	S, R
I8.1.1	R	Op, M, O, S	C	S, R	C	R
I8.1.2	R	S	R	S	C	R
I8.1.4	S	-	C	R, RI	C	R, RI
CIFOR	PR	SR	PR	SR	PR	SR
V2.1.2.4	R	Op, S, RI	R	M, RI	-	R, C, RI
V2.1.2.5	R	Op, S, RI	R	M, RI	-	R, C, RI
V2.1.2.8	R	Op, S, RI	R	M, RI	-	R, C, RI
V2.1.3.1	Op	M, R, RI	RI	M, R	-	R, C, RI
V2.1.3.2	Op	M, R, RI	RI	M, R	-	R, C, RI
V2.1.3.6	Op	M, R, RI	RI	M, R	-	R, C, RI
V2.1.4.3	Op	M, R, S, RI	RI	M, R	-	R, C, RI
V2.1.4.X	Op	M, R, S, RI	RI	M, R	-	R, C, RI

PR = primary responsibility, SR = secondary responsibility; Institutions: Op = Forest operator/technician, M = Forest manager, O = Forest owner/producer, S = State Forestry Administration, R = Regent, C = Certifier/Evaluator, RI = Research institutions; Aspects of C&I application: Collection = data or information collection, Processing = information management (data entry and management through preparation and presentation of data results), Interpretation = determination of tendencies over time, comparison with reference or previous data and judgment of general state of management

Table 11. Adaptive set of PCI&V for the evaluation of ecological sustainability

	C	I	V	
P6 Management Impact: Forest management will promote the conservation of biological diversity and water and soil resources, and by so doing, will maintain the ecological functions, integrity and environmental services of the forest.				
6.1 Forest management seeks to reduce: impact on the structure and composition of the forest, soil erosion, water contamination due to erosion and sedimentation of natural drainage systems and should orient itself towards the maintenance of ecological functions of the forest ecosystem which include: a. Natural regeneration and succession b. Sufficient genetic diversity to maintain the production system. c. Natural processes that affect the productivity of the forest ecosystem. d. The functions and processes of the natural drainage system.				
6.1.1 The rate of harvest forest products does not exceed the rate of grouth of the resource.				
6.1.2 The felling cycle is determined from information available concerning natural forest growth and takes into account the particular dynamics of the forest under management.				
6.1.3 Harvest intensity and silvicultural treatments are determined in direct proportion to the abundance of each species.				
6.1.4 All commercial species with abundance equal to or greater than 0.3/ha are harvested, exceptions must be justified in terms of the current market in the general management plan or harvest operation plan.				
6.1.5 The volume or quantity of standing or fallen dead wood corresponds to the volume or quantity justified in the management plan or the Annual Operational Plan.				
6.1.6 Mechanized extraction, skidding operations and the use of cables follow the code of forest practices.				
6.1.7 Measures exist to avoid hydric erosion and alteration of the natural drainage systems.				
6.1.8 The norms established in the code of practices in terms of the damage to productive forest area (e.g. road network, gaps, log landings, etc.) are respected and complied within the field.				
6.2 Rare, threatened and endangered forest species and their habitats are protected. Hunting, capturing and collecting of plant and animal species is controlled.				

6.2.1 Measures exist for the protection of rare, threatened, restricted and endangered tree species for those whose felling is prohibited, and for the protection of the characteristics of their habitats. Their location in the field and their identification numbers correspond with the map of tree location.
6.2.2 Measures exist to control hunting, capture and collection of plant and animal species.
P7 Management Planning: Forest management shall be expressed through policies and implementation of a management plan.
7.1 The management plan and supporting documents clearly establish and justify the management objectives and the means for achieving them.
7.1.1 There exists a management plan developed according to the code of practices and legally approved by the State Forestry Administration.
7.2 The management plan is updated
7.2.1 The management plan is revised in each cutting cycle to incorporate results from evaluation and monitoring and new scientific and technical information that responds to the changes in technological, environmental, social and economic circumstances.
P8 Monitoring and Evaluation: In a way appropriate to the scale of forest management, forest condition, forest product yield, chain of custody and the social and environmental impacts of management activities shall be monitored and evaluated.
8.1 The management plan includes a monitoring plan that allows the determination of the impact of management operations, and this plan is executed.
8.1.1 Records exist on management activities, yield volume per species, and numbers of stems harvested. These records are verifiable in accordance with the respective transportation guides.
8.1.2 Changes in diversity of habitat as a result of human interventions are monitored to determine their direction, magnitude and importance, and the need to take corrective measures.
8.1.2.1 The vertical structure of the forest *8.1.2.2 The frequency distribution of the phases of the regeneration cycle of the forest* *8.1.2.3 Canopy openness within the understory of the forest* *8.1.2.4 Standing and fallen dead wood*
8.1.3 Community guild structures are monitored to determine changes in especially sensitive guilds, pollinator and disperser guilds, their direction, magnitude and importance, and the need to take corrective measures.

	8.1.3.1 The relative abundance of seedlings, saplings and poles of canopy tree species belonging to the different regeneration guilds *8.1.3.2 The abundance of select indicator groups of birds* *8.1.3.3 The abundance and activity of select mammal indicator groups*
8.1.4	Changes in the diversity of selected groups are monitored to determine their direction, magnitude and importance, and the need to take corrective measures. *8.1.4.1 The diversity of selected indicator groups of butterflies* *8.1.4.2 The diversity and species composition of selected indicator species of the dung beetle guild (Scarabaeinae)*
8.1.5	In FMUs greater than 100 hectares and in the case of certified forests, permanent sample plots exist where monitoring of the dynamics of managemed stands takes place. The intensity of sampling is not inferior to 1% of the total area. The variables analyzed are: annual increment in dbh (mm/yr); annual increment in basal area (m^2/ha/yr); mortality, regeneration and recruitment; floristic composition.

Throughout the process of evaluation of the initially proposed set of PCI&V, the need for associated protocols and supporting documentation of justification, application procedures and analysis methodologies was indisputable. More than 90% of the I&V recommended for the final set of PCI&V were conditional upon the need for complementary documentation and/or provisions in the proposed Code of Practices. The manual for ecological C&I application, in preparation by Delgado *et al.*, did significantly facilitate the process of evaluation by providing the experts with extensive documentation on the ecological bases upon which the proposed C&I were developed. The manual also greatly facilitated field testing by providing scientifically documented methodologies. Nonetheless, there remains a lack of documentation related to specific CI&V and sets as a whole that should exist for the implementation of a forest management standard in Costa Rica.

There was also considerable emphasis placed on the lack of reference or "baseline" data for many of the outcome CI&V. In order to provide the reference data necessary for monitoring and for establishing acceptable practices, up-to-date information on different forest types should be utilized and referenced. This data would be greatly enhanced by the establishment and organization of a national system of permanent sample plots. Access to and interpretation of such data will also require the creation of agreements and working relationships between government and research institutions. Other liaisons between and within the government, non-government and private sectors must also be created in order to cover the various aspects of implementing a forest management standard, including collection and management of data, as well as management evaluation and control.

Respectively, although generally undetected throughout the evaluation process yet identified and modified by the research group in consideration of local conditions and discussed in the final workshop, many of the CIFOR verifiers from the C&I Generic Template (CIFOR C&I Team 1999) propose that changes in ecosystem components due to management impacts be maintained within predefined limits or ranges. If these verifiers were implemented as such, they would require extensive information on the critical limits and natural variation of forest components, the definition of acceptable ranges of change and essentially, submission to the ideal that a managed forest not differ significantly from an undisturbed forest, which is certainly debatable and not necessarily realistic nor the objective of sustainable forest management in the region.

As for the responsibility of implementing a national forest management standard, the tendency to designate much of the responsibility to regents and little to the forest manager and forest owner was duly noted. Placing the majority of responsibility on one particular group could obviously overburden that group, resulting in difficulties for carrying out and upholding the principles and goals of sustainability proposed by a forest management standard.

Conclusions and recommendations

Evaluating ecological sustainability can provide important information about the future availability of natural resources and their rates of productivity. Despite many efforts to develop systems for assessing sustainability, its determination remains difficult, if not elusive, especially when taking into account limitations associated with the institutional, political and social components necessary for its evaluation and those associated with the current state of scientific knowledge.

Today, systems for assessing the sustainability of forest ecosystems are often based on predetermined standards for reducing the impacts of forest management operations, with little, if any regard for the sometimes unpredictable responses of ecosystem components. However, while predetermined standards are essential, it is generally recognized that reducing negative impacts does not necessarily guarantee sustainability. And although CI&V that evaluate system responses to forest management operations often involve increased investment of time, training, costs and multi-institutional participation, they are important in assessing and monitoring sustainability. If forest management standards are to be useful in providing important information on the sustainability of forest management and provide indications of where adaptations or improvements may be made, they should move towards an integration of elements that evaluate the impacts of forest management, as well as its results.

C&I sets that integrate the means to evaluate the state of the eco- or social system, the stresses that act upon it and the system responses will provide a valuable overall understanding of the sustainability of forest management operations and become potentially powerful tools for the evaluation of sustainability. An encouraging result of the present study was the acceptance and recommendation of outcome and response elements along with the traditionally prevalent input and process elements. Such results are indicative of a definite step towards the adaptability and sustainability of forest management systems.

The present research has not only provided a proposal for an adaptive set of PCI&V for the evaluation of ecological sustainability of forest management in the Northern and Atlantic zones of Costa Rica, it has also contributed to the experiences of C&I development processes in the region.

Overall, the process applied in this research was very effective and based on the provisions for adaptability in the methodologies used for the evaluation and selection of elements, it produced the anticipated as well as initially unexpected, valuable results. It is recommended that, until much more experience has been had with selecting and determining C&I sets, future processes continue to incorporate adaptability in their methodologies.

Clarity is another important factor in C&I development which should be highly emphasized. It is suggested that all terms and methods associated with the development process of forest management standards be very clearly set out and explained before evaluations actually take place. In conclusion, these recommendations can be incorporated into the methodology used here and if adaptability and conscious learning are maintained, the strength of these methodologies as tools for developing standards for the evaluation of sustainable forest management will only increase.

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Appendix 1

Table 1A. Initial list of PCI&V proposed for the evaluation of the ecological sustainability of forest management

P	C	I	V	Description	Input/ Process/ Outcome	Pressure/ State/ Response
CNCF (1999)						
6				Management Impact: Forest management shall promote the conservation of biological diversity and its associated water and soil resources, and by so doing, shall maintain the ecological functions, integrity and environmental services of the forest.	**	**
	6.1			Forest management seeks to reduce the impact on the structure and composition of the forest, hydric erosion of the soil, water contamination due to erosion and sedimentation of natural drainage systems.		
		6.1.1		The management plan establishes agreement to maintain impacts within the limits mentioned under this principle.	I	P
		6.1.2		The management plan describes the means for controlling impacts and these are applied in the field.	P	P
		6.1.3		Before harvesting there is an assessment of the potential impacts on run-off, soil and water that has been signed by the regent.	P	P
	6.2			Infrequent, threatened and endangered forestry species are protected as well as their habitats. Hunting, capturing and collecting floral and fauna species is controlled.		
		6.2.1		Measurements exist for the protection of infrequent, threatened and endangered species, as well as the characteristics of their habitats	P	P
		6.2.2		Measures exist to control hunting, capture and collection of plant and animal species.	P	P
	6.3			Management should orient itself towards the maintenance of ecological functions of the forest ecosystem. These include: a. Natural regeneration and succession b. Sufficient genetic diversity to maintain the production system. c. Natural processes that affect the productivity of the forest ecosystem. d. The functions and processes of the natural drainage system.		
		6.3.1		Silvicultural treatments, if applied, maintain the disetaneous structure of the forest	P	P
		6.3.2		Harvest intensity and silvicultural treatments are determined in proportion to the abundance of each species. Harvesting intensity does not exceed 60% of the number of trees per species with a dap greater than or equal to 60 cm (technical justification is needed for harvesting trees of lesser dap.)	P	P
		6.3.3		The rate of forest products harvested does not exceed the rate of resource growth.	P	P
		6.3.4		Measures of control exist to avoid hydric erosion and alteration of natural drainage systems.	P	P
		6.3.5		The number of harvested trees is distributed proportionally among the greatest number of currently commercial species.	I	P
		6.3.6		A professional forester is able to determine the cutting cycle in function of the information available concerning natural forest growth and taking into account particular dynamics of the forest in question.	P	P
		6.3.7		Subsequent harvests are not carried out for at least 15 years since the last harvest in forests previously harvested.	P	P

	6.3.8	Species with an abundance of less than 3 trees per hectare (0.3 trees/ hectare) according to the preliminary inventory of species with dap > 30cm, are considered to be infrequent within the ecosystem and cannot be harvested.	P	P
	6.3.9	Banned or restricted tree species with a dap >60 dap should be marked in the field and located on a map. These complete the function of seed trees, but are not contemplated within the 40% of porter trees, reserved during harvesting.	P	P
	6.3.10	Dead standing and fallen trees can be harvested if it is technically justified that their removal does not negatively affect the ecological functions of the forest.	P	P
	6.3.11	Minimal impact is made on runoff, soil and water resources through management and harvesting which take into account the following aspects or applicable levels:	P	P
	6.3.11a	The area of clearings caused by cuttings does not surpass 15% of the area defined as productive forest.		
	6.3.11b	The area of gathering landings does not occupy more than 1% of the area of productive forest.		
	6.3.11c	Primary roads on which the trucks circulate, do not occupy more than 2% of the area of productive forest and side roads do not surpass 2% of said area. These roads have slopes less than 20% and have conservation measures necessary to minimize erosion and damage to soils and waterways.		
	6.3.11d	Secondary roads, on which the tractors or "skidder" circulate, do not surpass 8% of the productive forest. Slopes greater than 40% do not exist on these roads and the waterways are functional.		
	6.3.11e	Hauling trails occupy a maximum of 3% of the area of productive forest.		
	6.3.11f	In all cases, the sum of area impacted due to harvesting does not surpass 25% of the effective area.		
	6.3.11g	After harvesting, diagnostic and silvicultural sampling will show that harvesting plus loss due to damage does not exceed 15% of the original basal area.		
	6.3.12	Mechanized extraction operations only uses cables and the tractor or "skidder" does not go outside of the established trails.	P	P
7		Management Plan: The planning of long-term forest management shall be expressed through a written, implemented and up-fo-date management plan.		
	7.1	The management plan and support documents establish and clearly justify the objectives of the management and the means for achieving it.		
	7.1.1	The structure of the management plan includes a general plan and operational plans.	I	N/A
	7.1.2	The general plan contains the following aspects:	I	N/A
	7.1.2a	An executive summary to present to the forest owner, independent of whether s/he has delegated the administration of harvesting to a third party. This summary should include:		
		an evaluation of the sustainability of the ecosystem, in the case of certification; financial analysis in the case of certification; management objective(s); prognostics of the impacts and the most relevant means for controlling them; silvicultural activities; number of trees per species that will be harvested with the corresponding minimum dbh harvested; list of number of parent trees per species; cutting cycle; proportion of principal and extraction roads expressed in linear meters for road type and in hectares of forest; relevant aspects of the forest that affect sustainability or offer an alternative for non-timber production.		
	7.1.2b	Management objectives		

	7.1.2c	The state of the property, access roads, land use and a general description of the adjacent areas.		
	7.1.2d	A description of the forest resources that will be managed, based on the results of the preliminary inventory (made of all trees > 30cm), the biophysical limitations and risks of management in relation to the structure and composition of the forest. The sampling error in the preliminary inventory should not less than or equal to 20% with respect to the basal area of all species.		
	7.1.2e	A description of the silvicultural prescriptions based on characteristics of the forest and information obtained from the forest inventory.		
		The cutting cycle, list of species to be harvested and harvesting intensity for each species are indicated and justified.		
	7.1.2f	Monitoring plan.		
	7.1.2g	An evaluation of the possible impacts of forest operations on the residual mass, hydric and edaphic resources and the corresponding means for control.		
	7.1.2.h	The identification and protective measures for infrequent, threatened or endangered species.		
	7.1.2i	Maps that describe the forest resources, harvest areas, conservation areas, hydric resources and buffer zones, existing roads and land boundaries. The maps should possess the corresponding cartographic information. Conservation areas include fragile zones and areas of ecological and cultural importance.		
	7.1.2j	Describe the measures for controlling hunting, fishing, capture and collection of flora and fauna.		
	7.1.2k	If management affects community resources of vital importance, measures for their protection are indicated.		
	7.1.3	The operational plans for harvesting or silvicultural treatments contain the following:	I	N/A
	7.1.3a	The topographical mapping should be carried out according to a specialized computer system.		
	7.1.3b	Primary and secondary roads, landings, trees to be extracted and parent trees are specified and located on a map created in relation to the planned harvesting. A copy of the map is used in the field as an operational guide.		
	7.1.3c	There exists a description and justification of the equipment and silvicultural and harvesting techniques to be used.		
	7.1.3d	Operations which guarantee that natural drainage systems are not affected by harvesting or management, and that no waterway is obstructed due to harvesting, are based on the topographical map.		
	7.1.3e	Viable alternatives for the commercialization of timber and respective market prices are indicated.		
	7.1.3f	A list of the trees to be cut and those to be left as parent trees.		
	7.1.3g	Technical justification of the harvesting of dead standing or fallen trees.		
	7.1.4	The route of primary roads are marked in the field as well as trees to be extracted and parent trees.	P	P
8		Monitoring and Evaluation: Appropriate to the scale of forest management, forest condition, forest product yield, chain of custody and the social and environmental impacts of management activities shall be monitored and evaluated.		
	8.1	The management plan should include a monitoring plan that allows the determination of the impact of management operations.		
	8.1.1	Registers should exist of management activities, volume of production per species, and numbers of trunks that are verifiable with the respective transportation guides. Registers should also exist in the case of production of non-timber forest products.	P	P

8.1.2	Those in positions of responsibility must keep regency reports available with the certificates of receipt from the SFA (State Forestry Administration).	P	N/A
8.1.3	Parent trees, infrequent, banned and endangered species are marked as AP. Their location in the field and their numeration correspond with their identification on the map.	P	P
8.1.4	In FMUs greater than 100 hectares and the case of certified forests, permanent sample plots should exist where monitoring of the dynamics of management areas take place. The intensity of sampling is not inferior to 1% of the total area. The variables to be analyzed are:	P	P
	a. Annual increment in dap (mm/year)		
	b. Annual increment in basal area (m/ha/year)		
	c. Mortality, regeneration and recruitment		
	d. Floristic composition		

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2			**Maintenance of ecosystem integrity**		
	2.1		**The processes that maintain biodiversity are conserved in managed forests.**		
		2.1.1	**Landscape pattern is maintained.**		
			2.1.1.1 **The FMU compiles information about the size of area of each vegetation type in the area of intervention, compared with the area of vegetation type in the entire FMU.**	R	R
		2.1.2	**Change in diversity of habitat as a result of human interventions are maintained within critical limits as defined by natural variation and/ or regional conservation objectives.**		
			2.1.2.1 The vertical structure of the forest is maintained within natural variation.	R	R
			2.1.2.2 Class size distribution does not show a significant change from the natural variation.	R	R
			2.1.2.4 The frequency distribution of the phases of the regeneration cycle of the forest is maintained within the critical limits.	R	R
			2.1.2.7 The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest.	R	R
		2.1.3	Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds.		
			2.1.3.1 "The relative abundance of seedlings, saplings and trees of canopy tree species pertaining to the different guilds of regeneration do not show significant changes in comparison with the undisturbed forest.	R	R
			2.1.3.2 The abundance of select guilds of birds is maintained within the ranges of natural variation.	R	R
			2.1.3.6 The abundance and activity of terrestrial frugivorous mammals is maintained within critical limits.	R	R
		2.1.4	The richness/diversity of selected groups show no significant change.		
			2.1.4.3 The richness/diversity of selected groups of large butterflies is maintained within the natural ranges of variation.	R	R
			2.1.4.4 Numbers of species removed from the forest for sale in local markets	R	R
			2.1.4.6 Temporal changes in species richness is not significant.	R	R
		*	2.1.4.X The richness/diversity and species composition of species the dung beetle guild (Scarabaeinae) do not show significant changes.	R	R
		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 presented.		
			2.1.5.3 The age structure or tree size structure does not show significant changes in comparison with undisturbed forests.	R	R
			2.1.5.4 The rates of population growth do not show significant changes in comparison with undisturbed forests.	R	R
		2.1.6	The status of decomposition and nutrient cycling shows no significant change.		
			2.1.6.1 Dead standing wood and on the ground does not show significant changes in comparison with undisturbed forests.	R	R
			2.1.6.2 The state of decomposition of all dead wood does not show significant changes in comparison with the undisturbed forest.	R	R
			2.1.6.3 The abundance of woody debris does not show significant changes in comparison with undisturbed forests.	R	R

* 2.1.4.X as a verifier under I2.1.4 as recommended by N. Aguilar 1999.

N/A = Not applied.

** = only I a V are classified.

Table 2A. Form 2: Field Test and Evaluation Responses

Expert's Initials: ☐ Source of I/V: ☐ Number: Class (M/E):

RECOMENDATION AFTER FIEL TESTING YES ☐ NO ☐

Wording of selected I/V as stated in manual:

Justification or main argument for selection of I/V:

Use a scale of 1-5: 1=no/bad/unimportant; 5=yes/good/important

Provides a summary or integrative measure	
Closely and unambiguously related to the assessment goal	
Adequate response range to stress (sensitive)	
Diagnostically significant	
Appealing to users	
"Easy to detect, record and interpret? Feasible?	
Precisely defined? (clear)	
Will it produce replicabel results? (reliable)	
How relevant is this I/V?	

Provide bibliographic references (if any):

Would this I/V need to be evaluated:

In the field? ☐ In the office? ☐ In both? ☐

Note what documentation would be required if the I/V were used in a field assessment of FMU.

Does the I/V define:

Human Input ☐ Human Process ☐ Outcome ☐

Does the I/V refer to

Stress on the system ☐ State of the system ☐ Response of the system ☐

Final version of I/V (if different from original)

Please record your notes on evaluating this I/V here:

Diary of Important Actions to Evaluate I/V:

Date	Action	Remarks

Table 3A. Office evaluation results for element attributes, priority for further evaluation, relative importance and designation of responsibility for the initial set of PCI&V.

Principle	Criteria	Indicator	Verifier	Related to assessment goal	Easy to detect and register	Provides a summary	Sensitive to stresses	Overall score for further evaluation	Relative importance
CIFOR 1999									
P6									
	C6.1								
		I6.1.1		3	3	3	2	0.43	18
		I6.1.2		4	4	4	4	0.86	40
		I6.1.3		4	2	3	3	0.57	42
	C6.2								
		I6.2.1		4	3	4	3	1.00	61
		I6.2.2		3	3	3	3	0.86	39
	C6.3								
		I6.3.1		4	3	3	3	0.86	9
		I6.3.2		3	3	4	4	1.00	11
		I6.3.3		4	3	4	3	0.86	13
		I6.3.4		4	4	3	3	0.86	7
		I6.3.5		3	4	3	3	0.57	7
		I6.3.6		4	4	4	3	1.00	8
		I6.3.7		3	4	3	3	0.71	6
		I6.3.8		4	4	4	4	0.86	8
		I6.3.9		4	4	4	4	0.71	9
		I6.3.10		3	4	3	3	0.29	3
		I6.3.11		4	3	4	4	0.67	12
		I6.3.11a		3	3	3	3	0.71	13
		I6.3.11b		4	4	3	3	0.86	10
		I6.3.11c		4	4	4	3	0.86	13
		I6.3.11d		4	4	4	3	0.86	13
		I6.3.11e		4	4	4	3	0.71	10
		I6.3.11f		4	4	4	3	0.86	23
		I6.3.11g		4	3	4	3	0.86	18
		I6.3.12		3	4	3	3	0.71	6
	C7.1								
		7.1.1		3	5	4	3	0.57	13
		7.1.2		4	4	4	3	0.75	27
		7.1.2a		3	4	4	3	0.43	8
		7.1.2b		4	4	4	4	0.71	13
		7.1.2c		3	4	4	3	0.71	9
		7.1.2d		4	4	4	3	0.71	11
		7.1.2e		4	4	4	3	0.71	9
		7.1.2f		4	4	3	3	0.67	10
		7.1.2g		4	3	4	3	0.86	11
		7.1.2h		4	4	4	3	0.86	12
		7.1.2i		4	4	5	4	0.86	18
		7.1.3		3	4	4	3	0.67	20
		7.1.3a		3	5	4	3	0.43	34
		7.1.3b		4	4	4	4	0.71	12

	7.1.3c	4	4	4	4	0.71	14
	7.1.3d	4	4	4	4	0.57	8
	7.1.3e	2	3	3	2	0.29	22
	7.1.3f	4	4	4	4	0.71	10
	7.1.3g	3	4	3	3	0.29	0
	7.1.4	4	5	4	4	0.71	40
C8.1							
	I8.1.1	3	4	3	3	0.57	26
	I8.1.2	3	4	3	3	0.57	19
	I8.1.3	4	5	4	4	0.86	31
	I8.1.4	3	4	4	3	0.86	24

CIFOR 1999							
P2							
C2.1							
	I2.1.1						
	V2.1.1.1	3	3	4	3	0.71	100
	I2.1.2						
	V2.1.2.1	4	3	3	3	1.00	22
	V2.1.2.2	4	3	3	4	0.86	21
	V2.1.2.4	4	3	3	3	0.86	16
	V2.1.2.5	4	4	3	4	0.86	19
	V2.1.2.7	3	2	3	3	0.50	11
	V2.1.2.8	3	2	3	3	0.43	11
	I2.1.3						
	V2.1.3.1	4	2	11	3	0.71	33
	V2.1.3.2	4	2	3	3	0.86	33
	V2.1.3.6	4	2	3	3	0.86	33
	I2.1.4						
	V2.1.4.3	4	2	3	3	0.86	27
	V2.1.4.4	4	4	4	4	0.80	30
	V2.1.4.6	4	2	4	3	0.86	24
	V2.1.4.X	4	2	3	3	0.71	20
	I2.1.5						
	V2.1.5.3	4	4	3	4	0.86	56
	V2.1.5.4	4	3	3	3	0.71	44
	I2.1.6						
	V2.1.6.1	3	3	3	3	0.43	25
	V2.1.6.2	3	2	3	3	0.29	24
	V2.1.6.3	4	2	3	3	0.29	51

Table 4A. Summary statistics for the ranking and rating of the initial I&V (n = 9).

	RATING			RANKING		
CNCF	AVG	SD	CV%	AVG	SD	CV%
6.1.1	15.0	13.78	91.89	3.5	1.52	43.33
6.1.2	45.0	27.39	60.86	6.5	1.76	27.09
6.1.3	41.7	33.12	79.48	5.3	3.20	60.08
6.2.1	55.8	10.21	18.28	8.3	1.03	12.39
6.2.2	45.0	11.18	24.85	7.3	1.51	20.53
6.3.1	9.5	4.19	44.07	7.0	0.00	0.00
6.3.2	10.0	7.05	70.41	7.3	1.97	26.81
6.3.3	20.3	16.20	79.66	8.0	2.45	30.62
6.3.4	6.8	5.28	77.90	6.7	0.82	12.25
6.3.5	6.0	5.33	89.65	5.3	2.94	55.20
6.3.6	7.8	3.14	40.03	6.3	1.63	25.78
6.3.7	5.2	0.91	17.37	5.7	1.63	28.82
6.3.8	6.5	3.58	55.50	7.0	1.79	25.56
6.3.9	8.6	7.19	84.01	6.0	3.03	50.55
6.3.10	2.4	2.03	84.87	3.0	1.26	42.16
6.3.11	12.7	8.02	63.00	7.7	2.42	31.59
6.3.12	4.2	3.19	75.46	4.7	2.34	50.10
6.3.11a	12.5	13.95	111.4	5.0	2.19	43.82
6.3.11b	7.2	4.73	65.78	4.7	2.34	50.10
6.3.11c	14.2	8.70	61.24	6.2	2.23	36.14
6.3.11d	13.9	8.70	62.73	6.2	2.23	36.14
6.3.11e	7.9	5.61	71.49	4.3	2.42	55.90
6.3.11f	25.0	27.50	109.9	7.2	2.56	35.76
6.3.11g	19.4	13.05	67.44	7.2	2.23	31.10
7.1.1	13.3	12.52	93.87	3.8	2.99	78.12
7.1.2	26.7	25.82	96.82	5.5	3.08	56.04
7.1.3	22.5	18.64	82.85	5.5	3.08	56.04
7.1.4	37.5	31.58	84.22	7.3	1.51	20.53
7.1.2a	7.5	6.84	91.64	5.0	2.53	50.60
7.1.2b	14.5	13.36	91.87	6.0	2.10	34.96
7.1.2c	8.7	5.09	58.43	5.0	1.79	35.78

	RATING			RANKING		
CNCF	AVG	SD	CV%	AVG	SD	CV%
7.1.2d	9.0	5.68	63.32	6.7	1.51	22.58
7.1.2e	7.9	4.89	61.68	5.3	1.51	28.23
7.1.2f	9.9	6.56	66.13	5.3	2.66	49.84
7.1.2g	12.4	2.65	21.33	5.3	1.51	28.23
7.1.2h	12.3	5.49	44.81	5.7	1.63	28.82
7.1.2i	20.0	11.02	55.22	7.3	1.51	20.53
7.1.3a	5.4	3.79	70.75	3.3	1.97	58.99
7.1.3b	36.6	26.86	73.46	8.0	1.10	13.69
7.1.3c	8.7	7.08	81.51	5.7	1.63	28.82
7.1.3d	10.4	6.80	65.55	6.3	1.63	25.78
7.1.3e	9.2	7.53	81.74	3.7	3.01	82.12
7.1.3f	21.5	16.56	76.85	6.7	2.34	35.07
7.1.3g	8.2	8.27	100.4	3.7	2.73	74.52
8.1.1	25.3	12.72	50.37	7.2	1.83	25.60
8.1.2	16.9	14.30	84.52	6.2	2.23	36.14
8.1.3	33.2	28.67	86.45	6.3	2.42	38.24
8.1.4	24.7	12.88	52.21	6.5	3.08	47.42
CIFOR						
2.1.1.1	100.0	0.00	0.00	5.8	2.68	46.26
2.1.2.1	22.2	6.49	29.29	7.0	2.19	31.30
2.1.2.2	22.2	5.49	24.78	6.7	1.51	22.58
2.1.2.4	17.7	10.46	59.22	5.7	3.01	53.14
2.1.2.5	16.0	9.38	58.63	5.3	2.94	55.20
2.1.2.7	9.3	8.76	93.81	2.8	2.40	84.75
2.1.2.8	12.7	8.29	65.42	3.7	2.07	56.33
2.1.3.1	31.7	16.84	53.10	7.3	2.34	31.88
2.1.3.2	34.1	8.43	24.76	7.0	3.10	44.26
2.1.3.6	34.1	8.43	24.75	7.0	3.10	44.26
2.1.4.3	27.5	11.29	41.06	7.0	2.53	36.14

	RATING			RANKING		
CNCF	AVG	SD	CV%	AVG	SD	CV%
2.1.4.X	18.3	9.83	53.63	6.3	2.42	38.24
2.1.4.4	28.3	13.29	46.91	7.3	2.66	36.25
2.1.4.6	25.8	15.94	61.71	7.7	2.42	31.59
2.1.5.3	59.2	9.17	15.51	5.5	3.08	56.04

	RATING			RANKING		
CNCF	AVG	SD	CV%	AVG	SD	CV%
2.1.5.4	40.8	9.17	22.47	4.5	2.51	55.78
2.1.6.1	36.2	13.39	37.03	4.8	2.56	53.02
2.1.6.2	36.0	13.43	37.31	3.7	2.42	66.06
2.1.6.3	27.7	10.82	39.11	3.7	2.42	66.06

AVG = Average
SD = Standard Deviation
CV = Coefficient of Variation

Table 5A. Summary of recommendation status of CI&V after Phase 2.

Principle Criteria Indicator Verifier	Recommended	Modification	Requires CP	Description (shows recommended version when modified)	Observations
CNCF					
P6				Management Impact	
C6.1				Forest management seeks to reduce the impact on the structure and composition of the forest, hydric erosion of the soil, water contamination due to erosion and sedimentation of natural drainage systems.	This criterion should be combined with C6.3, resulting in on two criteria under P6.
I6.1.1	NO			The management plan establishes agreement to maintain impacts within the limits mentioned under this principle.	The idea is closer to a principle of sustainable management rather than an indicator. An agreement is not very relevant to ecological sustainability.
I6.1.2	NO*			The management plan describes the means for controlling impacts and these are applied in the field.	In its current form, this should be considered in a code of practices (CP) (see observations for I6.3.11 and P7). Here indicators could be proposed in terms of "results" or "system response" that incorporate indicators for changes in species composition (e.g. birds, insects, mammals). *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
I6.1.3	NO*	YES	YES	During and after harvesting impacts on the stand, soil and water are evaluated by the regent and reported to the State Forest Administration (AFE).	This indicator should be taken into consideration under I6.3.11. The aspects to evaluate and the methodologies for evaluation should be specified in the CP. And then C&I should be

					developed and used to determine the fulfillment of the performance standards proposed by the CP. *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
C6.2				Infrequent, threatened and endangered forestry species are protected as well as their habitats. Hunting, capturing and collecting floral and fauna species is controlled.	
I6.2.1	YES	YES	YES	Measures exist for the protection of infrequent, threatened, banned, restricted and endangered tree species, as well as for the protection of the characteristics of their habitats. Their location in the field and their identifying numeration corresponds with the map associated with tree location.	A description of the means for protection, conservation and management of these species and their associated habitats is necessary. This could be provided in the CP. These terms should be better and clearly defined by a group of experts, based on the information available from current forest inventories. Forest managers and those responsable for management evaluations must be provided with training in order for accurate identification of these species.
I6.2.2	YES	NO	YES	Measures exist to control hunting, capture and collection of plant and animal species.	The code of practices should describe the means for developing and carrying out these measures.
C6.3				Management should orient itself towards the maintenance of ecological functions of the forest ecosystem. These include: a. Natural regeneration and succession b. Sufficient genetic diversity to maintain	(see comments for C6.1)

				the production system. c. Natural processes that affect the productivity of the forest ecosystem d. The functions and processes of the natural drainage system.	
I6.3.2	YES	YES	YES	Harvest intensity and silvicultural treatments are determined in direct proportion to the abundance of each species.	Harvesting norms should be omitted from the indicator. The norms should be included in the CP.
I6.3.3	YES	NO	YES	The rate of forest products harvested does not exceed the rate of resource growth.	This is only verifiable at this level if the necessary information from monitoring is available.
I6.3.4	YES	NO	YES	Measures of control exist to avoid hydric erosion and alteration of natural drainage systems.	This should be included in the CP which should explain the measures and methodologies.
I6.3.5	YES	YES	YES	All commercial species with abundance equal to or greater than 0.3/ha are harvested, exceptions must be justified in terms of the current market.	This indicator requires lists of commercial tree species according to forest type. It is noted that trees accepted in the market at a given time is very dynamic.
I6.3.6	YES	YES	YES	The cutting cycle is determined in function of the information available concerning natural forest growth and taking into account particular dynamics of the forest in question.	Methodologies to determine cutting cycles and the minimum allowed period should be indicated in the CP.
I6.3.7	NO*	NO	YES	Subsequent harvests are not carried out for at least 15 years since the last harvest in forests previously harvested.	This is a norm and an aspect of planning and should be considered in the CP. *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
I6.3.8	NO		YES	Species with an abundance of less than 3 trees per hectare (0.3 trees/hectare) according to the preliminary inventory of species with dap > 30cm, are considered to be infrequent within the	Redundant. This should be integrated with I6.2.1.

				ecosystem and cannot be harvested.	
I6.3.9	NO		YES	Banned or restricted tree species with a dbh >60 cm should be marked in the field and located on a map. These complete the function of seed trees, but are not contemplated within the 40% of porter trees, reserved during harvesting.	Redundant. This should be integrated with I6.2.1.
I6.3.10	YES	YES	NO	The volume or quantity of dead standing wood or on the ground corresponds to the volume or quantity justified in the management plan or the harvest operation plan.	
I6.3.11	YES	YES	YES	The aspects and levels established in the code of practices in terms of the damage to productive forest area (e.g. road network, gaps, loading area, etc.) are respected and carried out in the field.	All of the sub-indicators related to I6.3.11 are norms for reducing forest management impacts. It is recommended that these norms be removed from the national standard for sustainable forest management and form part of a separate decree that serves as a code of practices for the planning and implementation of forest management. *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
I6.3.11a	NO*	NO	YES	The area of clearings caused by cuttings does not surpass 15% of the area defined as productive forest.	The term "clearing" should be clearly defined in the CP as well as the methodology for its quantification. Decreases in percentage should be evaluated periodically over time after harvesting.
I6.3.11b	NO*	NO	YES	The area of gaps does not occupy more than 1% of the area of productive forest.	The term "gap" should be clearly defined in the CP.

I6.3.11c	NO*	NO	YES	Primary roads on which the trucks circulate, do not occupy more than 2% of the area of productive forest and secondary roads off these roads does not surpass 2% of said area. Primary roads only exist on slopes less than 20% and include conservation measures necessary in order to minimize erosion and damage to soils as well as the methodology waterways.	The terms "primary road" and "side roads" should be clearly defined in the CP as for their quantification.
I6.3.11d	NO*	NO	YES	Secondary roads, on which the tractors or "skidder" circulate, do not surpass 8% of the productive forest. These roads do not exist on slopes greater than 40% and waterways remain functional. At the end of the operation, these roads are closed and measures are taken to avoid erosion and restore the functions and processes of the natural drainage system.	The term "secondary roads"should be clearly defined in the CP as well as the methodology for its quantification.
I6.3.11e	NO*	YES	YES	Skid trails occupy at least 25% of road infrastructure.	An increased area of skid trails, indicates a decreased area of secondary roads.
I6.3.11f	NO*			In all cases, the sum of area impacted due to harvesting does not surpass 25% of the effective area.	
I6.3.11g	NO			After harvesting, diagnostic and silvicultural sampling will show that harvesting plus loss due to damage does not exceed 15% of the original basal area.	The precision of diagnostic sampling is inferior to the percent of the reduction in basal area that is being evaluated.
I6.3.12	YES	YES	YES	Mechanized extraction/ skidding operations follow the protocol for the use of cables.	The CP should define the term "skid trails" as well as when and how to use cables. It should be noted that the most important and effective measure with skid trails is to assure that there are no unnecessary

					trails, or trails of an unnecessary width.
P7	YES	YES	YES	Planning	*It is recommended that Principle 7 and its respective C&I, as they currently appear in the Standards and Procedures for Sustainable Management and Forest Certification in Costa Rica (CNCF 1999) are removed from the current document and made into a separate national decree that serves as a code of practices (CP) for the planning and implementation of forest management. It is also recommended that Principle 7 and its respective C&I be modified as they appear here. It should be noted that it is of the utmost importance that this code of practices is created and upheld legally before modifications to P7 and its respective C&I are made as they appear in this document. *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
C7.1	YES	NO	YES	The management plan and supporting documents clearly establish and justify the management objectives and the means for achieving them.	
I7.1.1	YES	YES	YES	There exists a management plan developed according to the code of practices and legally approved by the SFA.	
C7.2	YES	YES	YES	The management plan is updated.	

I7.2.1	YES	YES	YES	The management plan is revised in each cutting cycle to incorporate results from evaluation and monitoring and new scientific and technical information that responds to the changes in technological, environmental, social and economic circumstances.	
P8				Monitoring and Evaluation	
C8.1				The management plan should include and execute a monitoring plan that allows the determination of the impact of management operations.	
I8.1.1	YES	YES		Records exist on management activities, production volume per species, and numbers of trunks. These registers should be verifiable in accordance with the respective transportation guides.	
I8.1.2	NO*			Regent reports and appropriate certificates of approval by the SFA are maintained available.	This should be taken into account in the CP, which would indicate the minimum amount of information necessary in the regent reports as well as the standard methodology for data collection. *However, until a CP is developed and legally upheld, this indicator should not be removed from the current standard.
I8.1.3	NO			Parent trees, infrequent, banned and endangered species are marked as AP. Their location in the field and their numeration correspond with their identification on the map.	Redundant after revisions made to I6.2.1.

I8.1.4	YES	YES	YES	In FMUs greater than 100 hectares and the case of certified forests, permanent sample plots should exist where monitoring of the dynamics of management areas take place. The intensity of sampling is not inferior to 1% of the total area. The variables analyzed are: annual increment in dbh (mm/yr); annual increment in basal area (m^2/ha/yr); mortality, regeneration and recruitment; floristic composition.	PSP are essential for following changes in the ecosystem. A code of practices should indicate the means for establishment, maintenance and measurement associated with PSP as well as the variables to analyze. The appropriate personnel should be provided with the associated training for their management. An organized data base should be created and made available for coordination and research efforts.

CIFOR					
P2				Maintenance of ecosystem integrity.	
C2.1				The processes that maintain biodiversity are conserved in managed forests.	
I2.1.1				Landscape pattern is maintained.	
V2.1.1.1				The FMU compiles information about the size of area of each vegetation type in the area of intervention, compared with the area of vegetation type in the entire FMU.	
I2.1.2				Change in diversity of habitat as a result of human interventions are maintained within critical limits as defined by natural variation and/or regional conservation objectives.	

V2.1.2.1	YES	YES	YES	The vertical structure of the forest.	The *critical limits* and *natural variation* need to be defined and/or monitoring must be implemented. This indicator is more direct than the measurement of clearings, but not as precise.
V2.1.2.2	NO			Class size distribution does not show a significant change from the natural variation.	The legally permitted harvest does not greatly affect diametric distribution. Furthermore, the precision for such measurement is poor.
V2.1.2.4	YES	YES	YES	The frequency distribution of the phases of the regeneration cycle of the forest.	The idea is recommendable for monitoring yet it should be noted that dynamic sampling is required (e.g. two times during the cutting cycle) as well as highly trained personnel.
V2.1.2.5	YES	YES	YES	Canopy opening within the understory.	Seeks to minimize direct light which reaches the forest floor. This indicator requires reference data (before harvesting) and/or the implementation of monitoring.
V2.1.2.7	NO			The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest.	Current methodologies for determining biomass are not precise. Changes in volume are more easily measured and more important for evaluating sustainability.

V2.1.2.8	YES	YES	YES	Dead standing wood and on the ground.	This is clearly associated with the existence of habitats and is easy to detect. Care must be taken with precision of measurements and points of reference.
I2.1.3				Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds.	
V2.1.3.1	YES	YES	YES	The relative abundance of seedlings, saplings and trees of canopy tree species pertaining to the different guilds of regeneration.	Sapling sampling (<30cm dbh) should be added to the CP or to CNCF I7.1.2d. It should also be made clear that changes recoverable with reasonable amounts of time are permitted. This V also requires a list of canopy species for the region or area of management with the respective classification according to guild. There also exists the need for personnel to be trained in the associated evaluation and management of these species.
V2.1.3.2	YES	YES	YES	The abundance of select indicator groups of birds.	References data is needed according to forest type. The indicator groups and the monitoring methods and periods should be included in the CP.

V2.1.3.6	YES	YES	YES	The abundance and activity of select indicator mammal groups.	The indicator groups should be defined in the CP, and reference data, or a system of control with an undisturbed forest or monitoring methods should be implemented.
I2.1.4					The richness/diversity of selected groups show no significant change.
V2.1.4.3	YES	YES	YES	The diversity of selected Indicator groups of butterflies.	The indicator groups should be defined in the CP, and reference data, or a system of control with an undisturbed forest or monitoring methods should be implemented.
V2.1.4.X	YES	YES	YES	The diversity and species composition of select indicator species of the dung beetle guild (Scarabaeinae).	Indicator species and their relationship with other organisms should be clearly defined in the CP. The methodology for identification needs to be determined as well as reference data according to forest type.
V2.1.4.6	NO			Temporal changes in species richness is not significant.	This V is not very precise and would require very intensive sampling.
I2.1.5				Population sizes and demographic structures of selected species do not show significant change and demographically and ecologically critical life cycle stages continue to be presented.	

V2.1.5.4	NO			The rates of population growth do not show significant changes in comparison with undisturbed forests.	This is important from the point of view of timber production, not necessarily from ecological sustainability.
I2.1.6					The status of decomposition and nutrient cycling shows no significant change.
V2.1.6.1	**NO			Dead standing wood and on the ground does not show significant changes in comparison with undisturbed forests.	**The idea is relevant for evaluating ecological sustainability but it requires more research at this time in order to define the appropriate lapse of time for measurement. Verifiers 2.1.6.1, 2.1.6.2 and 2.1.6.3 could be integrated and used to determine the state of decomposition in relation to volume/ abundance according to forest type. The importance of leaf litter (presence/absence) could also be considered as an indicator of the rate of decomposition. A in all cases, this requires points of reference or monitoring.
V2.1.6.2	**NO			The state of decomposition of all dead wood does not show significant changes in comparison with the undisturbed forest.	
V2.1.6.3	**NO			The abundance of wood debris does not show significant changes in comparison with undisturbed forests.	

Table 6A. Attribute scores evalu

Juego de P C I y V desarrollado por CIFOR - Pra

Principle	Criteria	Indicator	Verifier
P6			
	C6.1		
		I6.1.1	
		I6.1.2	
		I6.1.3	
	C6.2		
		I6.2.1	
		I6.2.2	
	C6.3		
		I6.3.1	
		I6.3.2	
		I6.3.3	
		I6.3.4	
		I6.3.5	
		I6.3.6	
		I6.3.7	
		I6.3.8	
		I6.3.9	
		I6.3.10	
		I6.3.11	
		I6.3.11a	
		I6.3.11b	
		I6.3.11c	
		I6.3.11d	
		I6.3.11e	
		I6.3.11f	
		I6.3.11g	
		I6.3.12	
	C8.1		
		I8.1.1	
		I8.1.2	
		I8.1.3	
		I8.1.4	YES	YES	3
P	C	I	V			
P2						
	C2.1					
		I2.1.1				
			V2.1.1.1			3
		I2.1.2				
			V2.1.2.1	YES	NO	4
			V2.1.2.2	NO		4
			V2.1.2.4	NO		4
			V2.1.2.5	NO		4
			V2.1.2.7	NO		3
			V2.1.2.8	YES	NO	3
		I2.1.3				
			V2.1.3.1	YES	YES	4
			V2.1.3.2	YES	YES	4
			V2.1.3.6	YES	YES	4
		I2.1.4				
			V2.1.4.3	YES	YES	4
			V2.1.4.X	YES	YES	4
			V2.1.4.4			4
			V2.1.4.6			4
		I2.1.5				
			V2.1.5.3	NO		4
			V2.1.5.4	NO		4
		I2.1.6				
			V2.1.6.1	**		3
			V2.1.6.2	**		3
			V2.1.6.3	**		4

** See Table 5A for observations regarding these

ıbhu, *et al.* 1999.

2	4	5	4	5	3	1	5	5	5	5	5
	3		4		3						
5	3	2	3	3	3	3	5	2	2	2	2
2	3	2	3	2	4	2	5	5	2	5	2
5	3	2	3	2	3	4	4	2	2	2	2
4	4	2	3	2	4	4	5	2	2	1	2
3	2	3	3	2	3	4	3	2	2	3	2
5	2	5	3	4	3	4	3	3	3	2	5
5	2	2	11	5	3	5	5	4	5	5	3
5	2	4	3	4	3	5	5	5	5	3	3
5	2	5	3	4	3	5	5	5	5	5	4
5	2	5	3	4	3	5	5	5	5	5	4
5	2	2	3	2	3	5	5	2	4	5	4
	4		4		4						
	2		4		3						
3	4	2	3	2	4	2	5	3	2	5	2
3	3	4	3	5	3	3	5	4	3	5	3
3	3	1	3	5	3		5	4	3	3	2
3	2	1	3	5	3	3	5	3	3	5	3
3	2	1	3	5	3		5	4	3	5	2

verifiers.

Appendix 2

DISCUSSION 1:

Scores for attributes, priority for further evaluation and overall relative importance for the initial set of PCI&V

Examples of the highest scoring CNCF elements after Phase 1 include: I6.3.3 under P6: Management Impact; I7.1.4 under P7: Management Plan; and I8.1.3 under P8: Monitoring and Evaluation. Each of these indicators received the highest overall score of relative importance for their sub-group of indicators, as well as high scores of priority for further consideration and evaluation (≥0.71) and average to above-average attribute scores (≥3) and were preliminarily considered most adequate for the final set of PCI&V.

Under CNCF criterion 6.1 both I6.1.2 and I6.1.3 received almost equally high scores of relative importance (40, 42). However, I6.1.2 received higher attribute scores (all = 4) than I6.1.3 which was given a low score (2) for easy to record and interpret.

Under CNCF C6.2, measurements for protecting rare, threatened and endangered tree species, as well as the characteristics of their habitats as described in I6.2.1 were considered more important (RI = 61) than measures to control hunting, capture and collection of plant and animal species as described by I6.2.2 (RI = 39). Under C6.3 the range of scores for relative importance was relatively small (6-13) for all 12 indicators and several indicators received equal scores. The only exception was I6.3.10 with a score for RI = 3. Similarly, small score ranges were found for the sub-indicators under I7.1.2 which describes the contents of the management plan. The scores for relative importance ranged from 8-18 for the nine sub-indicators under I7.1.2 and, as with the indicators under C6.3, several sub-indicators received equal scores for importance. Small ranges in scores of relative importance generally indicate elements of relatively equal importance, yet it is noted that when large groups of elements are assessed for relative importance the ability to designate large differences of importance between elements decreases (Mendoza and Prabhu 2000).

The lowest scoring CNCF elements and subsequently, those considered the least adequate for inclusion in the final set of PCI&V included: I6.1.1, I7.1.1, and I8.1.2. Each of these elements received the lowest overall score of relative importance in their sub-group of indicators, and low scores of priority for further consideration and evaluation (≤0.57). I6.1.1 received the lowest attribute score (2) for its sensitivity to stress, while I7.1.1 and I8.1.2 did not receive notably low scores for any of the four important attributes (all ≥3).

The highest scoring CIFOR elements encompassed maintenance of the vertical structure of the forest (V2.1.2.1), the relative abundance of seedlings, saplings and

poles of canopy tree species of different regeneration guilds (V2.1.3.1), abundance of selected avian guilds (V2.1.3.2), and abundance and activity of terrestrial frugivorous mammals (V2.1.3.6). V2.1.2.1 received average to above average attribute scores (≥3), the highest overall score for relative importance within its sub-group of verifiers and was unanimously considered a priority for further consideration and evaluation (1.0). The three verifiers evaluated under I2.1.3 received almost equal scores of relative importance (33, 33.5, 33.5). They also received high scores of priority for further consideration and evaluation (≥0.71) and received average to above-average attribute scores (≥3) with the exception of a low score for ease of detection and register (2). Similarly, the scores of relative importance for the four verifiers evaluated under I2.1.4, related to richness and diversity of large butterflies (V2.1.4.3), richness/diversity and species composition of dung beetle guilds (V2.1.4.X), number of species removed from the forest for sale in local markets (V2.1.4.4) and temporal changes in species richness (V2.1.4.6) received high scores for further consideration (≥ 0.71), a very small range (20-31) of scores for relative importance and above average attribute scores (≥3), excepting low scores for their ease of detection and registration (2).

The CIFOR elements receiving the lowest scores were V2.1.2.7; V2.1.5.4 and V2.1.6.2. All three verifiers received the lowest score for relative importance in their sub-group and were not considered easy to detect or register with a score of 2. Both V2.1.2.7 and V2.1.6.2 received low scores of priority (0.50, 0.29), however V2.1.5.4 received a relatively high score of priority for further consideration and evaluation (0.71).

After Phase 2, CNCF I8.1.1 received the highest attribute scores of both sets and was subsequently recommended for the final set of PCI&V (Appendix 1 Table 4A). The CNCF element receiving the lowest attribute scores in Phase 2, sub-indicator 6.3.11g was not recommended for the final set. CIFOR V2.1.3.6 received the highest attribute scores of the CIFOR set and after modification to the original wording, was recommended for the final set. The lowest scoring CIFOR element: V2.1.4.6 was not recommended for the final set of PCI&V. In general, elements receiving above – average scores for the majority of the nine attributes evaluated in Phase 2, were modified and subsequently recommended for the final set (see Appendix 1 Table 6A for all attribute scores).

DISCUSSION 2:

Specific recommendations and observations for the initial PCI&V made by the expert group after Phase 2: Field Application and Evaluation

Under the CNCF P6: "Management Impact" it was recommended that C6.1 and C6.3 be combined to result in only two criteria under P6. Under C6.1, no indicator was recommended for inclusion neither in the final, integrated set of PCI&V due to conceptual weaknesses nor in the proposed Code of Practices (Table 7). However, in regards to the ideas associated with C6.1, it was recommended that the new, integrated criterion (C6.1 + C6.3) take into account indicators associated with the forest management and incorporate new indicators that monitor changes in species composition.

Both of the original indicators under C6.2 were recommended. In association with I6.2.1 it was noted that there exists a need for descriptions of the means for the protection, conservation and management of rare, threatened, banned, restricted and endangered tree species as well as their associated habitats, and in association with I6.2.2 descriptions of measures for controlling hunting, capture and collection of plant and animal species. It was suggested that these descriptions and measures be established and defined in the proposed Code of Practices. It was also suggested that the terms (e.g. rare, threatened, etc.) be better and clearly defined by a group of experts, based on the information available from current forest inventories. For both indicators, it was also noted that forest managers and those responsible for management evaluations must be provided with training in order to achieve accurate identification of these species.

Under C6.3, eight of the original 11 indicators were recommended, six of which were modified from their original wording. I6.3.7 was not recommended for the final set of PCI&V and considered to be more efficient if placed in proposed Code of Practices. I6.3.8 and I6.3.9 originally referred respectively, to rare and banned or restricted species. Due to redundancy in regards to the information already contemplated in I6.2.1, I6.3.8 and I6.3.9 were not individually recommended, but were combined with the final recommended version of I6.2.1 (Appendix 1 Table 5A). The recommended indicators under C6.3, were associated with the harvest intensity (I6.3.2), harvest rate (I6.3.3), harvest of all commercial species (I6.3.5), harvesting of dead wood (I6.3.10), cutting cycle (I6.3.6), control of hydric erosion and changes in natural drainage (I6.3.4), minimal impact on stand, soil and water resources (I6.3.11) and extraction operations (I6.3.12). All were considered in need of supplementary documentation in the form of lists and/or provisions in the proposed Code of Practices.

Based on the recommended modifications to P7 and its associated C&I, this principle was reworded and recommended as: "Planning". The first criterion, C7.1 was not modified and its associated indicator, 7.1.1 was recommended, with modifications, as: *"There exists a management plan developed according to the Code of Practices and legally*

approved by the State Forestry Administration". The second criterion, 7.2 and its associated indicator, 7.2.1 both reflect modifications to their original wording. It is noted that P7 and its associated C&I are significantly simplified after the recommended modifications, however, they maintain the evaluation of sustainable forest management by requiring the fulfillment of guidelines established by the proposed Code of Practices.

Under CNCF P8: "Monitoring and Evaluation", two of the original four indicators under the modified version of C8.1 were recommended for the final integrated set of PCI&V. Both I8.1.1 and I8.1.4 were recommended with revisions to the original wording (as they appear here within the context of this document).

It was noted that permanent sampling plots are essential for following changes in the ecosystem and that the proposed Code of Practices should indicate the means for their establishment, maintenance and measurement as well as the variables to analyze. Furthermore, it was recommended that the appropriate personnel should be provided with the training necessary for their installation and management. I8.1.2 was not recommended based on the view that it should be taken into account in the proposed Code of Practices, which would indicate the minimum amount of information necessary for acceptable reports and the methodology for their preparation. I8.1.3 was rejected because of redundancy and combined with I6.2.1 (see Table 7 for rejected elements).

Of the CIFOR elements evaluated under C2.1.4 of the six verifiers under I2.1.2 were recommended. The recommended verifiers are associated with the vertical structure of the forest (2.1.2.1), regeneration phases (2.1.2.4), canopy opening in the understory (2.1.2.5) and dead standing wood and on the ground (2.1.2.8). Reference data and/or monitoring was considered necessary for all four of the recommended verifiers. The original wording for each verifier was modified from an original format which included pre-set levels or ranges (typical to that of a norm), to encompass only what should be measured in relation to the indicator. V2.1.2.2 was not recommended because of poor precision in measurement and the argument that the legally permitted harvest in Costa Rica does not greatly affect the diameter distribution. V2.1.2.7 was not recommended due to present lack of precise methodologies for determining biomass (Table 7).

Under CIFOR I2.1.3, all three verifiers evaluated were recommended with revisions to the original wording. These verifiers are associated with abundance of seedlings, saplings and trees of canopy tree species belonging to different guilds of regeneration (2.1.3.1), abundance of selected bird groups (2.1.3.2) and abundance and activity of selected mammal groups (2.1.3.6). For each of these verifiers, it was noted that lists must be developed and distributed to trained personnel and that all associated information and methodologies be included in the proposed Code of Practices.

Two of the three verifiers evaluated under I2.1.4 were recommended with modifications to the original wording which originally included predefined levels. The modified version of V2.1.4.3 were recommended with need for the clear identification of the indicated species and methodologies for their sampling, to be defined in the proposed Code of Practices. V2.1.4.6 was not recommended due to the associated requirement for intensive sampling and poor precision (Table 7).

The remaining CIFOR verifiers were not recommended (Table 7). Under I2.1.5, V2.1.5.4 was not recommended based on the breadth of its scope and need for intensive sampling in the field. The three verifiers evaluated under I2.1.6 were not recommended based on insufficient scientific development (methodologically, analytically). However, these three verifiers were considered relevant for the evaluation of ecological sustainability and recommended for further scientific research and development.

Títulos publicados en esta Colección

(Anteriormente llamada Colección Silvicultura y Manejo de Bosques Naturales)

1. **Blaser, J.; Camacho, M.** Estructura, composición y aspectos silviculturales de un bosque de roble (*Quercus* spp.) del piso montano en Costa Rica

2. **Orozco, L.** Estudio ecológico y de estructura horizontal de seis comunidades boscosas de la Cordillera de Talamanca, Costa Rica

3. **Pedroni, L.** Sobre la producción de carbón en los robledales de altura de Costa Rica

4. **Räber, C.** Regeneración natural sobre los árboles muertos en un bosque nublado de Costa Rica

5. **Finegan, B.** El potencial de manejo de los bosques húmedos secundarios neotropicales de las tierras bajas

6. **Aus der Beek, R.; Sáenz, G.** Manejo forestal basado en la regeneración natural del bosque; estudio de caso en los robledales de altura de la Cordillera de Talamanca, Costa Rica

7. **Hutchinson, I.D.** Puntos de partida y muestreo diagnóstico para la silvicultura de bosques naturales del trópico húmedo

8. **Aus der Beek, R.; Navas, S.** Técnicas de producción y calidad del carbón vegetal en los robledales de altura de Costa Rica

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The Natural Forest Management Unit (UMBN) of CATIE was established to promote the diversified, sustainable management of natural forests in the neotropics. The mission of the UMBN is to foster, promote and carry out research and technical cooperation activities which contribute to the management of natural forests, and which seek to reduce the conversion of forested areas to other land-uses. Appropriate diversified, forest management has shown to be an effective strategy for conserving biodiversity and maintaining ecosystem productivity, and at the same time foster sustainable and equitable development in the Central American region.