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DETERMINATION OF AN INTEGRATED SET OF PRINCIPLES, CRITERIA, INDICATORS AND VERIFIERS FOR THE EVALUATION OF THE ECOLOGICAL SUSTAINABILITY OF FOREST MANAGEMENT IN COSTA RICA

POR

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Thesis submitted for consideration by the Graduate School, Program of Education for Development and Conservation of the Tropical Agricultural Center for Research and Higher Education as a partial requisite for the degree of:

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DEDICATION

for my mother

may this reflect, in part, the result
of her unyielding love, support and contribution

We do not inherit this earth from our ancestors, we borrow it from our children
- Navajo Indian proverb -

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Never regard study as duty, but as the enviable opportunity to learn to know the liberating influence of beauty in the realm of the spirit of your own personal joy, and the profit of the community to which your later work belongs

Albert Einstein

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Key words: forest management standard, principles criteria indicators and verifiers, sustainable forest management, adaptive forest management, ecological sustainability, Costa Rica

ABSTRACT

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. Evaluations can be achieved through the use of practical and scientifically founded sets of principles, criteria, indicators and (in specific cases) verifiers (PCI&V). These sets of PCI&V should be tested and validated through application and practice, and count with the tools necessary for their implementation (i.e. documentation on their justification, their conceptual bases and guides for their application).

The research herein presented was carried out with the general objective of developing an integrated set of site-specific PCI&V for the reliable and efficient evaluation of ecological sustainability of forest management in Costa Rica. The process began with an initial set of PCI&V comprised of elements from the Costa Rican national forest management standard (CNCF 1999) and the CIFOR generic C&I template (CIFOR C&I Team 1999). The concept of integration of elements from the two original sets of C&I was incorporated with the objective of reaching a balance between aspects which define good forest management practices, typical of the CNCF set (predominated by elements which evaluate forest management *inputs* and *processes*), and aspects which monitor forest management impacts, typical of the CIFOR set (predominated by elements which evaluate the *results* of forest management. The desired outcome was the determination of an integrated set of PCI&V comprising elements for evaluating the *inputs* (objects or intentions, i.e. forest management plan), *processes* (actions, i.e. silvicultural treatments, timber extraction) and *results* (state or response of eco- or social system components to forest management, i.e. state of regeneration) of forest management.

The research process consisted of three phases of evaluation and participation by a multi-disciplinary group of experts in forest ecology and management. The three phases included: evaluations on the relative importance of the initial PCI&V; application, testing and evaluation in the field and a final workshop with a larger group of experts for the revision and approval of the results and recommendations.

The strengths and weaknesses of the original, individual PCI&V were identified through this research, as well as the strengths, weaknesses and gaps in the evaluated aspects of the CNCF and CIFOR sets. Of the initial integrated set of PCI&V, 55% were recommend for the final set, of these 86% were modified from their original wording before recommendation and 91% require supplementary documentation for implementation and evaluation. Forty-five percent of the initial elements 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%). Based on the recommended elements, an integrated set of PCI&V was developed for the evaluation of

ecological sustainability of managed forests in Costa Rica. The integrated set consists of 3 principles, 5 criteria, 17 indicators and 10 verifiers. Of the 22 final C&I, 4 account for the evaluation of forest management *inputs*, 13 are for evaluating the *processes* of forest management and 5 are for evaluating the *results* of forest management and its impacts.

General recommendations in regards to the current state of standard development in Costa Rica included the need for an instructive manual for the implementation of the national PC&I, as well as the need for an instructive manual or a national *code of practices* for the implementation of sustainable forest management practices. Throughout the process there was a clear identification of the need for the realistic distribution of institutional responsibilities for C&I implementation. In Costa Rica, distribution and designation of responsibility should include important actors such as forest operators, forest managers, regents, evaluators, research institutions and the State Forestry Administration.

McGinley, K. 2000. Determinación de un conjunto integrado de principios, criterios, indicadores y verificadores para la evaluación de la sostenibilidad ecológica del manejo forestal en Costa Rica. Tesis M.Sc. CATIE. Turrialba, Costa Rica. p. 116

Palabras claves: estándares para el manejo forestal, principios criterios indicadores y verificadores, manejo forestal adaptativo, sostenibilidad ecológica, Costa Rica

RESUMEN

Hoy en día la evaluación de la sostenibilidad del manejo forestal se considera elemental para asegurar el mantenimiento de la producción y las funciones ecológicas y socioeconómicas de los ecosistemas forestales. Esta evaluación se puede lograr mediante la implementación de un conjunto de principios, criterios, indicadores y (en casos específicos) verificadores (PCI&V) prácticos y científicamente bien fundamentados. El conjunto de PCI&V deben ser probados y validados en la práctica y además deben contar con los instrumentos necesarios para su implementación, tales como: la documentación de su justificación, bases conceptuales y guías de aplicación.

Esta investigación contempló el proceso para desarrollar un conjunto integrado de PCI&V para la evaluación confiable y eficiente de la sostenibilidad ecológica del manejo forestal en las zonas Norte y Atlántica de Costa Rica. El proceso tomó como base los PCI&V relacionados a la sostenibilidad ecológica de la Comisión Nacional de Certificación Forestal de Costa Rica (CNCF) y del Centro para la Investigación Forestal Internacional (CIFOR). Se incorporó el aspecto de integración de elementos de los dos entes con la meta de lograr un balance entre los aspectos de la buena práctica que caracterizan los PC&I de la CNCF y los aspectos del monitoreo de los resultados del manejo forestal que caracterizan los PCI&V del CIFOR.

La metodología contempló tres fases de evaluación con la participación de un grupo multi-disciplinario de expertos en las áreas de manejo y ecología forestal. Las tres fases abarcaron una evaluación de gabinete según importancia relativa de cada elemento, la aplicación, prueba y evaluación en el campo del desempeño de los PCI&V, y un taller final con un grupo ampliado de expertos para la revisión, discusión y consenso de los resultados.

Mediante este proceso, se identificaron las fortalezas y las debilidades de los estándares de la CNCF y del CIFOR, así como de los PCI&V individuales. Al final del proceso, se recomendó 55% de los PCI&V inicialmente propuestos, de los cuales el 85% fueron modificados. Cuarenticinco por ciento de los PCI&V fueron rechazados por las razones siguientes: redundancia (17%), debilidad conceptual (17%), baja precisión (17%), necesidad de desarrollo científico adicional (17%) y recomendación de incorporación en un código de prácticas (33%). Con base en los PCI&V recomendados, se estableció un conjunto integrado para la evaluación de la sostenibilidad ecológica de las operaciones forestales en las zonas Norte y Atlántica de Costa Rica. Este conjunto consiste en tres principios, cinco criterios, diecisiete indicadores y diez verificadores. De los 22 criterios e indicadores (C&I) dentro del conjunto final, cuatro evalúan los insumos y trece evalúan los procesos del manejo forestal. Estos C&I se pueden usar para determinar el cumplimiento de las operaciones de manejo con conceptos de buena práctica. Los otros cinco C&I del conjunto final sirven para evaluar los resultados del manejo y abarcan el monitoreo de los impactos de las operaciones forestales.

Otro aspecto importante del proceso fue la asignación de responsabilidad institucional para los diferentes componentes de la evaluación de la sostenibilidad ecológica mediante PCI&V. En cuanto a la implementación de un conjunto integrado de PCI&V que evalúan insumos, procesos y resultados, queda claro que un aspecto fundamental es la asignación realista de las responsabilidades entre actores claves como el manejador de bosque, el operador forestal, el regente, las instituciones de investigación y el Estado.

I. Introduction

1.1 Background

1.1.1 Framework for forest management standards

Over the last decade, as global awareness of the multiple benefits provided by forest ecosystems has increased while global forest coverage has continued to decrease, the subsequent demands for sustainability have resulted in various initiatives to define guidelines for sustainable forest management at global, regional, national and forest management unit (FMU) levels (Higman *et al.* 1999). These initiatives have led to the development of forest management standards, considered important "tools" for promoting sustainable forest management and effective means for monitoring and evaluating forest management practices (Lammerts van Bueren and Blom 1997). Such standards are based on a hierarchical framework of principles, criteria, indicators and in certain cases, verifiers (PCI&V) that aim to define the elements and parameters of sustainable forest management.

Lammerts van Bueren and Blom (1997) define principles as fundamental laws or rules which serve as a basis for reasoning and action. They are the objectives or attitudes concerning the function of the forest ecosystem or related social systems. A criterion is defined as the state or aspect of the eco- or social system, which should be in place as a result of adherence to a principle. Criteria create a link between the conceptual or transcendental nature of principles and the objective, assessable nature of indicators. Indicators can be interpreted as the quantitative or qualitative parameters which can be assessed in relation to a criterion. They describe in an objectively verifiable and unambiguous way, features of the ecosystem, the related social systems or the prevailing policy and management conditions, indicating the state of these components. Indicators are measurable parameters that simplify the evaluation process by providing tangible information about specific components of the related forest systems. Verifiers are the sources of information or reference values associated with specific indicators. They provide descriptions of how an indicator should be measured in the field, clarifying the way in which indicators are examined and how reference values are established. (Lammerts van Bueren and Blom 1997).

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Within the framework of forest management standards, criteria define the desired state or aspect of a forest system component while indicators define the parameters by which these states or aspects can be assessed. Criteria and indicators (C&I) are developed in accordance with different attributes of the forest ecosystem or associated social systems and can be classified by these attributes. One system of classification, groups C&I according to attributes associated with the *inputs*, *processes* and *outcomes* of forest management[1].

C&I classified as *input* or *process* take into account objects (i.e. the management plan), intentions (i.e. silvicultural treatments planned in the management plan) or actions (i.e. harvesting) introduced into the eco- or social systems by human driven processes (Lammerts van Bueren and Blom 1997). C&I based on the widely-accepted Forest Stewardship Council (FSC) principles and criteria tend to be classified by *input* and *process* parameters which principally seek to reduce the impact of management operations on forest systems and define good management practices, providing a means for determining conformity to predefined standards associated with the eco- or social system (FSC 1998). *Input* and *process* C&I are often easy to apply, measure and evaluate, but they do not provide a direct measure of forest management impacts on the affected systems (Lammerts van Bueren and Blom 1997; Prabhu *et al.* 1999).

C&I characterized by *outcome* parameters, on the other hand, define the desired or actual results of the management process and provide measures for the impacts of forest management on the associated systems. *Outcome* C&I can be used to determine the state (i.e. habitat diversity) or capacity of the system component (i.e. change in nutrient cycling) in respect to management impacts, provide unambiguous information for ecosystem 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 "*stresses*" that affect the "*states*" of forest systems and the "*responses*" that these systems demonstrate. *Stress* refers to the external factors, forces or stimuli applied to the eco- or social system that can cause changes in the status of system components (i.e. silvicultural treatments). *State* is the

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

desired condition or quality of the particular system component (i.e. status of decomposition and nutrient cycling), regardless of the *stresses* that act upon it. *Response* is the human- or ecosystem – related reaction to *pressures* or changes in the *state* of the system (i.e. diversity of selected groups show no significant change) (Prabhu *et al.* 1999).

1.1.2 Making forest management adaptive

Many of the forest management standards in development and practice today consist primarily of *input* and *process* C&I which define good management practices and often establish predefined standards for reducing management impacts.[2] These types of 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 very persuasive (Howard and Majid 1996; Raison and Flinn 2000) and sustainability assessments based only on *inputs* and *processes* do not provide the information necessary for management to be adaptive. Yet, when *outcomes* and *results* are incorporated into forest management standards through monitoring and evaluation, the associated C&I provide important information for adaptive management, as well as mechanisms for continuous learning (Howard and Majid 1996). An integrated set of PCI&V that evaluates the *inputs*, *processes* and *outcomes* of forest management would provide the means to determine the actual *state* of the system and the system *responses* to management impacts and subsequently, identify *stresses* or aspects of management practices which can be adapted to reduce negative impacts and promote sustainability.

Although capacity to implement monitoring in the neotropics is limited, the complexity of tropical forest ecosystems results in a required 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 their facilitated understanding, determination of

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

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, characteristic of tropical forests (Taylor 1996). Taking into account the complexity and dynamics of natural ecosystems, Johnson (1999) states that "the overall goal of adaptive management is not to maintain an optimal condition of the resource, but to develop an optimal management capacity [that is used to] manage within a range of acceptable outcomes while avoiding catastrophes and irreversible negative effects." In the development of adaptive forest management, evaluation tools which assess forest management *inputs*, *processes* and *outcomes* as well as system *stresses*, *states* and *responses* become important components in the six basic steps of adaptive management identified by Taylor (1996): assessment, design, implementation, monitoring, evaluation and adjustment of management activities (Figure 1).

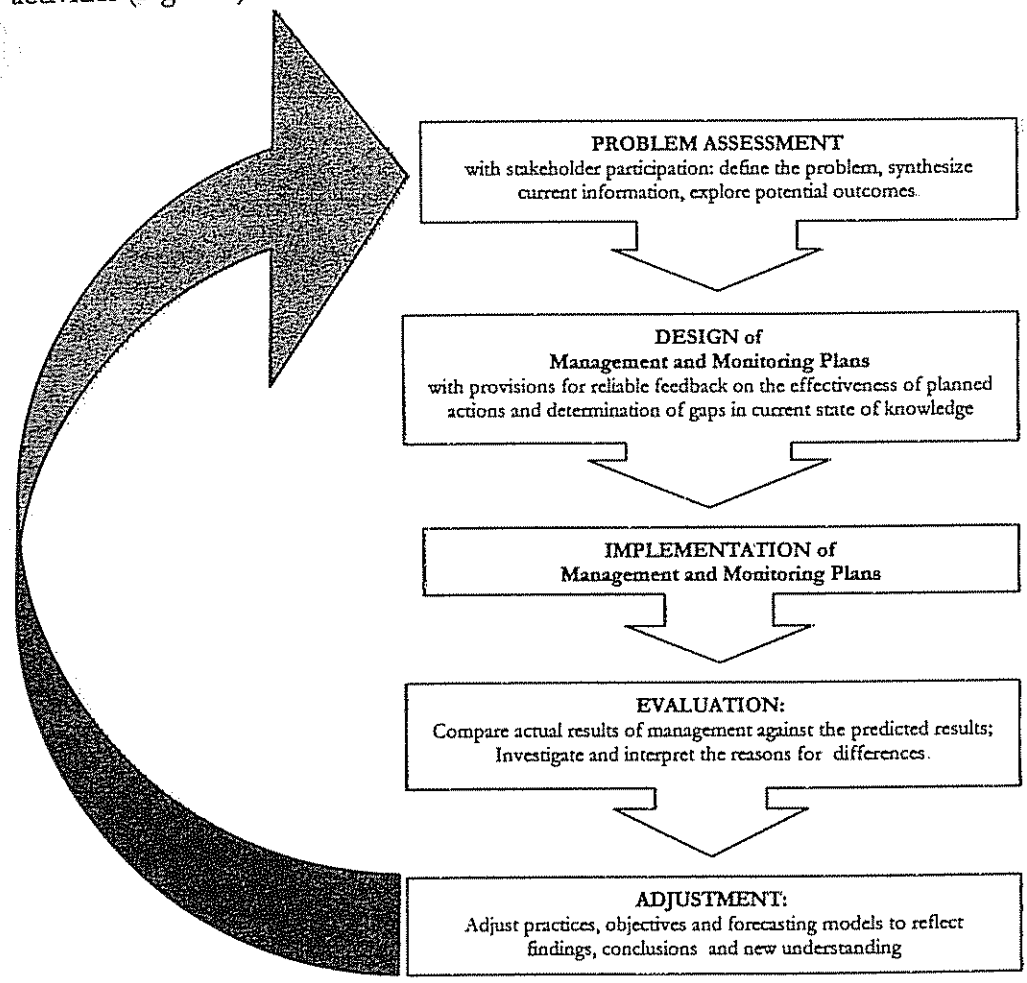

Figure 1. Framework for adaptive management (adapted from Taylor 1996).

1.1.3 Development of forest management standards in the neotropics

Much progress has been made in the development of forest management standards at regional and national levels in many tropical countries over the last ten years and most notably, there seems to be a strong common foundation for evaluating sustainability among different processes (Castañeda 1999). This higher level development of forest management standards, and their respective principles and criteria provide the bases for further development of criteria, indicators and verifiers (CI&V) on a local scale or FMU level in accordance with specific site conditions (Lammerts van Bueren and Blom 1997). Site specific CI&V can be used as tools for assessing the state of particular system conditions and determining the sustainability of forest management practices at local levels (Prabhu, *et al.* 1999).

In Costa Rica, initiatives to create a forest management standard began in 1994. The national set of PC&I (CNCF 1999) was developed in cooperation with the public and private sectors, by the National Commission for Forestry Certification and based on the forest management standard defined by the Forest Stewardship Council (FSC). The national standard was created with the hopes of establishing an accepted and applicable mechanism for nationwide measurement and monitoring of forest management at the forest management unit level (Campos and Müller 1999). Also 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 development of a core set 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 generic C&I template (the Generic C&I Template, CIFOR C&I Team, 1999).

1.2 Justification

Despite the initiatives and advances at regional, national and FMU levels in the development of forest management standards, there is little experience or understanding of the process of site specific C&I development in the neotropics. Once developed, site specific C&I must also

be tested and validated through practice and implementation, and count with the tools necessary for their application, such as documentation on their justification and conceptual bases and guides for their application. Currently there in Costa Rica, a guide for the application and analysis of C&I is in development, however no guide or protocol for C&I application existed at the time of this study nor did there exist forest-type specific C&I exist that had been tested or validated in the field. However, as a 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, 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. This information can be used as the basis for developing, testing and justifying a site specific set of CI&V for the evaluation of the ecological sustainability of managed forests in the region.

In 1999, a group of researchers from the Tropical Agricultural Center for Research and Higher Education (CATIE) and CIFOR initiated a process for the development of an integrated 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 Atlantic region of Nicaragua. The forests in these areas represent valuable timber and non-timber forest resources, yet they are under continuous pressure from traditional, destructive harvesting practices as well as demands for land for settlement and agriculture. The CATIE/CIFOR process was developed with the objective of contributing to the assessment of the sustainability of forest management as a means for assuring the maintenance of production and the ecological and socioeconomic functions of these forest systems. Results from the process are expected to contribute, furthermore, to advances in management capacity in the region and to strengthen institutional capacity in the control and monitoring of forestry operations. The CATIE/CIFOR initiative 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 C&I for the forests of a defined region. The present thesis represents the realization of the Costa Rican aspect of this joint initiative. It signifies a contribution to the definition of sustainable forest management in Costa Rica and provides a practical and scientifically-based tool for evaluating the ecological sustainability of forest management in the country.

1.3 Objectives

1.3.1 General Objective:

- Contribute to the understanding of the development process of forest-type specific criteria and indicators for the assessment of the ecological sustainability of natural tropical forest management, using existing generic sets of criteria and indicators as a starting point.

1.3.2 Specific Objectives:

- Assess the applicability, interpretability and efficiency of the generic principles, criteria and indicators 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 *stress*, *state* and *response* elements for the evaluation of ecological sustainability.
- Propose an integrated set of principles, criteria, indicators and verifiers for the evaluation of ecological sustainability of forest management operations in Costa Rica, according to the results of expert assessment and application in the field.

1.4 Hypotheses:

An integrated set of *input*, *process* and *outcome* PCI&V, based on ecosystem *stress*, *state* and *response*, can be developed through the testing and selection of elements from the CNCF and CIFOR forest management standards, that meet the needs of different stakeholders in the assessment of the ecological impacts of forest management practices in the Northern and Atlantic forests of Costa Rica .

With respect to the current state of knowledge, there exists a difference in the applicability, interpretability and efficiency of *input* and *process* CI&V versus *outcome* CI&V for the evaluation of ecological sustainability.

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II. LITERATURE REVIEW

2.1. The General Framework

Tropical forests are considered among the most valuable ecosystems in the world – ecologically, biologically, economically and socially. They are valued not only for their high levels of biodiversity, but for their association and relation with the existence and preservation of indigenous and local cultures and for providing important environmental services such as carbon sequestration, water and soil protection and climate regulation (WCMC 1992; Colfer *et al.* 1997). Nonetheless, deforestation and forest degradation continue to occur in the tropics (Putz *et al.* 2000) and can result in potentially significant losses of biodiversity at local levels, changes in nutrient cycling and other ecological processes at landscape levels and even climatic changes at regional and global levels (Noss 1990). In view of the inherent values of tropical forests and the persisting threats of deforestation, significant efforts have arisen over the last decade to curb destructive trends through the development, implementation, monitoring and regulation of forest management practices (Prabhu *et al.* 1996, Castañeda 1999).

Forestry practices in the tropics today encompass varying intensities of management, ranging from low impact natural forest management to high intensity logging. Forest management impacts and their effects on biodiversity depend largely on harvest intensity and the care taken in planning and extraction as well as post-harvest interventions (Bawa and Seidler 1997; Johns 1997). At one extreme, forest management may sustainably produce an array of products and favorably conserve the biological diversity of a managed area. Yet, at the other extreme "unplanned management" may significantly alter the area, degrading ecosystem functions or reducing the forest to a significantly simplified system. Ideally, forest management can be carried out so that the associated anthropogenic disturbances mimic natural disturbances, thus mimicking the natural processes that create and conserve biodiversity in tropical forests (Sayer and Wegge 1991).

Efforts to conserve biodiversity and reverse current tropical deforestation rates are primarily focused on conservation, sustainable production, improved practices and more so recently, on adaptive natural forest management (Johns 1997, Lindenmeyer *et al.* 2000). The concept of natural forest management (NFM) is continuously evolving, changing throughout history according to changes in times and the needs of society. Traditionally, most forest managers

considered NFM to be the "controlled and regulated harvest of timber species in natural forests, combined with the use of various silvicultural and protective measurements to sustain or increase the commercial value of forest stands that return after the initial logging" (Johnson and Cabarle 1993). In the last decade NFM has broadened its focus from sustainable timber production to incorporate the sustainability of ecological, social and economic functions. The International Tropical Timber Organization (ITTO) defines NFM as "the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to a continuous flow of desired forest products and services without undue reduction in its inherent values and future productivity and without undue undesirable effects on the physical and social environment" (ITTO 1990). Recently, the concept of adaptability has become more prominent in sustainable forest management, taking into account the dynamism and complexity of the natural and human components of forest systems. Forest management becomes adaptive when it is part of a continuous learning process that monitors the impacts of forest operations and activities, assesses the negative impacts and incorporates the results and new information into the management system, improving practices in subsequent management cycles (Baskerville 1985, Bormann *et al.* 1995).

2.2. Standards for Natural Forest Management

2.2.1 Basics of Forest Management Standards

Over the last decade many efforts have arisen to define and develop forest management standards at global, regional, national and FMU levels that can be used to measure, monitor and control forest management practices. Lammerts van Bueren and Blom (1997) have developed a conceptual means for the formulation of forest management standards based on hierarchically placed principles, criteria, indicators and verifiers (see section 1.1.1 for definitions). A standard can be considered as the overall goal that is translated through principles and criteria, which are analyzed through the use of indicators and verifiers. The hierarchical framework suggested by Lammerts van Bueren and Blom (1997) aims to achieve consistency both horizontally and vertically at the different levels of organization within and between forest management standards. Horizontal consistency refers to parameters that do not overlap at the same level and vertical consistency refers to the correct placement of parameters within different levels of the hierarchy. When this consistency is achieved principles appear as "fundamental laws or rules" concerning the management process, criteria

refer to the actual results or desired outcomes of the management process, and indicators are quantitative or qualitative parameters which can be assessed using the information provided by verifiers and describe specific features of the eco- and social systems. The goal for describing a hierarchical framework is linked to the need for consistency within forest management standards and comparability between them at the same and different levels of development.

In the different processes which have arisen at different levels to define forest management standards, Higman *et al.* (1999) have identified two basic types of standards. The first type guarantees acceptable minimum levels of performance by defining fixed levels and actions which must be met in order for management to be considered sustainable. These types of standards are known as "performance standards". Performance standards are evaluated on a "pass/fail" basis in which the system component evaluated either meets the set standard or does not. Performance standards must be developed for each level of organization (regional, national, FMU) according to level-specific conditions and thus cannot be developed on a global basis, fitting for all forest types or conditions. Most processes to date primarily constitute performance standards (i.e. FSC P&C and FSC based standards, ITTO C&I and ITTO based standards).

The second type of standard identified by Higman *et al.* (1999) defines how to carry out the processes that are believed to ensure consistent, sustainable performance but do not set performance levels which must be met. These are known as "process standards". Process standards are generally based on documented management systems which set objectives and management goals and make a commitment to a process of continuing improvement. These standards require that monitoring is carried out and that the resulting information is fed back into the system. Through process standards a framework for controlling, maintaining and improving performance is provided but there is no guarantee that certain levels of performance will be met. It is important to note that performance and process standards are not mutually exclusive and can complement eachother when combined in a practical, efficient and applicable manner. (Higman *et al.* 1999).

Monitoring is an important aspect in the evaluation of sustainability and thus, of forest management standards. It involves repeated observations or inventories over time and space

that serve to measure change and response of ecosystem components (Stork and Samways 1996, Lindenmeyer *et al.* 2000). Monitoring is generally oriented towards the goal of "predicting" the response and behavior of key variables based on continuous observations so that management might be improved or so that precautions might be taken against early signs of negative changes in the monitored system. In forest management, where sustainability is directly related to the vitality of the forest system and its levels of productivity, monitoring acts as a mechanism to note changes in the ecosystem that may require adjustments or corrections (Boyle and Sayer 1995). Monitoring can be used to improve control of forest management practices and is often contemplated as an important component of standards for sustainable forest management. Many of the C&I that are based on outcome parameters can be used as a means for monitoring (see section 1.1.1 for definitions of outcome parameters). The information that these C&I provide can be reincorporated or "fed back" into the system, providing a means for continued improvement in forest management (Lammerts van Bueren and Blom 1997; Prabhu *et al.* 1999).

2.2.2 Developments in Forest Management Standards

2.2.2.1 United Nations Conference on Environment and Development

Following initial efforts for the development of forest management guidelines established by ITTO in 1990 (section 2.2.2.2), extended efforts have since been made at international, regional and sub-regional levels of organization for the development of forest management standards. These efforts were greatly increased after the Earth Summit Meeting of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. Among the conventions and treaties developed at UNCED, the Guiding Principles on Forests was supported and endorsed by more than 170 countries. This endorsement resulted in the first global consensus on forest policy. Agenda 21,a global plan for action, was another product from UNCED and includes several chapters focused on the sustainability of the world's forests. Chapter 11 encompasses details on deforestation and highlights the need for "the formulation of scientifically sound criteria and guidelines for the management, conservation and sustainable development of all forest types" (Keating 1993). Many different processes for the development of forest management standards have arisen at international, regional and national levels since UNCED. Below are a few examples of these processes and their development at different levels of organization.

2.2.2.2 International Initiatives

Several international initiatives for determining standards for forest management have been in development over the last decade. These initiatives primarily attempt to define a series of basic C&I that are accepted and recognized on a global level which can be adapted to specific conditions at lower levels of organization (i.e. national, FMU). Below are four of the most-widely recognized processes.

International Tropical Timber Organization

The first widely recognized and published guidelines for sustainable forest management were developed by the International Tropical Timber Organization (ITTO) before the United Nations Conference on Environment and Development in 1990. Following the creation of these guidelines, ITTO developed and published a set of C&I for measuring sustainable tropical forest management for member countries in 1992. These were soon followed by guidelines for measuring sustainability in managed forest plantations and for measuring the conservation of biological diversity in managed forests. Through the development of the initial guidelines, ITTO provided a precedent for the creation of standards for sustainable forest management (ITTO 1992, ITTO 1998). Since the first set of guidelines was published in 1992, ITTO has reviewed and revised the initial C&I and published an updated set of seven criteria and 66 indicators for the sustainable management of natural forests in the tropics, applicable at the national and FMU level. The revised ITTO C&I set includes aspects of management practices as well as biodiversity and community involvement (ITTO 1999).

Currently, efforts are being made to adapt the ITTO C&I to national standards for member countries. The Colombian project for the application and evaluation of C&I for the sustainable management of national forests is an example of the national level application of ITTO's C&I. In 1998, the project began a process of applying, evaluating and revising the ITTO C&I in order to determine a national set of C&I for Colombia. The methodology consisted of four phases which included (1) the revision and analysis of associated documentation, (2) seminars, workshops and meetings, (3) field and office research and (4) construction of a preliminary, national C&I set. The resulting set of C&I consists of 7 criteria and 53 indicators which were accepted and adapted from the original ITTO set to fit national

conditions in Colombia. These C&I are currently being applied in a pilot test in two regions of Colombia as part of a validation phase, at the end of which the C&I will be revised again, where necessary and made into national law (Colombian Republic 1999).

Forest Stewardship Council

The Forest Stewardship Council (FSC) is a non – governmental organization (NGO) that defines sustainable forest management through a generic standard of forestry principles and criteria. The FSC also accredits certification organizations, providing authenticity to their claims of certifiable forest management. To date, the FSC has accredited 6 certifying bodies which include: the Forest Conservation Program of Scientific Certifications Systems (US), Woodmark of Soil Association (UK), QUALIFOR of SGS Forestry (UK), SmartWood of Rainforest Alliance (US), EKO of Skal (Netherlands) and IMO (Institut Fur Marktokologie) (Higman *et al.* 2000). In 1996, the FSC published a set of P&C with the objective of developing a globally accepted standard for voluntary forest certification as an incentive for improving forest management. These P&C were developed at a general level to cover all forest types and country conditions, with the intention that indicators would be developed at regional or national levels according to site specifics. The FSC set of P&C emphasizes minimization of the negative environmental impacts of forest operations, maximization of social benefits and maintenance of managed areas in the most natural state possible (FSC 1999). This set of P&C focuses primarily on the operational aspects of forest management and setting performance standards which should be met in order for forest management to be sustainable (section 2.2.1). The significance of the FSC P&C and the associated accredited certifiers includes their broad acceptance by environmental, consumer, and retail groups world-wide (Higman *et al.* 1999). Currently, there are many countries in the process of developing national standards based on FSC P&C (i.e.: Belgium, Sweden, Bolivia, Costa Rica).

ISO 14001

The International Organization for Standardization developed a voluntary standard for the certification of environmental management systems applicable in any country, published in 1996. ISO 14001 emphasizes the management system and its use of monitoring, feedback, and continuous improvement as well as the development of related policy. ISO 14001 sets standards for the processes involved in management rather than setting performance standards

(except general legal requirements) (section 2.2.1). This standard ensures that management systems are in place and that they allow for continual improvement of environmental performance. Some countries have taken the initiative to adapt the standards set by ISO 14001 in the development of a national standard for forest management; as is the case with the Canadian sustainable forest management standard and the standard proposed by the American Forest and Paper Association (AFPA) for forest management in the US (Higman *et al.* 1999).

Taking into account that ISO 14001 is not specific to forestry, a technical report (ISO Technical Report 14061) was developed as a proposal for forest management. This report proposes using both the concepts of performance standards and process standards for the development of standards for forest management systems. The objective this technical report was to explore an integration of performance standards which define specific objects or levels (typical of FSC P&C and ITTO C&I) and process standards which define the tools and actions necessary for achieving sustainability (typical of ISO14001) (Higman *et al.* 1999).

Center for International Forestry Research

In 1996, the Center for International Forestry Research (CIFOR) initiated a process for the development of a generic template of PCI&V which could be specified to fit local conditions. With a group of independent, international multi-disciplinary teams, CIFOR tested over 1100 C&I from existing forest management standards, in Germany; Indonesia; Cote d' Ivoire, Cameroon, Brazil and Austria. The goal of the C&I testing was the identification of a core set of applicable, objective, relevant and cost-effective C&I for the measurement of sustainable forest management (Prabhu *et al.* 1996, 1999). As part of their philosophy, CIFOR emphasizes the importance of evaluating the quality of forest management and the impacts that management has on eco- and social system functions as well as identifying the areas where practices can be improved when determining the sustainability of forest management. CIFOR also proposes that adaptive approaches to management should be incorporated into forest management, in consideration of the dynamic characteristics of the natural and social components of forest systems. Based on these philosophies the resulting generic C&I set includes elements for evaluating human inputs and forest practices, as well as the state of eco- and social systems and the impacts of management, providing the means for identifying where management can be adapted or improved (Prabhu *et al.* 1999, Soberón *et al.* 2000).

2.2.2.3 Regional Initiatives

Many processes have also developed at the regional level. These efforts primarily propose to develop a framework for assessing the state and sustainability of forest management in collaborating countries. Following are three examples of regional processes and their recent developments.

The Montreal Process

The Montreal Process began in 1993 and involved non-European countries with extensions of temperate and boreal forests. The process initiated with the participation of ten countries and currently includes twelve countries (Argentina, Australia, Chile, China, Japan, Korea, Mexico, New Zealand, Russia, Uruguay, USA) which account for 60% of the world's forests, 90% of the world's temperate and boreal forests, 45% of the world trade in wood and wood products and 35% of the world's population (Montreal Process Liaison Office (MPLO) 2000). The objective of the Montreal Process is the development and international agreement of C&I for sustainable management of boreal and temperate forests in non-European countries. The process culminated with the signing of the Santiago Declaration in 1995 and the creation of a non-binding set of seven criteria and 67 indicators at the national level. These C&I were intended to provide tools for characterizing the state of participating nations' forests and for producing information on changes in forest cover and use at the national level. The Montreal Process C&I cover a wide range of issues that include indicators for production in the forest sector, recreation and tourism, employment and community needs, property rights, levels of public participation in forest planning, economic incentives and institutional capacity for forest monitoring and research (MPLO 2000).

Part of the Montreal Process philosophy is centered on the idea that C&I are not static and that they must be reviewed and refined over time in order to reflect changes in technology and society and improvements in monitoring and measuring indicators (MPLO 2000). In order to determine necessary adjustments in the original C&I set, the Montreal Process has supported national application and associated data collection. A progress report published in 2000 provides information on the current state of the Montreal Process C&I application and analysis. The report states that general data is currently being collected and reported for 68% of the proposed indicators and detailed data for 39% of the indicators. Each country has

applied and implemented the C&I under different conditions, some choosing to expand the C&I for national purposes as is the case with Russia where more indicators were incorporated for more detailed reporting. In China, the Montreal Process C&I were used as a basis for a national set which includes eight criteria and 80 indicators. Other countries (Australia, Canada, USA) report the need for the development of sub-national indicators which is currently the subject of a Montreal Process Working Group. Despite differences in forest area and ownership as well as in social, economic and political conditions, all twelve countries are committed to applying the Montreal Process C&I according to the 2000 Progress Report. Furthermore, it is expected that implementation and continuous monitoring of the C&I will provide the information necessary to assess trends in national forest conditions and to adapt national policies so that all countries involved will be able to move toward the sustainable management of their forests (MPLO 2000).

The Tarapoto Proposal

In 1995, the Tarapoto Proposal was developed by the eight countries comprising the Amazon region (Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela). The proposal sought to establish common guidelines for forest management in the Amazon. Initiatives were founded on desires to ensure continued wood production and economic development, within the boundaries of ecological sustainability, and on concerns for the potential threats caused by international timber import bans and tariff barriers. The proposal resulted in the development of 12 criteria and 81 indicators for the determination of progress towards sustainably managed forests at the national, global and FMU level (Crossley 1996). The established C&I include aspects of maintaining productivity, biological diversity, ecological services, and socio-economic benefits. Analysis and evaluation of the proposed set of C&I is currently underway in each of the participating countries to determine the relevance of the proposed C&I in association with national conditions and capacities for implementation. After completion of the country level evaluations, the second meeting of the Tarapoto Proposal is expected to take place in which the C&I will be reviewed, revised and adjusted where necessary and then put into practice, converting the proposal into the Tarapoto Process (Castañeda 1999; Finegan and Campos 2000).

Lepaterique Process

The countries of Central America developed a proposed set of C&I for sustainable forest management with support from the Food and Agriculture Organization (FAO) and the Central American Council for Forests and Protected Areas through the Lepaterique Process in 1997. The objectives included the formulation of regional and national C&I, as well as recommendations for C&I implementation in each country according to ecological, economic, social and political conditions. C&I were proposed for managed forests as well as protected areas and for different forest types including: high, tropical humid, and deciduous forests (Corrales 1997). Since the creation of the initially proposed C&I, a process of evaluation has been initiated for C&I validation in the participating countries. Efforts have also been made to develop a proposal for FMU level C&I. Upon completion of the validation process, the proposed C&I will be revised and implemented on a regional level (Castañeda 1999).

2.2.2.4 National Initiatives: the Case of Costa Rica

There exist varied degrees of development in national forest management standards and subsequent certification initiatives around the world and in association with the processes described above. In South America, Bolivia claims the most widely recognized and progressed efforts in development of national standards for forest management. In Central America, many countries have partaken in the pursuit of a regional standards system (mentioned above) as well as a regional certification scheme through the Central American Council for Forests and Protected Areas (CCBAP) which was created to reach consensus on regionally applicable C&I (de Camino and Alfaro 1997; Shima and Koblents 1999) . At present in Central America, Costa Rica has made the most progress in the development and application of a national forest management standard (Campos and Müller 1999).

Initiatives began in 1994 to development a national forest management standard in Costa Rica, led by the private forestry sector and directed by the Costa Rican Chamber of Forestry, with support from two international agencies. With the rise of a political movement aimed at banning all forestry activities in natural forests, the private sector initiated a campaign to propose a system of control for the harvesting of timber. This system of control would

guarantee the sustained use of Costa Rican forest resources and could be used to strengthen the governing bodies of the forestry sector through control and monitoring of current and future forestry activities (Watson *et al.* 1998; Campos and Müller 1999).

An important result of the process initiated in 1994 was the decree of Forestry Bill 7575, published in 1996, which provided for the development of new forestry initiatives and the creation of National Commission for Forestry Certification (CNCF). In Article 20 of the new bill, it was established that management in natural forests must comply with an approved standard for sustainable forest management. The CNCF was formed in order to develop the national standard for forest management, as well as to monitor and supervise future certification bodies. Later that same year, the Commission drafted and designed the Costa Rican forest management standard and guidelines for forest certification, based on the P&C defined by the Forest Stewardship Council. More than 200 representatives from state agencies, academic institutions, environmental interests, NGO's and the private sector participated in the development process in which representation by all stakeholders was of the utmost importance in order to achieve an equilibrium between the technical, ecological, social and economic aspects of forest management in Costa Rica (Campos and Müller 1999).

In 1998, the national standard for forest management was approved and published under executive decree (Watson *et al.* 1998; Campos and Müller 1999). The Costa Rican national standard for forest management includes the 10 principles established by the FSC for natural and plantation forest management, and an 11th principle which was published in 1999 for the sustainable management of secondary forests. The implementation of the national standard and the system for forestry certification are expected to be strong tools in the improvement of forest management practices in Costa Rica (Watson *et al.* 1998). A three-year trial period of implementation and field applications began in 1999 in order to observe and analyze the applicability and pertinence of the national set of PC&I. Upon completion of the testing period, updating of the national forest management standard is expected to produce an efficient and applicable set of PC&I that will not only improve unsustainable management practices and strengthen control and monitoring of forestry operations, but will also gain international recognition and approval (Campos and Müller 1999).

2.3 Validating and Testing existing sets of C&I

As an obvious step in the process of C&I development, there should be a phase of validation, testing and revision so that standards can be efficiently implemented at the operational scale at their level of organization. Considering the still relatively early development of most standards and C&I sets, testing and application processes are scarce or in early stages as well. The principal aim of field testing and validation is generally to identify PC&I that are applicable, relevant and cost-efficient for the evaluation of sustainable forest management. Following are a few examples of current efforts to develop, test and validate sets of C&I.

North American Test of C&I of Sustainable Forestry

The Center for International Forestry Research (CIFOR) began testing of their generic C&I template in 1998 as part of the CIFOR C&I Test Phase 2. One such test was carried out in Boise, Idaho in the U.S. The Boise Test examined over 400 C&I taken from the CIFOR generic C&I template, the Canadian Council of Forest Ministers C&I for sustainable forest management in Canada, the Idaho Forest Practices Act local and regional indicators and the Greater Fundy Ecosystem Guidelines developed for the Model Forest derived C&I (Woodley *et al.* 1999). The methodology applied was a modification of that proposed by CIFOR for the testing, selection and development of C&I (Prabhu *et al.* 1999) and included four stages of evaluation by a multi-disciplinary group of nine international experts in forestry, social sciences, policy and economics. At the end of each stage the evaluated C&I were either rejected or modified and/or merged with other elements and passed on to the next stage (Woodley *et al.* 1999).

The first stage included desk exercises and an initial evaluation of all the original C&I. The second stage consisted of the initial field work and an orientation workshop for discussion and debate of the results from Stage 1 after which the C&I were either rejected or merged and passed on the next stage. Stage 3 included detailed field evaluations of the remaining C&I, which were then rejected, merged or passed on to the final stage. Stage 4 concluded with a workshop attended by the initial group of experts plus 60 other experts in related fields, during which the results from previous phases were reviewed and evaluated (Woodley *et al.* 1999).

Of the original C&I, 207 were examined in detail and of these, 71 were accepted at the end of Stage 4. The majority of the recommended C&I were modified from their original wording. More than one third of the original C&I were combined to compensate for redundancy and 65 C&I were rejected due to conceptual weakness, irrelevance or deemed impossible to use operationally. The final set of C&I included 7 C and 17 I of ecological emphasis, 5 C and 17 I of social emphasis, 4 C and 17 I of management emphasis and 1 C and 3 I of a general emphasis for overall forest management sustainability. Specific observations of the ecological C&I included the recognition of limitations to the current understanding of ecosystem functions. The test also demonstrated the lack of practical means for measuring the associated, complex ecological variables as well as the lack of supporting or explanatory documentation to support the ecological bases of the these C&I. Concern was also expressed about the high costs and time investments associated with ecological C&I. Nonetheless, the importance of ecological C&I was recognized as well as the relatively advanced development of these forest management standard elements. (Woodley *et al.* 1999).

Evaluation of C&I in the Eastern Amazon

In 1998, a process was initiated in a joint effort by CIFOR and EMBRAPA (Brazilian Agricultural Research Center in Eastern Amazon) to develop a monitoring system to be used by forest enterprises to auto- assess their management and for government institutions to effectively audit such enterprises in the Eastern Amazon. The process used the CIFOR generic C&I template as a starting point and adapted it according to local conditions in order to arrive at an original set of PCI&V to be tested by four different stakeholder groups. This resulting set consisted of 5 principles, 15 criteria, 51 indicators and 114 verifiers which was then evaluated by four different stakeholder groups with the objective of contributing to the understanding of stakeholder views and degree of involvement in the development of forest management standards. The stakeholder groups included (1) local managers, (2) local actors(local inhabitants affected by forest management), (3) local government and (4) researchers. (Pokorny *et al.*, in prep.).

The methodology incorporated a preparation phase in which the participants were provided with the necessary information for the testing, development and selection of a set of C&I for monitoring forest management in the region. The second phase consisted primarily of a field

test carried out by each of the four stakeholder groups to evaluate the original set of PCI&V. The field test was very basic and served mostly for the observation of the FMU and generalizations on the applicability of the original set. Detailed applications were not carried out. After the field test, the four groups individually evaluated the original set based on attributes such as importance of content, clarity, value of information for evaluation purposes, ease of understanding and precision, among others. These evaluations were then discussed by the four groups, identifying similarities and differences between each group and examining the possibility for determining a consensus set of PCI&V based on agreement between all groups.

The study showed that there exists a high degree of agreement about forest management issues between the involved stakeholder groups. Nonetheless, there were general difficulties for all four groups with the hierarchical system of C&I development. In specific association with the ecological C&I, it was observed that there do not currently exist simple, effective methods for their application which results in obvious difficulties in their evaluation. Furthermore, it was noted that due to the lack of set thresholds and application methods, many ecological verifiers received negative or poor evaluations results. Overall, the study concluded that there is potential for the collaboration and participation of different stakeholder groups in the process of C&I development and application (Pokorny *et al.*, in prep.).

Application of Ecological C&I in Quintana Roo, Mexico

Soberón *et al.* (2000) examined the implications of developing and applying C&I according to the hierarchical structures of biodiversity at ecosystem and landscape, community, population and genetic levels of organization. As part of their study, the indicators and verifiers proposed by Stork *et al.* (1997) which served as the basis for the ecological elements of the CIFOR Generic C&I template, were applied to the Plan Piloto Forestal in Quintana Roo, Mexico, a certified community based forest management program. The application found that the Plan Piloto Forestal is considered sustainable at the community and ecosystem levels, where most of the indicators for landscape pattern, habitat structure, guild structure, taxic richness and composition received acceptable evaluations. However, the project was not considered sustainable at the population level due to management emphasis on mahogany (*Swietenia macrophylla*). It should be noted that the majority of the verifiers proposed by Stork *et al.* (1997) were evaluated only on a qualitative level and were not quantitatively assessed. The study

concluded that biodiversity indicators should be developed according to hierarchical levels of biodiversity and the processes that links these levels with human activities and the economic and social functions of forest systems. (Soberón *et al.* 2000).

2.4 Closing Comments

Sustaining natural tropical forests is crucial to sustainable development in the tropics. The sustainability of these forests is partially dependent upon improved and adaptive natural forest management (NFM) practices and their proper implementation and evaluation. With the development of objective, effective and cost-efficient forest management standards, the essential elements of sustainable forest management can be conceived, communicated, implemented, assessed, monitored and modified. This process leading to the overall adaptability for forest management. Based on the CIFOR generic C&I template (CIFOR C&I Team 1999), a set of CI&V has been proposed for the conditions of forest management units in Costa Rica. Also, efforts in Costa Rica for the validation of a national standard for forest management are currently invested in the testing and revision of the original proposed set of PC&I. Based on the integration of aspects from both of these efforts, the proposal to determine a practical and accepted set of PCI&V for the evaluation of the ecological sustainability of forest management operations in Costa Rica was developed and gave rise to the work described in the present thesis.

III. Materials and methods

The process applied for the determination of an integrated set of PCI&V comprised three phases of research and evaluation.[3]

3.1 Initial evaluation: Phase 1

During Phase 1, the initial set of PCI&V was assessed by a multi-disciplinary group of experts in forest ecology and management[4]. Three "home-base" desk evaluations were carried out in order to make a preliminary assessment of the applicability, interpretability and efficiency of the I&V and to determine their relative importance.

3.1.1 Expert group

A multi-disciplinary group of experts was incorporated into the evaluation process in order to facilitate, as well as lend credibility, to the determination of an integrated 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 expertise in the fields of forest ecology and management and their extensive experience in the region of study. 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 for FUNDECOR (Foundation for the Development of the Central Volcanic Chain), a public official for the National System of Conservation Areas (SINAC), a functionary of the Tirimbina Rainforest Center and M.Sc. in wildlife biology, a professor of Forest Management for more than 15 years with the Technology Institute of Costa Rica (ITCR) and a forestry engineer and regent for the Osa Peninsula in the southwest region of Costa Rica.

[3] 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).
[4] In this document, "initial set of PCI&V" refers to the original elements proposed from the CNCF forest management standard (1999) and the CIFOR Generic C&I Template (1999)

3.1.2 Evaluations of the proposed CI&V

The expert group was provided with a list of the proposed PCI&V (Annex: Table 1A Initial Set of PCI&V) documentation regarding the development and phases of evaluation of the research project and a draft manual which documents the justification and scientific bases for the original set of PCI&V (Delgado *et al.* in prep.). Revision of these documents provided the expert group members with the background information necessary to complete the home-base desk evaluations (HBDEs).

It should be noted that the HBDEs 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. Furthermore, it should be emphasized that the resulting scores were not used to eliminate any element from the initially proposed set of PCI&V before evaluation in the field (section 3.3).

3.1.2.1 HBDE 1: assessment of important attributes and priority for further evaluation

In the first HBDE, each indicator or verifier was evaluated individually based on important attributes associated with the assessment of ecological sustainability in forest management operations (Table 1 for sample form; for complete form see Annex: Table 2A Evaluation Form 1A). 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 (section 3.3).

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

Source: CIFOR or CNCF	No. of I/V in source doc.	Class: Mngt (M) Or Ecology (E)	Closely and ambiguously related to the assessment goal? (1-5)	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)	Important and therefore selected as "priority"? 1- yes 0- no

Responses from each of the expert group members for the first HBDE were later tabulated to determine the average scores for each of the four attributes for each I&V and the percent of priority for further consideration and evaluation assigned to each I&V. 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. Priority proportions were calculated to determine the preliminary expert group assessment of the original elements which should be included in the final set and which elements might be modified or excluded.

3.1.2.2 HBDE 2: multi-criteria analysis through ranking and rating

Taking into account the large number of elements to consider when evaluating importance, an evaluation tool known as multi-criteria analysis (MCA) was selected to facilitate this process. 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.

The methodology used for the second HBDE was based on the MCA techniques developed by CIFOR for selecting C&I (Mendoza *et al.* 1999). Relative importance was determined by considering the applicability, interpretability and efficiency of each I/V in relation to the other I/V under the same C/I and in relation to the C/I with which it is associated (for example: 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 indicator under the same criterion (or, each V under the same I) was ranked on a 9-point scale of importance in association with its respective criterion or indicator (Table 2 for sample form; for complete form see Annex: Table 3A).

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. Regular ranking 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 (0-100%) of importance to each element and indicate differences in their degree of importance. A percentage score of importance 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. Sample of Form 1b: Ranking & Rating of I associated with CNCF C6.1.

P6, C 6.1	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.

Upon completion of HBDE 2, 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.

3.1.2.3 HBDE 3: designating responsibility for the assessment of sustainability

The third HBDE was utilized to designate institutional responsibility for the application of different subsets of I&V (Annex: Table 4A Evaluation Form 1C). Subsets of indicators and verifiers were identified by each criterion associated with a group of indicators (CNCF C6.1, C6.2, C6.3, C7.1, C8.1) , or by each indicator associated with a group of verifiers (CIFOR I2.1.1 - I2.1.6, CIFOR' 1-4). Expert team members indicated whether the forest manager or another entity should be responsible for the evaluation of each sub-group of I&V and provided suggestions when "other entity" was indicated. This line of assessment was intended to illustrate which aspects of the CI&V set should be carried out by forest managers and considered essential for the successfully fulfillment their duties and obligations, and which elements would require cooperation from other entity(s) for measurement and assessment.

3.1.3 Integrating and analyzing the initial evaluation results

The results from each of the HBDEs were tabulated, analyzed and consolidated for presentation to the expert group before the field test, during the second phase of evaluation (section 3.2). 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 to be 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.

3.2 Field application and evaluation: Phase 2

3.2.1 Site selection and field preparations

During Phase 2 members of the research group (K. McGinley, D. Delgado) 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.). Following preparations for the field application exercise which included the development of a framework for sampling and field activities and the respective field forms for data collection (Annex: Field forms, see section 4.2.1 for sampling framework), 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 sight selected, owned by RAMAREMASEPRO LMTDA, 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 area for management. Within the management area, 70.4 ha are under effective management and 64.4 ha are described and conserved as area for protection purposes.

After site selection, field exercises for the application of I&V from the initial set of PCI&V were carried out by members of the research group. During these field exercises, the respective sampling plots and transects were established and the corresponding data was collected. According to observations made in the practice application, all field forms and the frameworks for sampling and field activities were modified where necessary before the field test carried out by the expert group (section 3.2.2).

3.2.2 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.

Phase 2 was organized as a "workshop" in which the expert group members spent 4 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 in order 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 (section 3.1). The expert group was then divided into two – three person task-oriented teams which would be responsible for the evaluation of specific elements associated with their area of expertise.

Field evaluations of the I&V consisted of actual applications using the methodologies suggested by CATIE (Delgado *et al.* in prep.). Each task-oriented team carried out the field exercises associated with their assigned subset of CI&V, utilizing the field forms prepared in the first part of Phase 2 for actual data collection (Annex: Field Forms) and noting specific observations associated with each element and its application. During the days dedicated to field work, group discussions were held both in the field as well as at home base to review the events associated with the field test and allow the entire group 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 important attributes concerning the applicability, interpretability and efficiency of the elements tested (Table 4 for attribute description; for complete form see Annex: Table 5A Evaluation Form 2). Before recording their final recommendations, each team presented the experiences and perspectives associated with the evaluation of their sub-group of I&V 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, integrated set of CI&V for the evaluation of ecological sustainability of forest management operations in the Northern and Atlantic zones of Costa Rica (section 4.6).

Table 4. Important C&I attributes and their descriptions, as defined by CIFOR (1999).

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 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

3.3 Final workshop: Phase 3

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 other experts in forest ecology, management and policy. The workshop opened with a presentation and discussion of the results and observations of the original set of PCI&V from the first three 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. The workshop also served to evaluate and discuss the distribution of institutional responsibility for C&I implementation which was classified by the aspects of (1) data and information collection, (2) data processing and management and (3) data interpretation (Table 5 for sample form; for complete form see Annex: Table 6A Evaluation Form 3). Evaluation results for institutional responsibility were analyzed and incorporated into the recommendations for the application and implementation of newly proposed, integrated 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	IR
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

* Where 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; and the 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.

IV. RESULTS AND DISCUSSION

4.1 Initial evaluation results

Results from Phase 1 served to indicate the original elements preliminarily considered the most and least adequate for the final, proposed set of PCI&V for the evaluation of ecological sustainability, based on overall scores of relative importance (RI), priority for further consideration and evaluation, and overall scores for their important attributes. All results from the Phase 1 HBDEs are displayed in the Annex – Table 7A HBDE Results.

4.1.1 Scores for important attributes, priority for further evaluation and relative importance for initial PCI&V

Examples of the highest scoring CNCF elements include: I6.3.3 "The rate of forest products harvested does not exceed the rate of resource growth" under P6: Management Impact; I7.1.4 "The path of primary roads, trees to be extracted and parent trees are shown and clearly marked in the field" under P7: Management Plan; and I8.1.3 "Parent trees, rare, banned and endangered species are marked as AP. Their location in the field and their numbering correspond with their identification on the map" 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 "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" both I6.1.2 "The management plan describes the means for controlling impacts and these are applied in the field" and I6.1.3 "Before harvesting there is an assessment of the potential impacts on run-off, soil and water that has been signed by the regent" 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 being easy to record and interpret. Under CNCF C6.2 "Rare, threatened and endangered tree species are protected as well as their habitats. Hunting, capturing and collecting floral and fauna species is controlled", measurements for protecting rare, threatened

and endangered species, as well as the characteristics of their habitats as described in I6.2.1 were considered more important (RI = 61) than measurements to control hunting, capture and collection of plant and animal species as described by I6.2.2 (RI = 39). Under 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 the production system. c. Natural processes that affect the productivity of the forest ecosystem. d. The functions and processes of the natural drainage system" 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 "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" with a score for RI = 3. Similar tendencies were found for the sub-indicators under I7.1.2 which describes the contents of the management plan. The range of scores for relative importance for all nine sub-indicators was 8-18 and as with the indicators under C6.3, several sub-indicators received equal scores for importance. Small ranges in scores of relative importance were interpreted to indicate elements of relatively equal importance. However, it should be noted, that when large groups of elements are assessed for relative importance the ability to designate large differences of importance between elements decreases.

The lowest scoring CNCF elements and subsequently, considered the least adequate for inclusion in the final set of PCI&V included: I6.1.1 "The management plan establishes agreement to maintain impacts within the limits mentioned under this principle"; I7.1.1 "The structure of the management plan includes a general plan and operational plans"; and I8.1.2 "Those in positions of responsibility must keep regency reports available with the certificates of receipt from the AFE (State Forestry Administration)." 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).

Examples of the CIFOR elements which received the highest scores include: V2.1.2.1 "The vertical structure of the forest is maintained within natural variation" and all three of the verifiers under I2.1.3 "Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds." V2.1.2.1 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). V2.1.5.3 "The age structure or tree size structure does not show significant changes in comparison with undisturbed forests" also received a much higher score of relative importance (62) in comparison to the other verifier found under the same indicator (V2.1.5.4 "The rates of population growth do not show significant changes in comparison with undisturbed forests").

The three verifiers evaluated under I2.1.3 received almost equal scores of relative importance (33, 33.5, 33.5), indicating they were considered to be equally important. 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 under I2.1.4 "The richness/diversity of selected groups show no significant change" demonstrated a very small range (20-31) and were interpreted to be of relatively equal importance.

The CIFOR elements receiving the lowest scores were V2.1.2.7 "The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest"; V2.15.4 "The rates of population growth do not show significant changes in comparison with undisturbed forests" and V2.1.6..2 "The state of decomposition of all dead wood does not show significant changes in comparison with the undisturbed forest." 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).

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, with the exception of three indicators which received one below-average score (2) for one attribute. I6.1.1 "The management plan establishes agreement to maintain impacts within the limits mentioned under this principle" received a score of 2 for its sensitivity to stress, I6.1.3 "Before harvesting there is an assessment of the potential impacts on run-off, soil and water that has been signed by the regent" received a score of 2 in association with the ease of recording and interpreting and sub-indicator 7.1.3e "Viable alternatives for the commercialization of timber and respective market prices are indicated" received a score of 2 for its relation to the assessment goal. 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 associated with their ease for detection and register. Overall, it was interpreted 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 in regards 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, in regards to the overall tendencies in the HBDE results, it was noted that there was a general level of concordance in the order of elements derived from relative importance and priority for further consideration and evaluation, indicating a general, direct relation between priority for further evaluation and relative importance . However, it should be noted that when larger subsets were considered (i.e. sub-group of indicators under C6.3, sub-group of sub-indicators under I6.3.11), the scores for relative importance and priority 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 (Table 6). 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.

In regards to the overall results, it should also be 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 descriptive degrees 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 provided for by simple ranking.

The average ranking and rating scores from the summary statistics can also be used to determine consistency in ranking and ranking of each I&V by comparing the order of importance derived from rating and the order of importance derived from ranking in the sub-sets of elements evaluated. In general, the experts were very consistent in the ranks and rates assigned to each element, however, as stated above, consistency decreases somewhat when larger sub-sets of elements are compared. Yet perhaps most important to note is that a 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).

Table 6. 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
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
2.1.4.3'	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
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
CIFOR						
1.1	41.7	13.29	31.90	6.7	1.97	29.50
1.2	34.2	14.97	43.82	6.0	2.10	34.96
1.3	24.2	16.25	67.25	5.0	2.19	43.82
2.1	46.7	13.66	29.28	6.5	2.17	33.35
2.2	53.3	13.66	25.62	7.8	0.98	12.55
3.1	48.2	28.15	58.43	6.0	2.76	45.95
3.2	28.0	14.21	50.76	4.3	3.08	71.00
3.3	23.8	16.62	69.73	4.5	3.67	81.65
4.1	100.0	0.00	0.00	7.7	1.63	21.30

4.1.2 Designation of institutional responsibility for groups of I&V

During Phase 1, designation of responsibility associated with C&I application was also evaluated (see final column in Table 7A in Annex). The scores from this evaluation indicated that the evaluation of 4 of the 5 groups of CNCF elements should be designated as the responsibility of the forest manager by at least 80% of the expert group members. These included all three groups of indicators under P6: Management Impact (identified by C6.1, C6.2, C6.3) and the group under P7: Management Plan (identified by C7.1). The CNCF indicators identified by C8.1: Monitoring and Evaluation was the only group not designated as the responsibility of the forest manager, by 60% of the experts. The State Forestry Administration (SFA) and certifying bodies were suggested as possibilities for the institutional responsibility of implementation of this group of indicators.

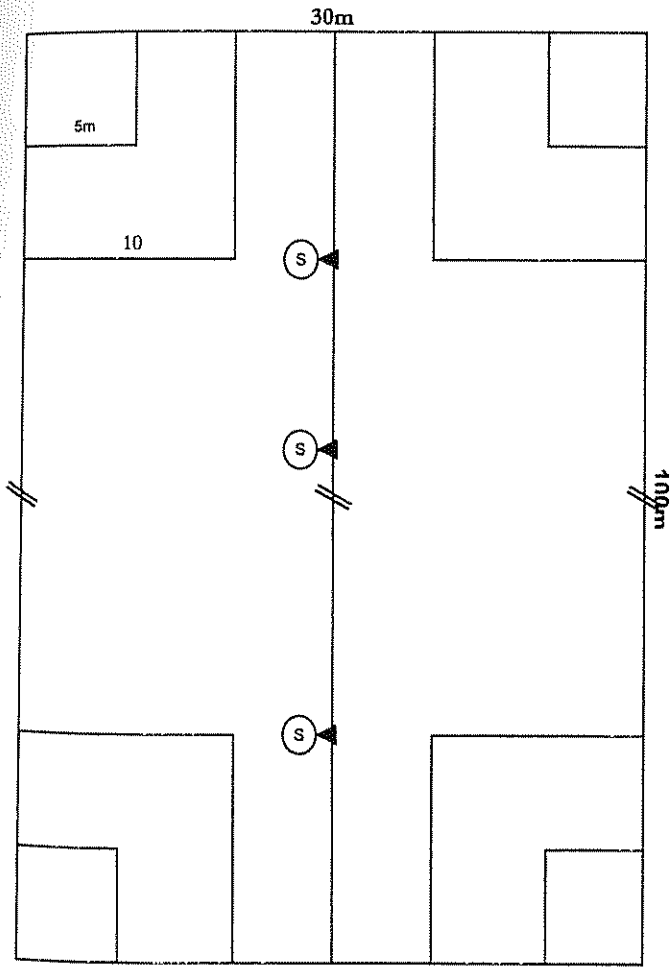
While the CNCF elements associated with the *inputs* and *processes* of forest management were designated as the responsibility of the forest manager, it is noted that the group of indicators associated with the monitoring and evaluating the *outcomes* and *results* of forest management were designated as the responsibility of another entity other than the forest manager. The same tendency was found with the CIFOR elements in which the verifiers identified by I2.1.1: "Landscape pattern is maintained" and 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" were designated as the responsibility of the forest manager by the majority (60%) of the experts questioned. Although these elements are based on forest management results, they are closely related to the actual activities and responsibilities commonly carried out by the forest manager. The remaining four groups of CIFOR verifiers were not designated as the forest manager's responsibility by 60% of the experts or more and were suggested to be the responsibility of the State Forestry Administration, certifying bodies or research institutions. The four groups were identified by the indicators 2.1.3 "Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds"; 2.1.4 "The richness/diversity of selected groups show no significant change"; 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."; and 2.1.6 "The status of decomposition and nutrient cycling shows no significant change." The four CIFOR' groups (Finegan *et al.* 1999)

were also designated as the responsibility of the SFA and certification bodies. Overall, results from this evaluation demonstrated that C&I associated with forest management *inputs* and *processes* are considered to be appropriately designated to the forest manager for implementation and interpretation, whereas implementing and evaluating C&I associated with *outcomes* of forest management require support from other entities such as state forestry institutions, certifiers and research institutions.

4.2 Field application and evaluation results

4.2.1 Field preparations

The second phase of evaluation commenced with the application of the initial CI&V in the field, development of field forms and a framework for field activities, plot establishment and related data collection. Figure 2 displays the sampling plot network that was developed for the application of particular I&V based on the methodologies proposed by CATIE (Delgado *et al.*, in prep.) Field forms and data results can be seen in the Annex – Field Application Results.



- **Transects** (center, sides of 30x100m plot)

Mammal abundance, activity (V2.1.3.6)
Butterfly groups (V2.1.4.3)
Dung beetle diversity (V2.1.4.3')*
*S – indicates *Scarabaeinae*

- **30x100m Plot**

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

- **10x10m 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)

- **5x5m 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)

4.2.2 Field Test and Evaluations

After the field preparations and preliminary application of the initial PCI&V, the field test and evaluations took place with the expert group which resulted in the recommendation, modification or rejection of the initial elements based on their performance in the field and observations made during group discussions.

4.2.2.1 General recommendations made by the expert group

An important product from Phase 2 was the generation 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 7).

Table 7. Requirements identified as necessary for the implementation of the national standard for forest management in Costa Rica after Phase 2.

Instructive manual for the implementation and interpretation of CNCF forest management standard
Up-to-date lists of banned, threatened and endangered species
Improved clarification, definition and description of terms and methodologies
Classification of forest types
Inter-institutional relationships
Instructive manual for the implementation of forest management – *Code of Practices*

During the Phase 2 group discussions and field evaluations, the need for an instructive 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 (i.e. skid trails), implementation (i.e. directional felling) and monitoring (i.e. permanent sampling plots) be better defined, clarified and described. The classification of forest types based on composition criteria relevant to forest management was considered crucial and, in effect, would provide the information necessary to establish the sustainable means and levels of management practices according to forest type as well as reference data for monitoring in different forest types. It was also strongly recommended that interinstitutional relationships be established in order to facilitate the processes of C&I development as well as

implementation and analysis (i.e.: CNCF and the National Commission of Forestry Investigation – a national NGO). Finally, it was noted that there exists the need for an instructive manual on the implementation of forest management or a "*code of practices*" for sustainable forest management in Costa Rica.

Taking into account the need for an instructive manual for forest management implementation, 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: "The management plan" be removed from the current standard and form part of a separate decree that serves as a national *code of practices*. It was duly noted that these elements are currently developed in the form of norms or predefined "levels" and "aspects" and would be better considered within the context of an instructive manual for planning and implementing sustainable forest management. The national standard for forest management and associated C&I could then be developed and used to determine the fulfillment of these "norms" or performance standards proposed by the *code of practices*. Most notably, it is crucial, that the *code of practices* be legally established, implemented and upheld before modifications are made to the current national standard.

4.2.2.2 Specific recommendations and observations made by the expert group[5]

Under the CNCF P6: "Management Impact" it was recommended that 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" and 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 the production system. c. Natural processes that affect the productivity of the forest ecosystem. d. The functions and processes of the natural drainage system" be combined to result in only two criteria under P6. Under C6.1, no indicator was recommended for inclusion in the final, integrated set of PCI&V due to conceptual weaknesses or development as norms and subsequent recommendation for inclusion in the *code of practices* (CP). However, in regards to the ideas associated with C6.1, it

was recommended that the new, integrated criterion (C6.1 + C6.3) contemplate indicators associated with the *results* of forest management and incorporate indicators that monitor changes in species composition.

Both of the original indicators under C6.2 "Rare, threatened and endangered tree species are protected as well as their habitats. Hunting, capturing and collecting floral and fauna species is controlled" were recommended. I6.2.1 was recommended based on modifications to the original wording, the final version reading "Measures exist for the protection of rare, 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 numbering corresponds with the map indicating tree location", while I6.2.2 was recommended without need for modification: "Measures exist to control hunting, capture and collection of plant and animal species." It was observed in association with both recommendations that there exists a need for the description of the means for protection, conservation and management of the indicated species and their associated habitats, as well as the measures for controlling their hunting, capture and collection. It was suggested that these descriptions and measures be established and defined in the recommended CP and that the terms be better and clearly defined by a group of experts, based on the information available from current forest inventories. In association with both indicators, it was also duly 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: "Subsequent harvests are not carried out for at least 15 years since the last harvest in forests previously harvested" was not recommended because in this form it is a norm and an aspect of planning and would be better considered in the 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" and 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 porter trees, reserved

[5] All results and observations from Phase 2 are summarized in Table 8A in Annex.

during harvesting" were not recommended based on redundancy and combined with I6.2.1. 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) and were all considered in need of supplementary documentation in the form of lists and/or provisions in the proposed CP. Again, it is noted that the sub-indicators associated with I6.3.11 were recommended for removal from the current standard for forest management and used in-part as the basis for a *code of practices* for sustainable forest management. Furthermore, it was recommended that the national standard C&I incorporate the evaluation of fulfillment of the guidelines set by the proposed *code of practices* (section 4.2.2.1).

As indicated in section 4.2.2.1, it was recommended that the original C&I associated with CNCF P7 be removed from the *Standards and Procedures for Sustainable Management and Forest Certification in Costa Rica* (CNCF 1999) and to be used in-part as a basis for a separate, national decree that would serve as a *code of practices* (CP) for the planning and implementation of forest management. Subsequently, P7 was reworded and recommended as: "Planning". The first criterion, C7.1: "The management plan and supporting documents clearly establish and justify the management objectives and the means for achieving them" was not modified and it's associated indicator, 7.1.1 was recommended with modifications to read: "There exists a management plan developed according to the *code of practices* and legally approved by the SFA". The second criterion, 7.2: "The management plan is updated" and its associated indicator, 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" 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 CP.

Under CNCF P8: "Monitoring and Evaluation", two of the original four indicators under C8.1: "The management plan should include and execute a monitoring plan that allows the determination of the impact of management operations" were recommended for the final integrated set of PCI&V. Both I8.1.1: "Records exist on management activities, production volume per species, and numbers of logs. These records should be verifiable in accordance with the respective transportation guides" and I8.1.4: "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 include: annual increment in dbh (mm/yr); annual increment in basal area (m^2/ha/yr); mortality, regeneration and recruitment; floristic composition" 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 a CP should indicate the associated 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: "Regent reports and appropriate certificates of approval by the SFA are maintained available" was not recommended based on the view that it should be taken into account in the CP, which would indicate the minimum amount of information necessary for acceptable reports and the methodology for their preparation. I8.1.3: "Parent trees, rare, banned and endangered species are marked as AP. Their location in the field and their numeration correspond with their identification on the map" was rejected because of redundancy and combined with I6.2.1.

Of the CIFOR elements evaluated under C2.1: "The processes that maintain biodiversity are conserved in managed forests", 4 of the six verifiers under 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" 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 and the original wording for each verifier was modified from an original format typical of norms to that of a verifier for the associated

indicator. V2.1.2.2: "Size class distribution does not show a significant change from the natural variation" was not recommended because of poor precision in measurement and the argument that the legally permitted harvest does not greatly affect the diameter distribution. V2.1.2.7: "The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest" was not recommended due to lack of precise methodologies for determining biomass.

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", all three verifiers evaluated were recommended with revisions to the original wording, which was typical of a norm rather than a verifier. 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). It was noted for each that lists would have to be developed and provided to trained personnel and that all associated information and methodologies should included in the CP.

Two of the three verifiers evaluated under I2.1.4: "The richness/diversity of selected groups show no significant change" were recommended with modifications to the original wording which was again, typical of norms. V2.1.4.3: "The diversity of selected indicator groups of butterflies" and V2.1.4.3': "The diversity and species composition of select indicator species of the dung beetle guild (Scarabaeinae)" were recommended with need for their clear identification and methodologies for sampling to be defined in the CP. V2.1.4.6: "Temporal changes in species richness is not significant" was not recommended due to its associated requirement for intensive sampling and poor precision.

The remaining CIFOR verifiers were not recommended. Under 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: "The rates of population growth do not show significant changes in comparison with undisturbed forests" 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: "The status of

decomposition and nutrient cycling shows no significant change" 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.

In relation to the scores for relative importance from Phase 1 (section 4.1.1, see Annex Table 7A) for elements under CNCF P6 there was both consistency and inconsistency with the outcomes from Phase 2. Under C6.1, 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. Under C6.2, I6.2.2 received a much lower score for relative importance (39) than I6.2.1 (61), nonetheless both were recommended after Phase 2. Under C6.3, 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. However, I6.3.10 (RI=3) and I6.3.12 (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 underwent unusual recommendations, in that they were not rejected based on weaknesses but inefficient placement within the standard and recommendation for consideration in other documentation. Nonetheless, the lowest scoring indicator for relative importance was I7.1.1 (RI=13) was the only indicator maintained after Phase 2. As for the elements under CNCF P8, it was noted that all four indicators evaluated in Phase 1 were relatively similar in scores of importance. After Phase 2, only two indicators were maintained.

When comparing the results for CIFOR elements after Phase1 and Phase 2, again there are consistencies and inconsistencies. Under I2.1.2, 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, 2.1.2.5) were both recommended for the final integrated set of PCI&V. There was considerable consistency under CIFOR I2.1.3 the three verifiers evaluated 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, in which the lowest scoring verifier after Phase 1 (2.1.4.3') was recommended after Phase 2 and the highest scoring verifier (2.1.4.6) was rejected after Phase 2. There was also inconsistency under I2.1.5 in which

the considerably lower scoring element in Phase 1 (2.1.5.4) was recommended after Phase 2. Finally, the three verifiers evaluated under I2.1.6 were scored with a relatively small range of difference in importance. Nonetheless, they were not recommended for the final integrated set after the final recommendation in 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, many currently accepted methodologies for C&I selection, testing and development propose the use of relative importance scores 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 accepted methodologies been applied. Consequently, precaution is recommended in the use of filters based on desk – evaluation results for rejecting elements before field testing. Furthermore, in regards 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.

4.2.3 Field evaluation attribute scores

Final recommendations for Phase 2 were facilitated by scoring each I&V according to 9 important attributes (Table 4). CNCF I8.1.1: "Records should exist on management activities, volume of production per species, and number of logs that are verifiable with the respective transportation guides. Registers should also exist in the case of non-timber forest product production" received the highest attribute scores of both sets and was subsequently recommended for the final set of PCI&V (Annex Table 9A Attribute Scores from Phase 1 and Phase 2). The lowest scoring element from the CNCF set was sub-indicator 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", which was not recommended for the final set because the precision of diagnostic sampling is inferior to the percent of the reduction in basal area that is being evaluated and was therefore considered impractical. CIFOR V2.1.3.6

"The abundance and activity of terrestrial frugivorous mammals is maintained within critical limits" 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 "Temporal changes in species richness is not significant" was not recommended for the final set of PCI&V. In general, elements receiving above – average scores for the majority of the nine elements were modified and subsequently recommended.

It should be noted that comparisons were made between the attribute scores from Phase 1 and from Phase 2 but definite similarities or discernible correlations were not evidenced (Annex Table 9A). In the CNCF group, for example, the group of indicators under CNCF C6.1 generally scored higher in Phase 1 than 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. In the CIFOR group, for example, 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 more detailed evaluation carried out in Phase 2 in which 9 attributes were examined as opposed to only 4 in the first phase, and thus resulting in both positive as well as 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 the consensus of the two to three person task-oriented teams.

4.2.4 Distribution of recommendation results for different groups of CI&V

4.2.4.1 Introduction

Comparisons were made between the overall number of recommended and rejected I&V and between different groups of I&V (Table 8). Groups were determined according to the original source (CNCF or CIFOR) and two classifications of parameters (*input, process, result; pressure, state, response*) (Annex Table 10A I&V Classification and Groupings; see section 1.1.1 for parameter definitions). Within the number of I&V recommended for each group, 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*. Within the number of I&V rejected for each group, a five-way comparison was made between elements rejected because of (1) recommendation for incorporation into the proposed *code of practices*, (2) redundancy, (3) conceptually weak (i.e. not related to the assessment goal), (4) poor precision for measurement or sampling or (5) need of further scientific development. A chi-square test was used to determine if and when a relationship existed between groupings (i.e. CNCF vs. CIFOR, *Input/Process* vs. *Outcome*, *Pressure* vs. *State* vs. *Response*) and recommendation status (i.e. not modified vs. modified, CP required vs. CP not required, Move to CP vs. Redundant vs. conceptually weak vs. poor precision vs. further development). The chi-square test was significant ($p \leq 0.01$) for all relationships except the comparison of CNCF vs. CIFOR elements and their recommendation or rejection status, and for *Input/Process* vs. *Outcome* elements and their recommendation or rejection status. This can be interpreted as the existence of little or no difference in the percent of elements recommended and rejected between the CNCF and CIFOR sets, as well as between elements for evaluating *inputs* or *processes* and those for evaluating *outcomes*

Table 8. Overall results and comparisons of final recommendations for three 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)
		$chi^2 = 2.08$		**$chi^2 = 3.40$**		**$chi^2 = 104.68$****		
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)
		$chi^2 = 129.16$**		**$chi^2 = 107.56$****		**$chi^2 = 200.00$****		
Recommended								
CP required	91% (20/22)	85% (11/13)	100% (9/9)	83% (10/12)	100% (10/10)	90% (9/10)	0% (0)	100% (10/10)
CP not required	9% (2/22)	15% (2/13)	0% (0)	17% (2/12)	0% (0)	10% (1/10)	0% (0)	0% (0)
		$chi^2 = 149.00$**		**$chi^2 = 143.56$****		**$chi^2 = 264.00$****		
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)
		$chi^2 = 198.60$**		**$chi^2 = 198.60$****		**$chi^2 = 567.56$****		

* = 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 $p \leq 0.01$: $chi^2 = 20.090$

4.2.4.2 Distribution of overall results

Slightly more than half of all the initial elements were recommended. Notably, almost all of the recommended elements required modifications to the original wording (86%) and even more require supplementary documentation (91%), which supports the general recommendations for the need for documentation on C&I implementation (section 4.3.1). Of the rejected elements, one third were recommended to be separated from the initially proposed set and incorporated into a code of practices. The remaining were elements rejected due to redundancy (17%), conceptual weakness (17%), poor precision (17%) and need of further research and development (17%). Figure 3 provides a graphical display of the overall results according to their recommendation and rejection status.

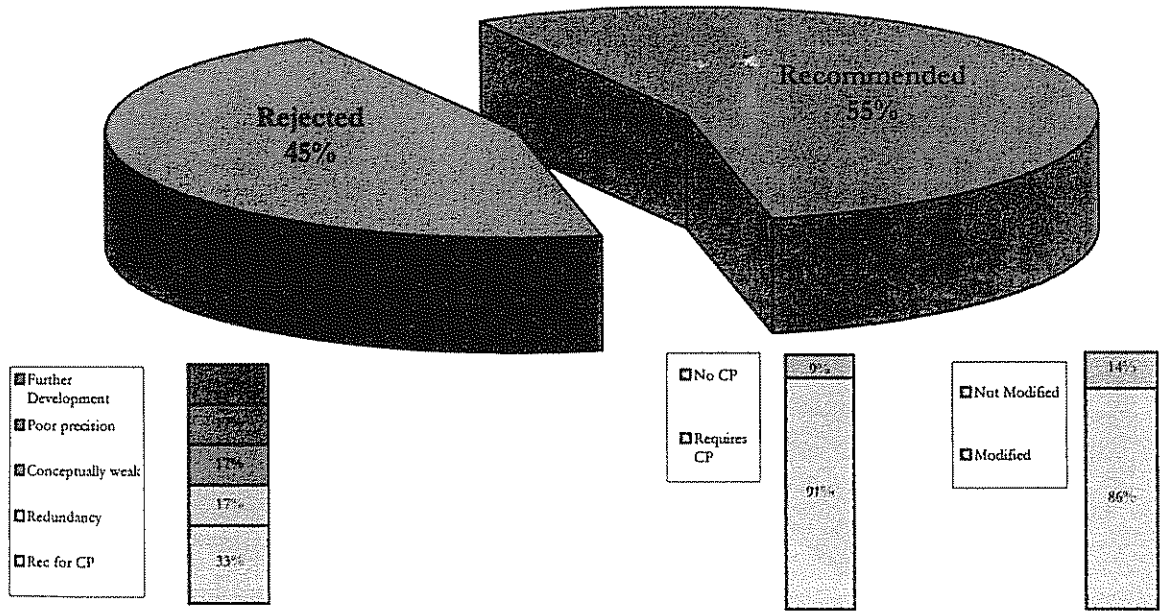


Figure 3. Final recommendation results for all I&V.

4.2.4.3 Comparison of distribution of results for CNCF and CIFOR elements

There was very little difference between the percent of CNCF and CIFOR elements which were recommended and rejected (Table 8). Both groups resulted in high percentages of elements in need of modification and supplementary documentation. Notably, all of the elements recommended from the CIFOR group were modified due to their present wording as

norms in the source documentation (Annex Table 8A for details). Furthermore, all of the recommended CIFOR elements require supplementary documentation in the proposed code of practices. In regards to the reasons for rejection there are however, marked differences between the two groups. The majority of elements rejected from the CNCF set (55%) was based on to their inefficient placement within the standard and their development as norms. These elements were subsequently recommended for incorporation into a *code of practices*. The remaining CNCF elements were rejected because of redundancy (27%) and conceptual weakness (18%). On the contrary, the majority of CIFOR elements were rejected due to poor precision in measurement, attributed to light intervention regimes (when silvicultural treatments are not applied), typical of Costa Rican FMUs (43%) or were considered relevant in regards to their ecological bases, but in need of further scientific development before being included in C&I sets (43%). The remaining rejected CIFOR elements (17%) were based on conceptual weakness. Figures 4 and 5 provide graphical displays of the CNCF and CIFOR recommendation and rejection results.

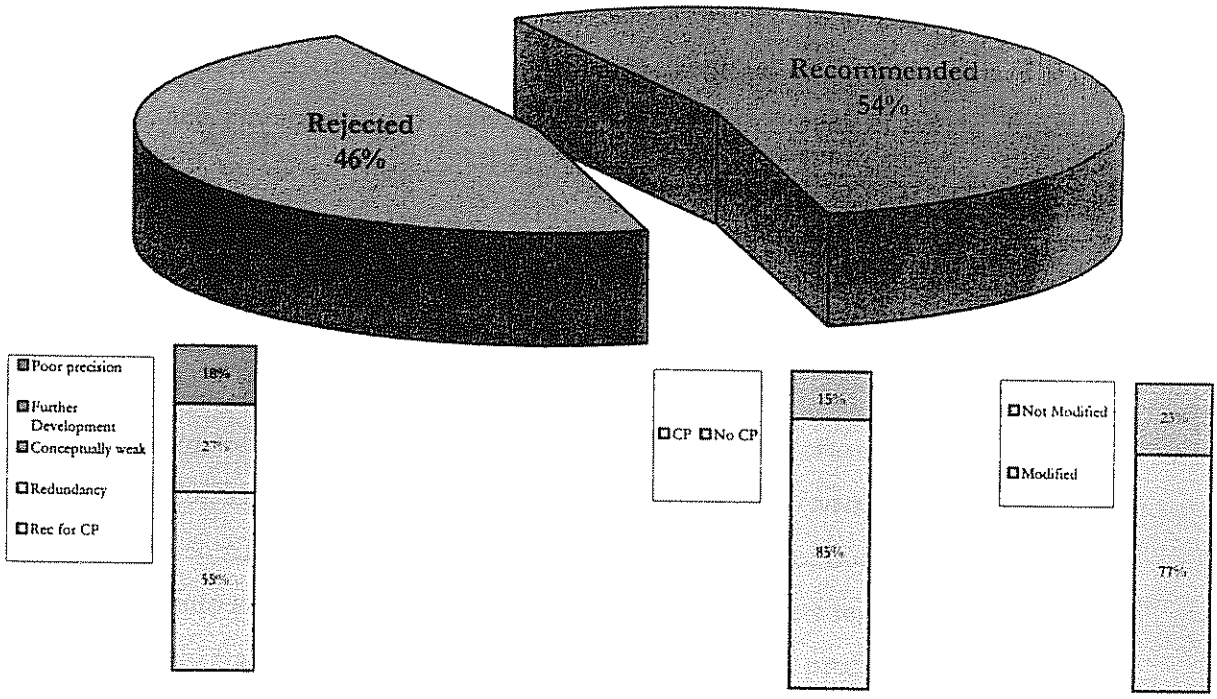


Figure 4. Final recommendation results for CNCF elements

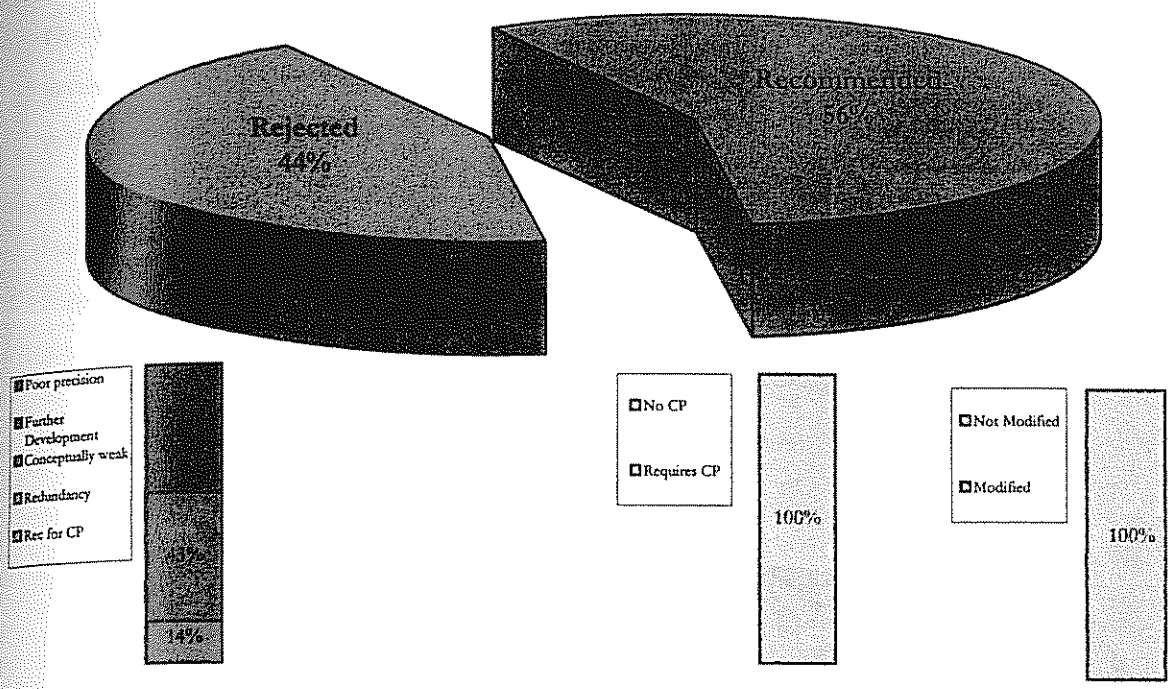


Figure 5. Final recommendation results for CIFOR verifiers

4.2.4.4 Comparison of distribution of results for Input/Process and Outcome elements

A slightly higher percentage of *outcome* elements (59%) were recommended for the final set of PCI&V in comparison to *input/process* elements (52%) (Table 8). Within the number of recommended elements, both groups showed high percentages of elements in need of modification and supplementary documentation. Higher percentages of *outcome* elements were recommended based on modifications (90% vs. 83% of recommended *input/process* I&V) and supplementary documentation (100% vs. 83% of recommended *input/process* I&V). The requirement for supplementary documentation for all of the *outcome* elements can be attributed to their increased complexity in both application and evaluation.

Notwithstanding the slightly greater percentage of rejected *input/process* elements, only 18% were rejected due to conceptual weakness. The majority of *input/process* elements (55%) were rejected based on recommendation for separation from the source documentation and incorporation into a code of practices and the remaining 27% were rejected because of redundancy. No *input/process* elements were rejected due to poor precision nor because of need for further development.

On the contrary, the majority of rejected *outcome* elements (43%) were based on poor precision in measurement or were considered relevant, but in need of further development through research (43%). Similarity between the CNCF/CIFOR and the *(input/process)/outcome* recommendation and rejection results is attributed to the majority of CNCF elements characterized as *input/process* and all CIFOR elements characterized as *outcome* elements. Figures 6 and 7 show graphical displays of distribution of results for the *input/process* and *outcome* elements.

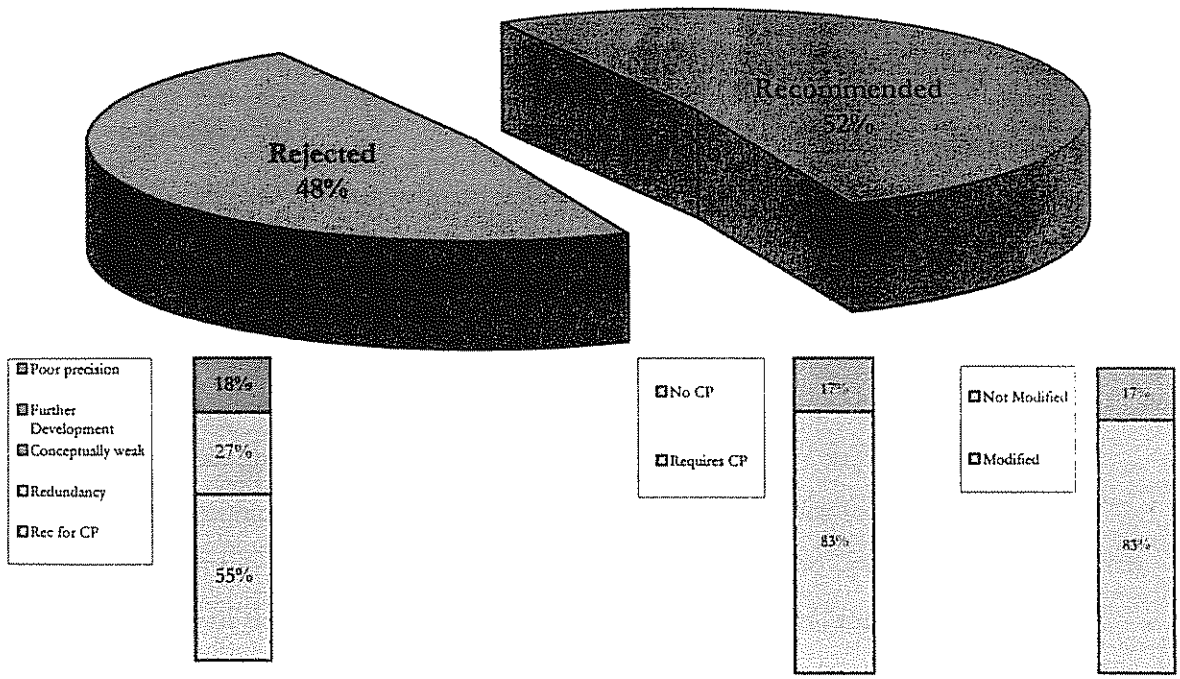


Figure 6. Final recommendation results for *input/process* elements

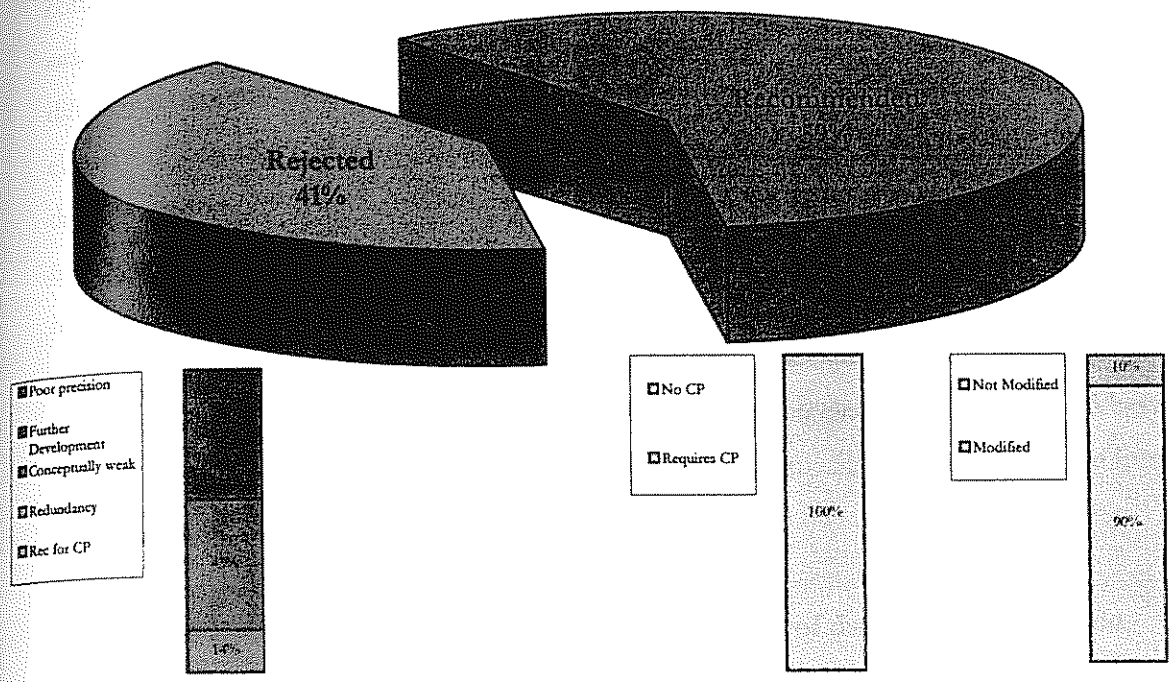


Figure 7. Final recommendation results for *outcome* elements.

4.2.4.5 Comparison of distribution of results for Pressure, State, and Response elements

Before discussion of the *pressure, state* and *response* elements, it should be noted that this type of classification was not as readily applied as the *input, process* and *outcome* classification. Particularly, *pressure* and *state* classifications were more difficult to apply to the C&I, where several elements could be interpreted under either classification (see for example CNCF I7.1.1 "The structure of the management plan includes a general plan and operational plans" which refers to the *state* of the management plan - a *pressure* on the system; see also CNCF I7.1.2, I7.1.3, I8.1.1, I8.1.2, I8.1.3) or simply were not applicable to the original format of the C&I (Annex Table 10A).

Once the elements were classified as *pressure, state* and *response* elements, comparison showed there was little difference between the percents of recommended and rejected *pressure* (56%, 44%) and *response* (59%, 41%) elements, but there was a notable difference between *pressure* and *response* elements and the recommended and rejected *state* elements (0, 100%) (Table 8). From these results, it might be interpreted that the *pressure* and *response* elements are more adequate than *state* elements for the final PCI&V set, but the difficulties in classification resulted in

comparisons that may not be as directly indicative of group characteristics as *input, process, outcome* classifications. Within the numbers of recommended elements, there was little difference between the *pressure* and *response* groups and both resulted in high percentages of elements recommended based on modifications (80%, 90%) and need for supplementary documentation (90%, 100%). Differences were noted among the reasons for rejection for the three groups. The majority of rejected *pressure* elements was distributed between recommendation for incorporation into the proposed code of practices (38%) and redundancy (38%), whereas the majority of the *response* elements were rejected because of poor precision (43%) or need for further development (43%). All of the *state* elements were rejected because of recommendation for separation from the source documentation and incorporation into a proposed code of practices.

Again, there are similarities between these results and those of the CNCF/CIFOR and *(Input/Process)/Outcome* comparisons due to the majority of CNCF elements being classified as *pressure* and *state* type elements, these same elements commonly being classified as *input* and *process* and all of the CIFOR elements being classified as *outcome* or *response* elements. Figures 8, 9 and 10 provide graphical displays of the recommendation and rejection results for *pressure, state* and *response* elements.

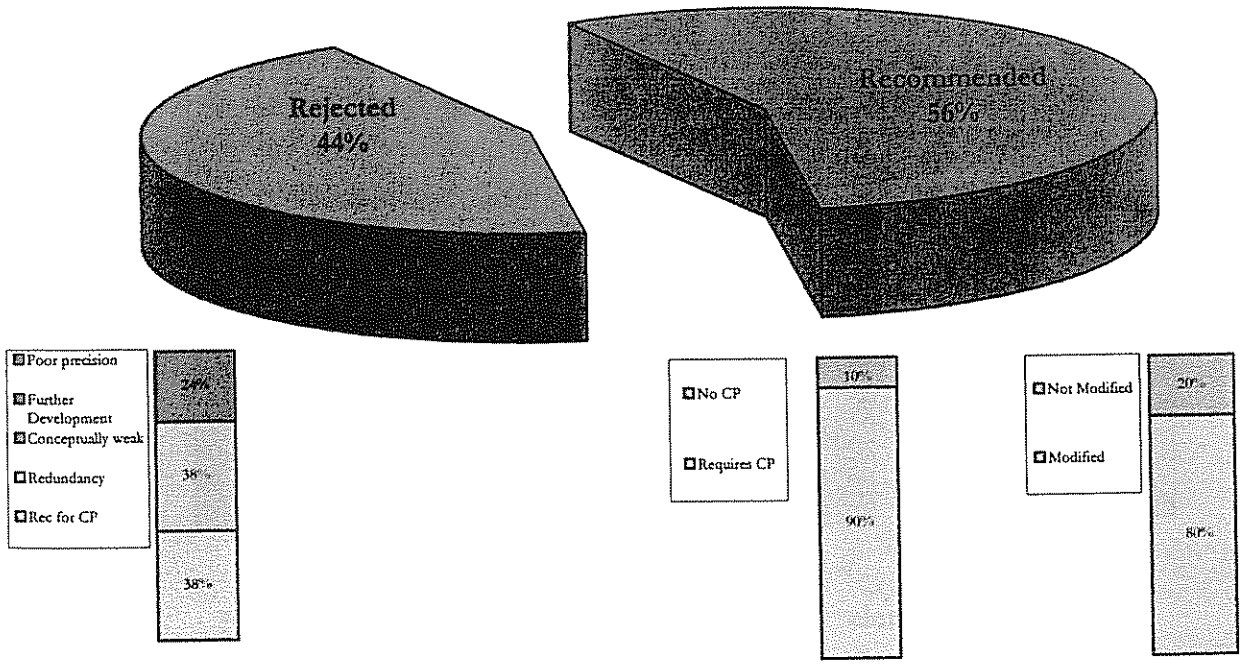


Figure 8. Final recommendation results for *pressure* elements

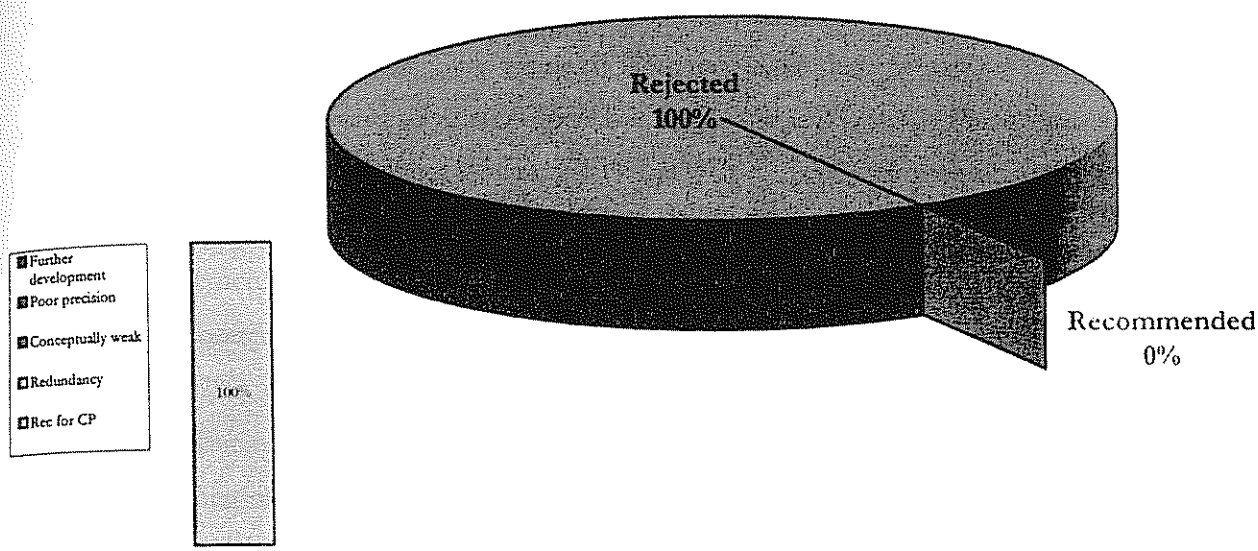


Figure 9. Final recommendation results for *state* elements

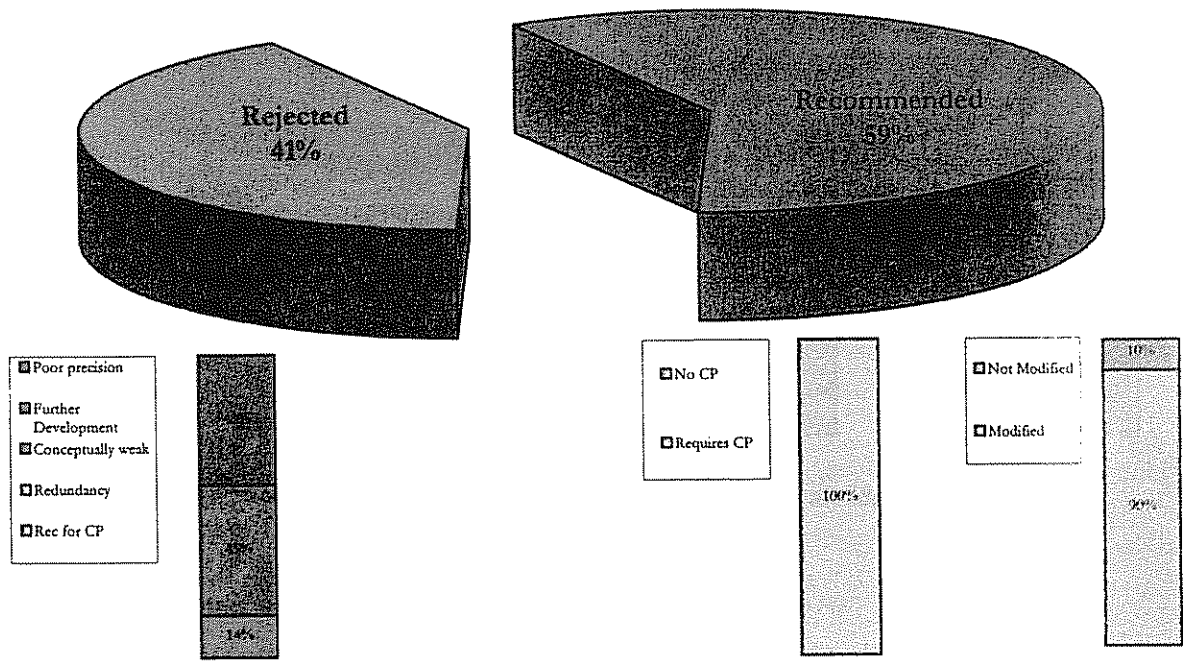


Figure 10. Final recommendation for *response* elements

4.2.4.2 Distribution of overall results

Slightly more than half of all the initial elements were recommended. Notably, almost all of the recommended elements required modifications to the original wording (86%) and even more require supplementary documentation (91%), which supports the general recommendations for the need for documentation on C&I implementation (section 4.3.1). Of the rejected elements, one third were recommended to be separated from the initially proposed set and incorporated into a code of practices. The remaining were elements rejected due to redundancy (17%), conceptual weakness (17%), poor precision (17%) and need of further research and development (17%). Figure 3 provides a graphical display of the overall results according to their recommendation and rejection status.

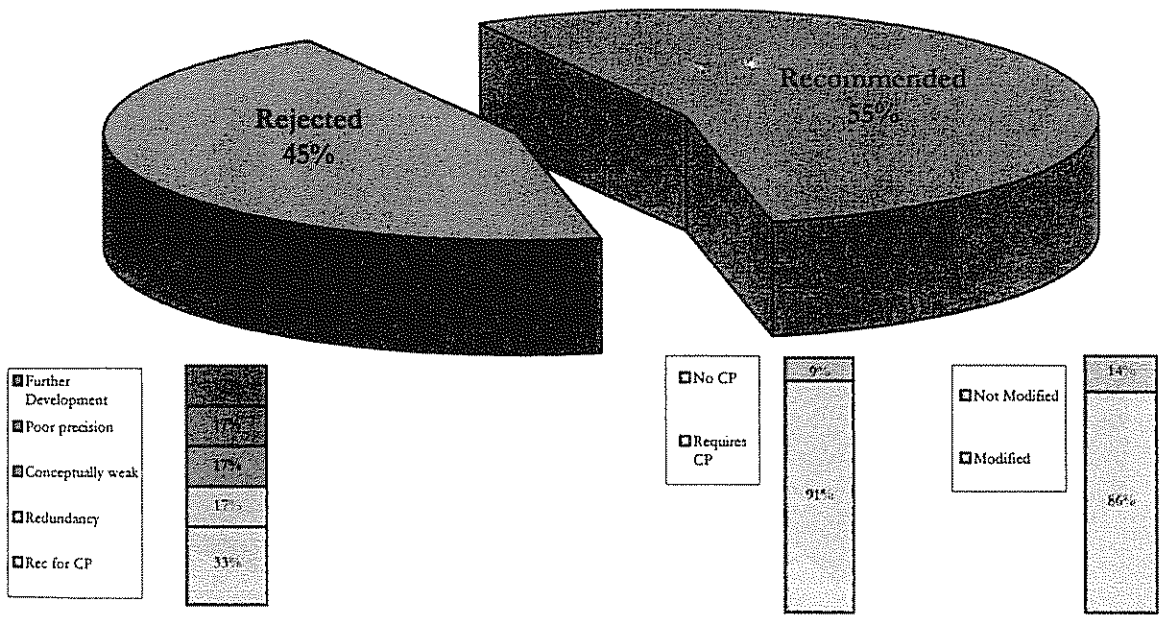


Figure 3. Final recommendation results for all I&V.

4.2.4.3 Comparison of distribution of results for CNCF and CIFOR elements

There was very little difference between the percent of CNCF and CIFOR elements which were recommended and rejected (Table 8). Both groups resulted in high percentages of elements in need of modification and supplementary documentation. Notably, all of the elements recommended from the CIFOR group were modified due to their present wording as

norms in the source documentation (Annex Table 8A for details). Furthermore, all of the recommended CIFOR elements require supplementary documentation in the proposed code of practices. In regards to the reasons for rejection there are however, marked differences between the two groups. The majority of elements rejected from the CNCF set (55%) was based on to their inefficient placement within the standard and their development as norms. These elements were subsequently recommended for incorporation into a *code of practices*. The remaining CNCF elements were rejected because of redundancy (27%) and conceptual weakness (18%). On the contrary, the majority of CIFOR elements were rejected due to poor precision in measurement, attributed to light intervention regimes (when silvicultural treatments are not applied), typical of Costa Rican FMUs (43%) or were considered relevant in regards to their ecological bases, but in need of further scientific development before being included in C&I sets (43%). The remaining rejected CIFOR elements (17%) were based on conceptual weakness. Figures 4 and 5 provide graphical displays of the CNCF and CIFOR recommendation and rejection results.

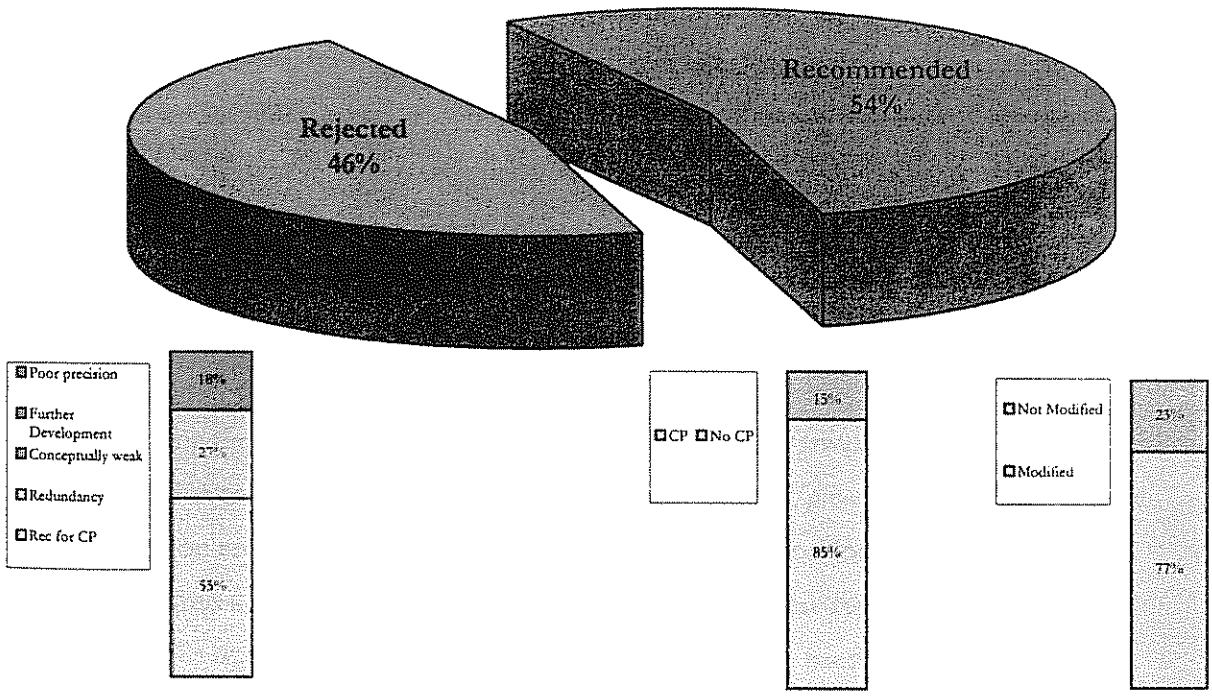


Figure 4. Final recommendation results for CNCF elements

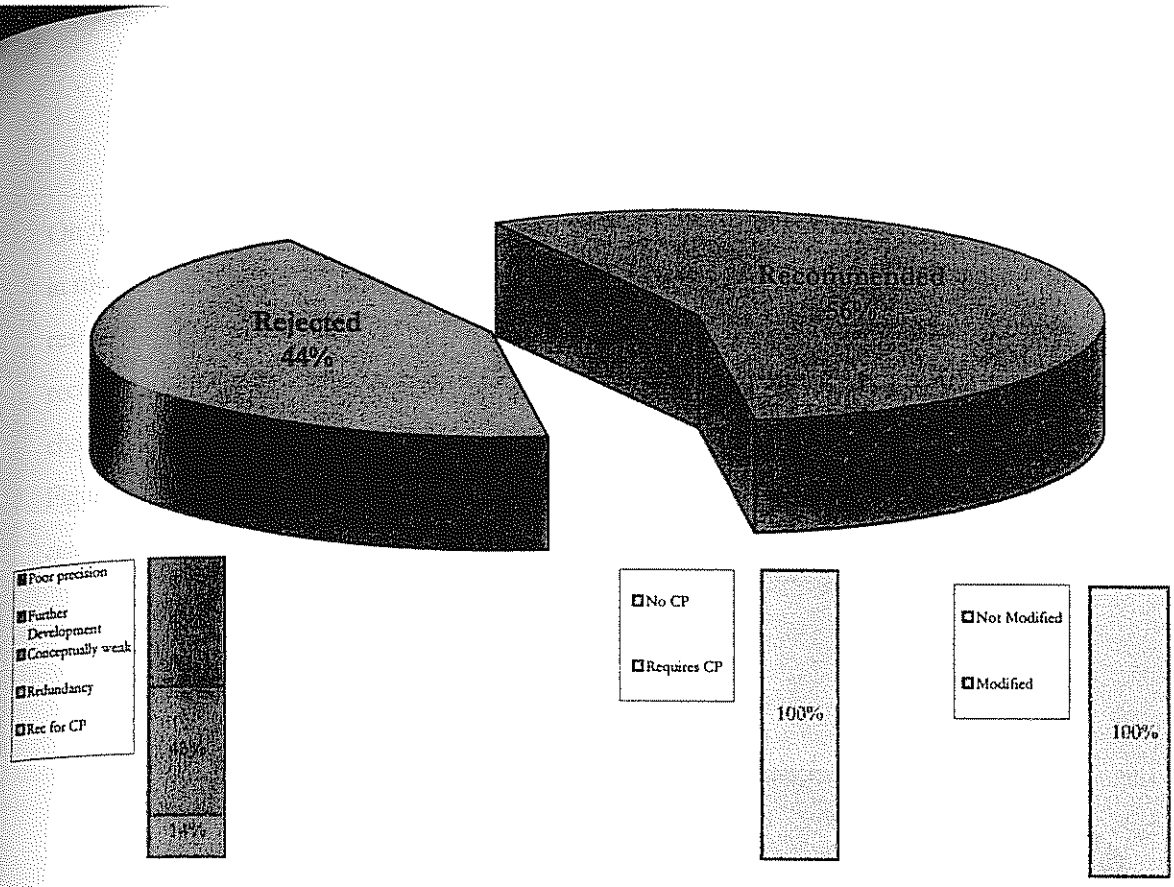


Figure 5. Final recommendation results for CIFOR verifiers

4.2.4.4 Comparison of distribution of results for Input/Process and Outcome elements

A slightly higher percentage of *outcome* elements (59%) were recommended for the final set of PCI&V in comparison to *input/process* elements (52%) (Table 8). Within the number of recommended elements, both groups showed high percentages of elements in need of modification and supplementary documentation. Higher percentages of *outcome* elements were recommended based on modifications (90% vs. 83% of recommended *input/process* I&V) and supplementary documentation (100% vs. 83% of recommended *input/process* I&V). The requirement for supplementary documentation for all of the *outcome* elements can be attributed to their increased complexity in both application and evaluation.

Notwithstanding the slightly greater percentage of rejected *input/process* elements, only 18% were rejected due to conceptual weakness. The majority of *input/process* elements (55%) were rejected based on recommendation for separation from the source documentation and incorporation into a code of practices and the remaining 27% were rejected because of redundancy. No *input/process* elements were rejected due to poor precision nor because of need for further development.

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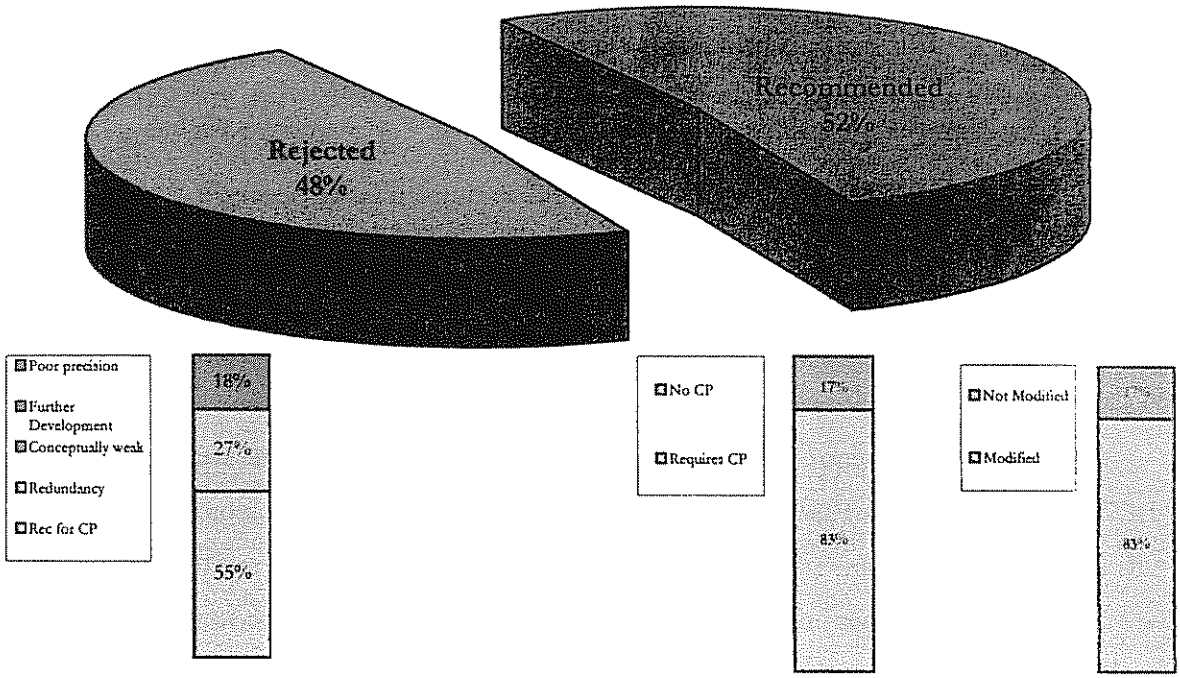

Figure 6. Final recommendation results for *input/process* elements

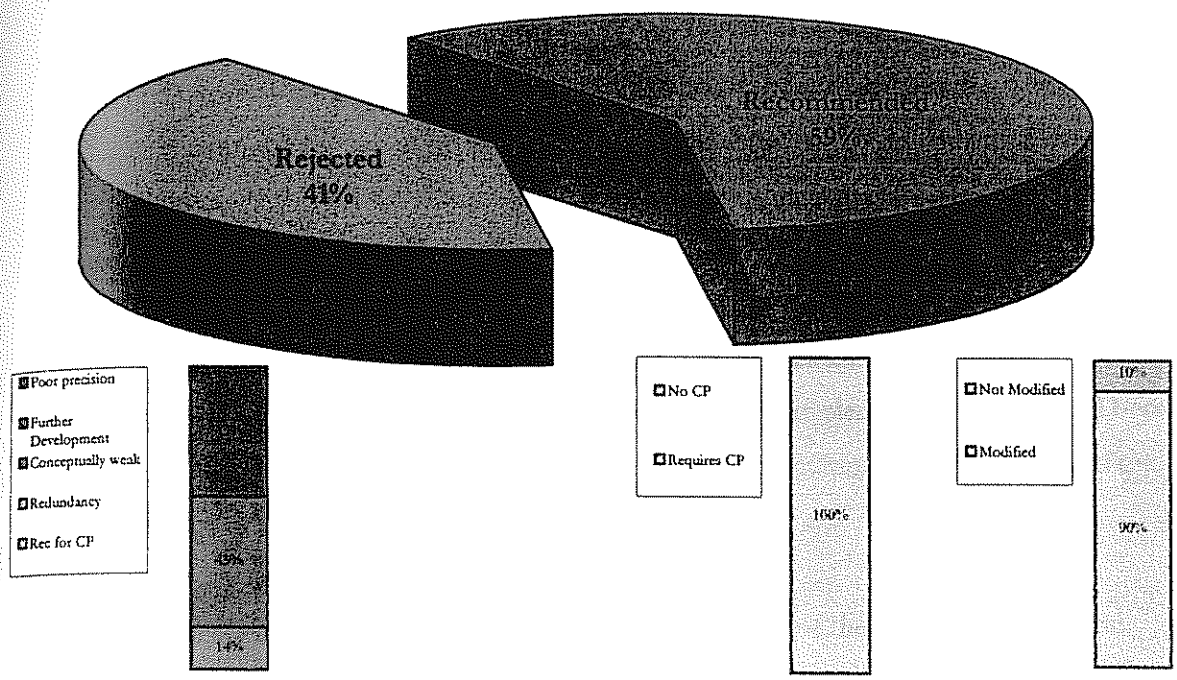

Figure 7. Final recommendation results for *outcome* elements.

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Before discussion of the *pressure, state* and *response* elements, it should be noted that this type of classification was not as readily applied as the *input, process* and *outcome* classification. Particularly, *pressure* and *state* classifications were more difficult to apply to the C&I, where several elements could be interpreted under either classification (see for example CNCF I7.1.1 "The structure of the management plan includes a general plan and operational plans" which refers to the *state* of the management plan - a *pressure* on the system; see also CNCF I7.1.2, I7.1.3, I8.1.1, I8.1.2, I8.1.3) or simply were not applicable to the original format of the C&I (Annex Table 10A).

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comparisons that may not be as directly indicative of group characteristics as *input, process, outcome* classifications. Within the numbers of recommended elements, there was little difference between the *pressure* and *response* groups and both resulted in high percentages of elements recommended based on modifications (80%, 90%) and need for supplementary documentation (90%, 100%). Differences were noted among the reasons for rejection for the three groups. The majority of rejected *pressure* elements was distributed between recommendation for incorporation into the proposed code of practices (38%) and redundancy (38%), whereas the majority of the *response* elements were rejected because of poor precision (43%) or need for further development (43%). All of the *state* elements were rejected because of recommendation for separation from the source documentation and incorporation into a proposed code of practices.

Again, there are similarities between these results and those of the CNCF/CIFOR and *(Input/Process)/Outcome* comparisons due to the majority of CNCF elements being classified as *pressure* and *state* type elements, these same elements commonly being classified as *input* and *process* and all of the CIFOR elements being classified as *outcome* or *response* elements. Figures 8, 9 and 10 provide graphical displays of the recommendation and rejection results for *pressure, state* and *response* elements.

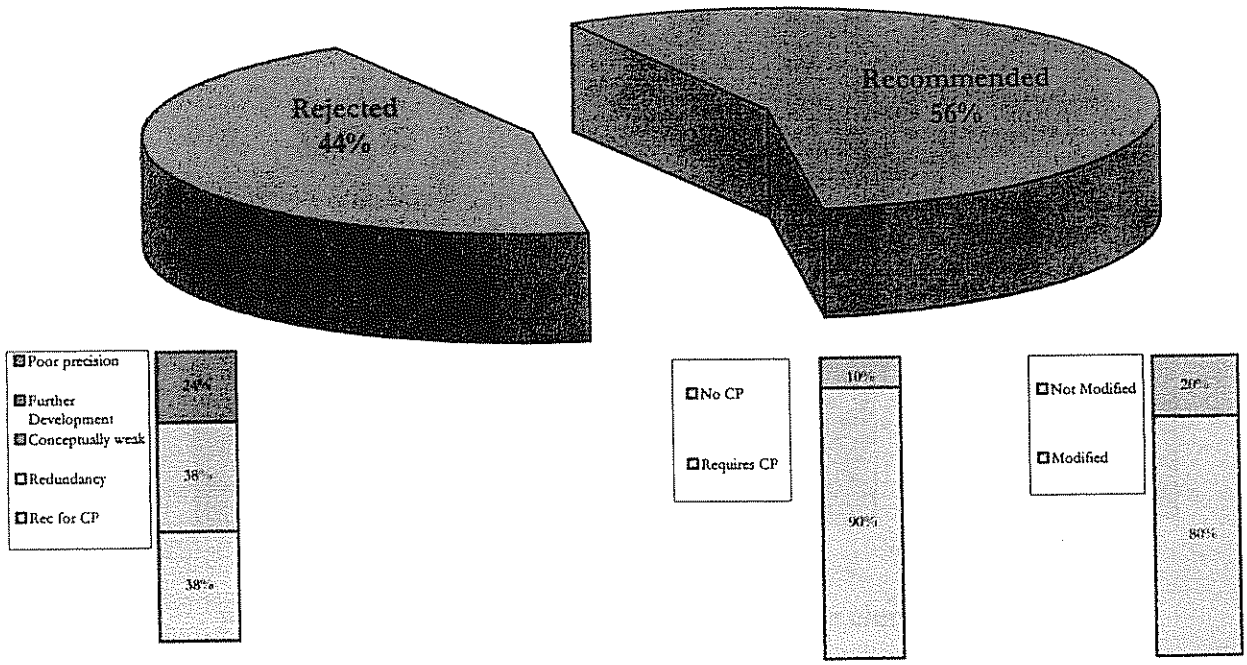

Figure 8. Final recommendation results for *pressure* elements

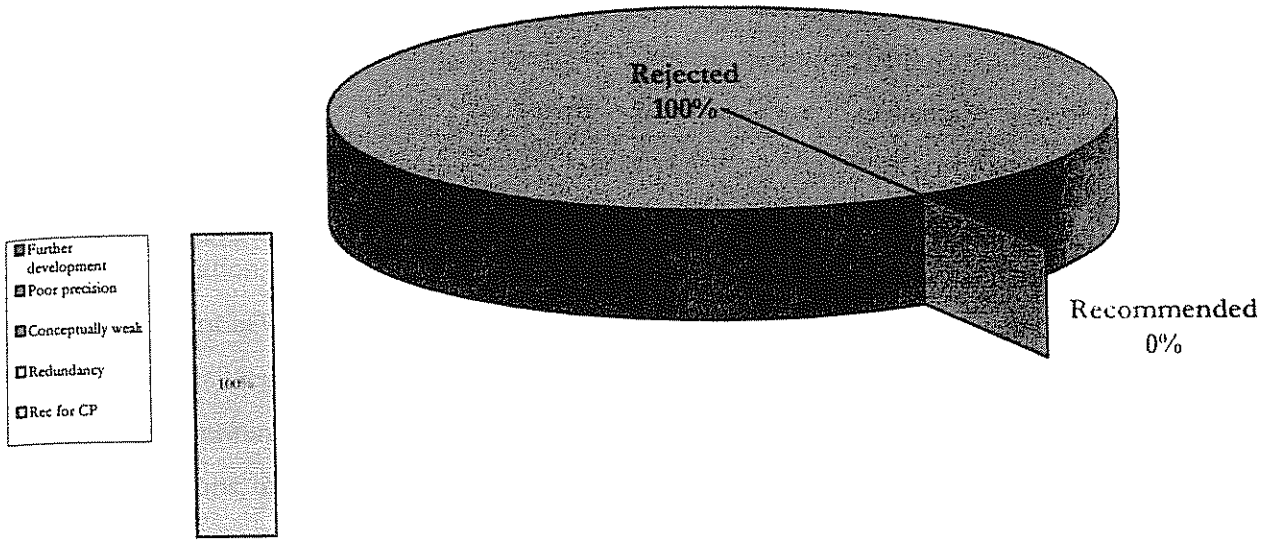

Figure 9. Final recommendation results for *state* elements

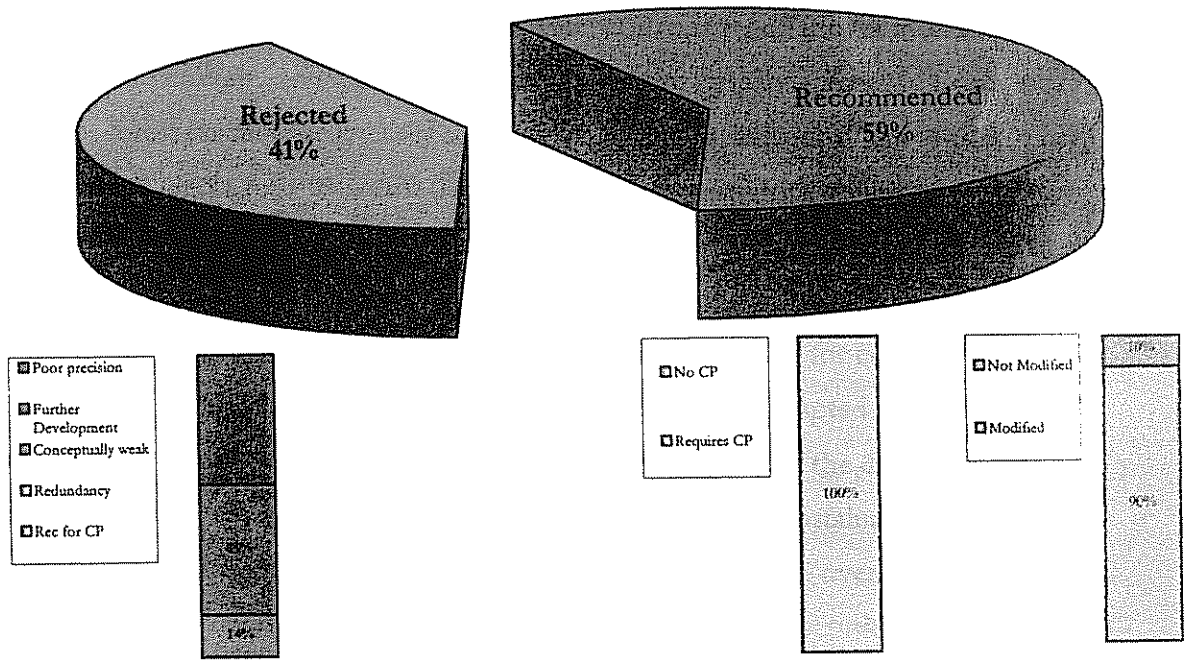

Figure 10. Final recommendation for *response* elements

4.3 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. 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 an M.Sc. student in Conservation and Management of Forests and Biodiversity at CATIE. An important overall result of the workshop was the group acceptance and approval of the process for determining an integrated set of PCI&V and the results to date, including the recommendations, modifications and rejections of the initial PCI&V.

4.3.1 Creating a code of practices

During group discussions in Phase 4 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. The group agreed on the need to separate these elements from the current forest management standard and use them as a basis for the creation of a currently, non-existent *code of practices* for forest management in Costa Rica. Codes of forest practice are typically sets of guidelines or "regulations" developed to help critical actors in the forestry sector (i.e. forest managers, operators, government officials, etc.) apply and carry out forest management operations (Dykstra 1994). When forest management operations are carried out according to a code of practice, they should theoretically meet standards set for sustainable forest management (i.e. harvest limits for commercial timber according to area). Codes of practice should be developed and adapted according to local conditions and focus on the actual harvesting practices rather than the desired outcome, resulting in guidelines and prescriptions for meeting the goals of sustainable forest management. 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, relevant information 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 (section 1.1.1). 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 standard for forest management should be developed and implemented in parallel with each other in Costa Rica. Upon consensus for the need for a national code of practices and its direct relation to the national standard, a list of potential users was created for both documents which were then distinguished as primary or secondary users (Table 9).

Table 9. Primary and secondary users for the Costa Rican forest management standard and the proposed code of practices (CP).

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
Agronomy College (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

P = primary user, S = secondary user, NA = not applicable (not a user)

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 Agronomy College, business owners, forest workers, and

environmental organizations (COVIRENAS), each with very different needs in regards to their use and application of a code of practices. In consideration of such differences, it is suggested that code of practices eventually be broken down into different volumes which would correspond to the different primary users and their needs (i.e. 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.

4.3.2 Determining distribution of institutional responsibility

Currently in Costa Rica there are several different "institutions" involved in the development and application of the national standard for forest management. 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 Agronomy Engineers, overseer for 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; and SFA accredited certifiers, responsible for auditing and "certifiying" the sustainability of forest management planning and execution (Costa Rica La Gaceta 1996).

Taking into account the distribution of institutional responsibility for the implementation of the forest management standard and the current actors involved, three aspects of responsibility for C&I implementation were evaluated in Phase 3. Table 10 displays the overall results from this evaluation (see Annex Table 8A for a 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 for data collection 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, distribution of 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 for data collection was distributed among 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 elements was not assigned, instead distributing the responsibility for interpretation among certifiers, regents and research institutions.

Table 10. Recommendations for the distribution of responsibility for aspects of I&V implementation according to the expert group after Phase 4.

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, IR
I6.2.2	R	Op	R	M	C	S, R, IR
I6.3.2	R	Op, S	R	M, S	C	S, R, IR
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

CNCF	PR	SR	PR	SR	PR	SR
V2.1.2.4	R	Op, S, IR	R	M, RI	-	R, C, RI
V2.1.2.5	R	Op, S, IR	R	M, RI	-	R, C, RI
V2.1.2.8	R	Op, S, IR	R	M, RI	-	R, C, RI
V2.1.3.1	Op	M, R, IR	RI	M, R	-	R, C, RI
V2.1.3.2	Op	M, R, IR	RI	M, R	-	R, C, RI
V2.1.3.6	Op	M, R, IR	RI	M, R	-	R, C, RI
V2.1.4.3	Op	M, R, S, IR	RI	M, R	-	R, C, RI
V2.1.4.3'	Op	M, R, S, IR	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

4.4 Integrated set of PCI&V

Based on the results from the three phases of research, an integrated 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. This final set integrates indicators and verifiers from the recommended CIFOR elements into the existing framework of the CNCF forest management standard and the elements recommended during this process. It is noted that this integrated set was developed based on fulfillment of conditions for the creation of a national code of practices and other supplementary documentation noted for each element in Table 8 and will continue to change in reflection of the changes in local environmental, social and political conditions. Table 11 presents the integrated set of PCI&V.

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

P	C	I	V	
P6 Impacto del Manejo				
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 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 forest products harvested does not exceed the rate of resource growth		
	6.1.2	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		
	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.
6.1.5	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
6.1.6	Mechanized extraction/skidding operations follow the code of forest practices for the use of cables.
6.1.7	Measures of control exist to avoid hydric erosion and alteration of natural drainage systems.
6.1.8	Minimum impact is made on the stand, soil and water resources in the execution of management and harvesting which take into account the aspects and levels established by the code of practices
6.1.9	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
	6.1.9.1 The vertical structure of the forest
	6.1.9.2 The frequency distribution of the phases of the regeneration cycle of the forest
	6.1.9.3 Canopy opening within the understory
	6.1.9.4 Dead standing wood and on the ground
6.1.10	Community structure of distinct guilds do not show significant changes in the representation of especially sensitive guilds, pollinator and disperser guilds
	6.1.10.1 The relative abundance of seedlings, saplings and trees of canopy tree species pertaining to the different guilds of regeneration
	6.1.10.2 The abundance of select indicator groups of birds
	6.1.10.3 The abundance and activity of select indicator mammal groups
6.1.11	The richness/diversity of selected groups show no significant change.
	6.1.11.1 *The diversity of selected indicator groups of butterflies*
	6.1.11.2 *The diversity and species composition of select indicator species of the dung beetle guild (Scarabaeinae)*
6.2 Rare, 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	Measures exist for the protection of rare, 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
6.2.2	Measures exist to control hunting, capture and collection of plant and animal species.
P7 Planning	
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 SFA.
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	
8.1 The management plan should include and execute a monitoring plan that allows the determination of the impact of management operations.	
8.1.1	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.
8.1.2	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

4.5 Closing Discussion

In regards to the methodology used to determine an integrated set of PCI&V, it was evident throughout this process that adaptability 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 home-base desk evaluation scores for relative importance did not prove to be reliable nor consistent enough in order 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 (see Mendoza and Prabhu 2000; Woodley *et al.* 1999).

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 clearly apparent. More than 90% of the elements recommended for the final set of CI&V were conditional upon the need for complementary documentation and/or provisions in the suggested *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 for the necessary field applications. Nonetheless, there remains a lack of documentation related to individual CI&V and sets as a whole that should be provided for the implementation of a forest management standard in Costa Rica.

There was also considerable emphasis placed on the lack of reference or "base-line" data for many of the 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 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, analysis and control.

As far as 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 the forest management standard.

Finally, it should also be noted that confusion seems to persist in association with hierarchical development and/or the terminology associated with PCI&V. One-third of the CNCF rejected indicators were due to development as norms, and subsequently recommended as the bases for a national *code of practices*. Furthermore, although generally undetected throughout the evaluation process, many of the CIFOR verifiers were also proposed as norms and in need of modification before integration into the final proposed set of PCI&V. Until such confusions are resolved, it will continue to be difficult to apply and compare forest management standards at different levels of application.

V. CONCLUSIONS AND RECOMMENDATIONS

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

Today, systems for assessing sustainability of forest ecosystems are often defined by predetermined standards for reducing the impacts of forest management operations, without regard for the sometimes unpredictable responses of ecosystem components. However, reducing negative impacts does not necessarily guarantee sustainability. Unfortunately, elements built upon system responses to forest management operations often involve increased investment of time, training, cost and multi-institutional participation. Nonetheless, for forest management standards to be useful, they must move towards integration of elements which evaluate impacts as well as their results, in order to better determine sustainability and provide indications of where changes or adaptations may be made in the management system.

When the requirements for C&I implementation are taken into account, they can become potentially powerful tools for the evaluation of sustainability. Sets that include the means to measure the stress, state and response of the system can provide a valuable understanding of the sustainability of forest management operations. 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* CI&V. 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 integrated set of PCI&V for the evaluation of ecological sustainability in the Northern and Atlantic zones of Cost Rica but has contributed to the experiences of C&I development processes. As a result of these experiences, recommendations can be made for later applications of similar processes. Overall, the process applied for this research was very productive and based on its adaptability,

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.

Furthermore, it is suggested that greater consistency and clarity be implemented throughout C&I development processes. For example, in the present process only four important attributes were assessed in the first phase of C&I evaluation, whereas 9 attributes were assessed in the second phase. In order to better compare between phase results, it is recommended that the same attributes be evaluated in each phase that incorporates them.

Clarity is another important factor in C&I development which should be highly emphasized. For example, terms associated with the evaluation process were often interpreted differently by different participants. It is suggested that all terms and methods associated with these processes are 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, such processes can be powerful tools for developing standards for the evaluation of sustainable forest management.

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annex

annex

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

P C I V CNCF (1999)	Description
6	Management Impact
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.
6.1.2	The management plan describes the means for controlling impacts and these are applied in the field.
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.
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
6.2.2	Measures exist to control hunting, capture and collection of plant and animal species.
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
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 60cm (technical justification is needed for harvesting trees of lesser dap.)
6.3.3	The rate of forest products harvested does not exceed the rate of resource growth.
6.3.4	Measures of control exist to avoid hydric erosion and alteration of natural drainage systems.
6.3.5	The number of harvested trees is distributed proportionally among the greatest number of currently commercial species.
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.
6.3.7	Subsequent harvests are not carried out for at least 15 years since the last harvest in forests previously harvested.
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.
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.
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.
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:
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.
7		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.
	7.1.2	The general plan contains the following aspects:
	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 the 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:
	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.
8		Monitoring and Evaluation
	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.
	8.1.2	Those in positions of responsibility must keep regency reports available with the certificates of receipt from the SFA (State Forestry Administration).
	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.
	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: a. Annual increment in dap (mm/year) b. Annual increment in basal area (m^2/ha/year) c. Mortality, regeneration and recruitment d. Floristic composition

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.

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.

2.1.2.2 Class size distribution does not show a significant change from the natural variation.

2.1.2.4 The frequency distribution of the phases of the regeneration cycle of the forest is maintained within the critical limits.

2.1.2.7 The distribution of above-ground biomass does not show significant changes with respect to the non-harvested forest.

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.

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 limits.

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.

2.1.4.3' The richness/diversity and species composition of species the dung beetle guild (Scarabaeinae) do not show significant changes.

2.1.4.6 Temporal changes in species richness is not significant.

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.

2.1.5.4 The rates of population growth do not show significant changes in comparison with undisturbed forests.

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.

2.1.6.2 The state of decomposition of all dead wood does not show significant changes in comparison with the undisturbed forest.

2.1.6.3 The abundance of woody debris does not show significant changes in comparison with undisturbed forests.

1 Cover of all forest types in the FMU and the spatial patterns formed by the forest types in the landscape are conserved.

1.1 Areas and proportions of each community type, both forest and non-forest in the FMU.

1.2 Degree of fragmentation (patch structure, connectivity and edge features) by forest types.

1.3 Restoration strategies implemented in deforested areas.

2 Forest types of special importance for biodiversity conservation are subject to special management regimes.

2.1 Management plan takes into account and, where necessary, acts upon national and regional priorities for ecosystem conservation.

2.2 Special measures are taken for the protection of natural forest types of limited area or unusual characteristics.

3 The modification of each forest type by management does not exceed established limits.

3.1 Natural disturbance regimes are not changed.

3.2 Areas extent and proportion of each forest type intervened, to be intervened and in unmodified reserve areas.

3.3 Proportion of intervened areas in which forest structural and florisitc recovery is underway.

4 Protection measures are effectively implemented.

4.1 Strictly protected areas are clearly marked on maps and in the field.

Table 2A. Evaluation Form fa: Evaluation of the priority of all I&V for further testing in the field.

Please fill in this form before 05/22/00.
For columns 4-7 use a scale of 1-5: 1 = poorly, 3 = satisfactorily, 5 = very well
For more information and/or detailed instructions please see the background document provided.

Source: CIFOR or CNCF*	No of the I/V	Class of the I/V: related to management(M) to the ecological impacts (E)?	Closely and unambiguously related to the assessment goal?	Easy to detect, record and interpret?	Provides a summary or integrative measure?	Adequate response range to changes in level of stress?	IMPORTANT and therefore selected as "priority" for further testing in the field? 1=yes 0=no
1	2	3	4	5	6	7	8
CNCF	6.1.1						
CNCF	6.1.2						
CNCF	6.1.3						
CNCF	6.2.1						
CNCF	6.2.2						
CNCF	6.3.1						
CNCF	6.3.2						
CNCF	6.3.3						
CNCF	6.3.4						
CNCF	6.3.5						
CNCF	6.3.6						
CNCF	6.3.7						
CNCF	6.3.8						
CNCF	6.3.9						
CNCF	6.3.10						
CNCF	6.3.11						
CNCF	6.3.12						
CNCF	6.3.11a						
CNCF	6.3.11b						
CNCF	6.3.11c						
CNCF	6.3.11d						
CNCF	6.3.11e						
CNCF	6.3.11f						
CNCF	6.3.11g						
CNCF	7.1.1						
CNCF	7.1.2						
CNCF	7.1.3						
CNCF	7.1.4						
CNCF	7.1.2a						
CNCF	7.1.2b						
CNCF	7.1.2c						
CNCF	7.1.2d						
CNCF	7.1.2e						
CNCF	7.1.2f						
CNCF	7.1.2g						
CNCF	7.1.2h						
CNCF	7.1.2i						
CNCF	7.1.3a						
CNCF	7.1.3b						
CNCF	7.1.3c						
CNCF	7.1.3d						
CNCF	7.1.3e						
CNCF	7.1.3f						

Form 1a. Evaluation of the priority of all I&V for further testing in the field (cont.).

Source: CIFOR or CNCF*	No of the I/V	Class of the I/V: related to management(M) to the ecological impacts (E)?	Closely and unambiguously related to the assessment goal?	Easy to detect, record and interpret?	Provides a summary or integrative measure?	Adequate response range to changes in level of stress?	IMPORTANT and therefore selected as "priority" for further testing in the field? 1=yes 0=no
1	2	3	4	5	6	7	8
CNCF	7.1.3g						
CNCF	8.1.1						
CNCF	8.1.2						
CNCF	8.1.3						
CNCF	8.1.4						
CIFOR	2.1.1.1						
CIFOR	2.1.2.1						
CIFOR	2.1.2.2						
CIFOR	2.1.2.4						
CIFOR	2.1.2.5						
CIFOR	2.1.2.7						
CIFOR	2.1.2.8						
CIFOR	2.1.3.1						
CIFOR	2.1.3.2						
CIFOR	2.1.3.6						
CIFOR	2.1.4.3						
CIFOR	2.1.4.3'						
CIFOR	2.1.4.4						
CIFOR	2.1.4.6						
CIFOR	2.1.5.3						
CIFOR	2.1.5.4						
CIFOR	2.1.6.1						
CIFOR	2.1.6.2						
CIFOR	2.1.6.3						
CIFOR'	1.1						
CIFOR'	1.2						
CIFOR'	1.3						
CIFOR'	2.1						
CIFOR'	2.2						
CIFOR'	3.1						
CIFOR'	3.2						
CIFOR'	3.3						
CIFOR'	4.1						

*CNCF 1999, CIFOR - Prabhu *et al.* 1999, CIFOR' - Finegan *et al.* 2000.

Table 3A. Form 1b. Ranking and Rating of I&V.

Please fill in this form before 05/22/00.
For more information and/or detailed instructions please see the background document provided.
Use the following scale to assign rank of each I&V.

1	3	5	7	9
weakly important	less important	moderately important	more important	extremely important

Evaluation of the indicators associated with CNCF* criteria 6.1.

Indicator	Rank	Rating (sum = 100)	Comments
6.1.1			
6.1.2			
6.1.3			

Evaluation of the indicators associated with CNCF criteria 6.2.

Indicator	Rank	Rating (sum = 100)	Comments
6.2.1			
6.2.2			

Evaluation of the indicators associated with CNCF criteria 6.3.

Indicator	Rank	Rating (sum = 100)	Comments
6.3.1			
6.3.2			
6.3.3			
6.3.4			
6.3.5			
6.3.6			
6.3.7			
6.3.8			
6.3.9			
6.3.10			
6.3.11			
6.3.12			

Evaluation of the sub-indicators associated with CNCF criteria 6.3.11.

Sub-Indicator	Rank	Rating (sum = 100)	Comments
6.3.11a			
6.3.11b			
6.3.11c			
6.3.11d			
6.3.11e			
6.3.11f			
6.3.11g			

Form 1b. Ranking and Rating of I&V (cont.).

Evaluation of the indicators associated with CNCF criteria 7.1.

Indicator	Rank	Rating (sum = 100)	Comments
7.1.1			
7.1.2			
7.1.3			
7.1.4			

Evaluation of the sub-indicators associated with CNCF criteria 7.1.2.

Sub-Indicator	Rank	Rating (sum = 100)	Comments
7.1.2a			
7.1.2b			
7.1.2c			
7.1.2d			
7.1.2e			
7.1.2f			
7.1.2g			
7.1.2h			
7.1.2i			

Evaluation of the sub-indicators associated with CNCF criteria 7.1.3.

Sub-Indicator	Rank	Rating (sum = 100)	Comments
7.1.3.a			
7.1.3.b			
7.1.3.c			
7.1.3.d			
7.1.3.e			
7.1.3.f			
7.1.3.g			

Evaluation of the indicators associated with CNCF criteria 8.1.

Indicator	Rank	Rating (sum = 100)	Comments
8.1.1			
8.1.2			
8.1.3			
8.1.4			

Evaluation of the indicators associated with CIFOR* criteria 2.1.1.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.1.1			

Form 1b. Ranking and Rating of I&V (cont.).

Evaluation of the indicators associated with CIFOR criteria 2.1.2.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.2.1			
2.1.2.2			
2.1.2.4			
2.1.2.5			
2.1.2.7			
2.1.2.8			

Evaluation of the indicators associated with CIFOR criteria 2.1.3.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.3.1			
2.1.3.2			
2.1.3.6			

Evaluation of the indicators associated with CIFOR criteria 2.1.4.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.4.3			
2.1.4.4			
2.1.4.5'			
2.1.4.6			

Evaluation of the indicators associated with CIFOR criteria 2.1.5.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.5.3			
2.1.5.4			

Evaluation of the indicators associated with CIFOR criteria 2.1.6.

Verifier	Rank	Rating (sum = 100)	Comments
2.1.6.1			
2.1.6.2			
2.1.6.3			

Evaluation of the indicators associated with CIFOR'* criteria 1.

Verifier	Rank	Rating (sum = 100)	Comments
1.1			
1.2			
1.3			

Form 1b. Ranking and Rating of I&V (cont.).

Evaluation of the indicators associated with CIFOR' criteria 2.

Verifier	Rank	Rating (sum = 100)	Comments
2.1			
2.2			

Evaluation of the indicators associated with CIFOR' criteria 3.

Verifier	Rank	Rating (sum = 100)	Comments
3.1			
3.2			
3.3			

Evaluation of the indicators associated with CIFOR' criteria 4.

Verifier	Rank	Rating (sum = 100)	Comments
4.1			

*CNCF 1999, CIFOR - Prabhu *et al.* 1999, CIFOR - Finegan *et al.* 2000.

Table 4A. Form 1c: Designation of responsibility for the application of identifiable groups of I&V.

Please fill in this form before 05/22/00.
Indicate column 2 with an "X" in the space provided.
Indicate column 3 with an "X" or suggestion of another entity in the space provided.
For more information of detailed instructions please see the background document provided.

Group of I/V identified by the assoicated C/I.	ENTITY DESIGNATED AS RESPONSIBLE FOR APPLYING GROUP OF I/V	
	Forest Manager or Operator	Other Entity
CNCF C6.1		
CNCF C6.2		
CNCF C6.3		
CNCF C7.1		
CNCF C8.1		
CIFOR I2.1.1		
CIFOR I2.1.2		
CIFOR I2.1.3		
CIFOR I2.1.4		
CIFOR I2.1.5		
CIFOR I2.1.6		
CIFOR' I1		
CIFOR' I2		
CIFOR' I3		
CIFOR' I4		

*CNCF 1999, CIFOR - Prabhu *et al.* 1999, CIFOR' - Finegan *et al.* 2000.

Table 5A. Form 2: Field Test and Evaluation Responses

Expert's Initials: JMS | Source of I/V: CIFOR | Number 2.1.1.1 | Class (M/E): M

RECOMMENDATION AFTER FIELD TESTING:

YES	X
NO	

Wording of selected I/V as stated in manual:

The FMU compiles information about the size of area of each vegetation type in the area of intervention, compared with vegetation type in the entire FMU.

Justification or main argument for selection of I/V:

Information about the area size is very important for any SFM process to succeed in time and space.

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

Provides a summary or integrative measure	5
Closely and unambiguously related to the assessment goal	5
Adequate response range to stress (sensitive)	4
Diagnostically significant	3
Appealing to users	5
Easy to detect, record and interpret? Feasible?	5
Precisely defined? (clear)	4
Will it produce replicabel results? (reliable)	4
How relevant is this I/V?	5

Provide bibliographic references (if any):

Would this I/V need to be evaluated:

In the field? | In the office? | In both? X

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

Vegetation maps, etc.

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

Favor asignar a cada I y V el grado de responsibilidad institucional para los tres aspectos de implementación donde:

1 = Responsable primario, 2 = Responsable secundario (se puede compartir, asumir o ser asignado parte de la responsabilidad)

	Levantamiento							Procesamiento							Interpretación						
CNCF 1999	O/T	G/M	D	E	R	C/E	I.I.	O/T	G/M	D	E	R	C/E	I.I.	O/T	G/M	D	E	R	C/E	I.I.
C6.1																					
I6.1.3																					
C6.2																					
I6.2.1																					
I6.2.2																					
C6.3																					
I6.3.2																					
I6.3.3																					
I6.3.4																					
I6.3.5																					
I6.3.6																					
I6.3.10																					
I6.3.11																					
I6.3.12																					
C7.1																					
7.1.1																					
C7.2																					
7.2.1																					
C8.1																					
I8.1.1																					
I8.1.2																					
I8.1.4																					

O/T=Operador/Tecnico Forestal, G/M=Gerente/Manejador, D= Dueño/Productor, E = Estado (AFE), R = Regente, C/E= Certificador/Evaluador, II= Instituciones de Investigación
Levantamiento = toma de datos y/o información; Procesamiento = manejo de información (dijitación de datos/info hasta la preparación y presentación de los resultados)
Interpretación = Determinación de tendencias sobre el tiempo, Comparar con datos de referencia ó datos previos y dar juicio sobre el manejo en general

CIFOR 1999	O/T	G/M	D	E	R	C/E	II.	O/T	G/M	D	E	R	C/E	II.	O/T	G/M	D	E	R	C/E	II.
I2.1.2																					
V2.1.2.1																					
V2.1.2.4																					
V2.1.2.5																					
V2.1.2.8																					
I2.1.3																					
V2.1.3.1																					
V2.1.3.2																					
V2.1.3.6																					
I2.1.4																					
V2.1.4.3																					
V2.1.4.3'																					

O/T=Operador/Tecnico Forestal, G/M=Gerente/Manejador, D= Dueño/Productor, E = Estado (AFE), R = Regente, C/E = Certificador/Evaluador, II= Instituciones de Investigación
Levantamiento = toma de datos y/o información; Procesamiento = manejo de información (dijitación de datos/info hasta la preparación y presentación de los resultados)
Interpretación = Determinación de tendencias sobre el tiempo, Comparar con datos de referencia ó datos previos y dar juicio sobre el manejo en general

Table 7A. HBDE 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 Eval.	Relative Importance	Forest Manager	Other Entity
CIFOR 1999								
P6								
C6.1							0.8	0.2
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							0.8	0.2
I6.2.1	4	3	4	3	1.00	61		
I6.2.2	3	3	3	3	0.86	39		
C6.3							1	0
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							1	0
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							0.4	0.6
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							0.6	0.4
V2.1.1.1	3	3	4	3	0.71	100		
I2.1.2							0.6	0.4
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							0.2	0.8
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							0.4	0.6
V2.1.4.3	4	2	3	3	0.86	27		
V2.1.4.3'	4	2	3	3	0.71	20		
V2.1.4.4	4	4	4	4	0.80	30		
V2.1.4.6	4	2	4	3	0.86	24		
I2.1.5							0.4	0.6
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							0.4	0.6
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		
CIFOR'								
1.1	4	3	4	3	0.86	40	0.2	0.8
1.2	4	3	4	3	0.86	36		
1.3	3	3	3	3	0.71	24		
2.1	3	3	3	3	0.86	46	0.2	0.8
2.2	4	3	3	3	1.00	54		
3.1	4	2	3	3	0.71	42	0.4	0.6
3.2	4	4	4	3	0.83	28		
3.3	4	3	4	3	0.83	30		
4.1	4	4	4	3	1.00	100	0.2	0.8

Table 8A. 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 (i.e. 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 the production system. c. Natural processes that affect the productivity of the forest ecosystem. d. The functions and processes of the natural drainage system.	(see comments for C6.1)
I6.3.2	YES	YES	YES	Harvest intensity and silvicultural treatments are determined in direct proportion to the	Harvesting norms should be omitted from the indicator. The norms should be included in the CP.

				abundance of each species.	
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 ecosystem and cannot be harvested.	Redundant. This should be integrated with I6.2.1.
I6.3.9	NO		YES	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.	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	Minimum impact is made on the stand, soil and water resources in the execution of management and harvesting which take into account the aspects and levels established by the code of practices.	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 and waterways.	The terms "primary road" and "side roads" should be clearly defined in the CP as well as the methodology 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 (i.e. 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.
V2.1.4.3'	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 and indicator of the rate of decomposition. Any 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 woody debris does not show significant changes in comparison with undisturbed forests.	

Principle	Criteria	Indicator	Verifier	Recommendation	Revised	Related to assessment goal - 1	Related to assessment goal - 2	Easy to detect and register - 1	Easy to detect and register - 2	Provides a summary - 1	Provides a summary - 2	Sensitive to stresses - 1	Sensitive to stresses - 2	Relavent to ecol. Sust. - 2	Precisely defined - 2	Reliable, replicable - 2	Diagnostically specific - 2	Attractive to users - 2
P6																		
	C6.1																	
		I6.1.1	NO			3	2	3	5	3		2	1	1	4	1	1	
		I6.1.2	NO			4	5	4	2	4	1	4	1	5	2	2	1	5
		I6.1.3	YES	YES		4	5	2	3	3	1	3	3	5	3	3	2	4
	C6.2																	
		I6.2.1	YES	YES		4	2	3	5	4	5	3	1	4	5	5	2	4
		I6.2.2	YES	NO		3	5	3	5	3	1	3	2	5	5	2	3	4
	C6.3																	
		I6.3.1				4		3		3		3						
		I6.3.2	YES	YES		3	5	3	5	4	5	4		5	5	5	4	5
		I6.3.3	NO			4	5	3	5	4	5	3		5	5	5	1	4
		I6.3.4	YES	NO		4	5	4	5	3	1	3	2	5	1	2	4	4
		I6.3.5	YES	YES		3	5	4	5	3	4	3	3	5	5	5	3	5
		I6.3.6	NO			4		4		4		3						
		I6.3.7	NO			3		4		3		3						
		I6.3.8	NO			4	2	4	5	4	5	4	1	4	5	5	2	4
		I6.3.9	NO			4	2	4	5	4	5	4	1	4	5	5	2	4
		I6.3.10	YES	YES		3	5	4	5	3	5	3	2	5	5	5	5	5
		I6.3.11				4		3		4		4						
		I6.3.11a	YES	NO		3	5	3	5	3	5	3	5	5	4	5	2	5
		I6.3.11b	YES	NO		4	5	4	5	3	3	3	3	5	5	5	5	5
		I6.3.11c	YES	NO		4	5	4	5	4	5	3	4	5	5	5	2	5
		I6.3.11d	YES	NO		4	5	4	5	4	5	3	4	5	5	5	2	5
		I6.3.11e	YES	YES		4	5	4	5	4	5	3	5	5	5	5	2	4
		I6.3.11f	NO			4		4		4		3					1	
		I6.3.11g	NO			4	3	3	1	4	1	3	2	2	1	1	2	1
		I6.3.12	YES	YES		3	5	4	4	3	4	3	5	5	3	3	5	4
	C8.1		YES	YES														
		I8.1.1	YES	YES		3	5	4	5	3	5	3	5	5	5	5	5	5
		I8.1.2	YES	YES		3	5	4	5	3	5	3	5	5	5	5	3	5
		I8.1.3	NO			4	2	5	5	4	5	4	1	4	5	5	2	4
		I8.1.4	YES	YES		3	2	4	5	4	5	3	1	5	5	5	5	5

Juego de P C I y V desarrollado por CIFOR - Prabhu, *et al.* 1999.

P C I V																
P2																
C2.1																
I2.1.1																
V2.1.1.1			3		3		4		3							
I2.1.2																
V2.1.2.1	YES	NO	4	5	3	2	3	3	3	3	5	2	2	2	2
V2.1.2.2	NO		4	2	3	2	3	2	4	2	5	5	2	5	2
V2.1.2.4	NO		4	5	3	2	3	2	3	4	4	2	2	2	2
V2.1.2.5	NO		4	4	4	2	3	2	4	4	5	2	2	1	2
V2.1.2.7	NO		3	3	2	3	3	2	3	4	3	2	2	3	2
V2.1.2.8	YES	NO	3	5	2	5	3	4	3	4	3	3	3	2	5
I2.1.3																
V2.1.3.1	YES	YES	4	5	2	2	11	5	3	5	5	4	5	5	3
V2.1.3.2	YES	YES	4	5	2	4	3	4	3	5	5	5	5	3	3
V2.1.3.6	YES	YES	4	5	2	5	3	4	3	5	5	3	5	5	4
I2.1.4																
V2.1.4.3	YES	YES	4	5	2	5	3	4	3	5	5	5	5	5	4
V2.1.4.3'	YES	YES	4	5	2	2	3	2	3	5	5	2	4	5	4
V2.1.4.4			4		4		4		4						
V2.1.4.6			4		2		4		3						
I2.1.5																
V2.1.5.3	NO		4	3	4	2	3	2	4	2	5	3	2	5	2
V2.1.5.4	NO		4	3	3	4	3	5	3	3	5	4	3	5	3
I2.1.6																
V2.1.6.1	**		3	3	3	1	3	5	3		5	4	3	3	2
V2.1.6.2	**		3	3	2	1	3	5	3	3	5	3	3	5	3
V2.1.6.3	**		4	3	2	1	3	5	3		5	4	3	5	2

Table 10A. I&V Classifications and Groupings

Principle / Criteria / Indicator / Verifier	Input, Process or Result	Pressure, State, Response	Class*
CNCF 1999			
P6			
C6.1			
I6.1.1	input	pressure	M
I6.1.2	process	pressure	M
I6.1.3	process	pressure	M
C6.2			
I6.2.1	process	pressure	M
I6.2.2	process	pressure	M
C6.3			
I6.3.1			
I6.3.2	process	pressure	M
I6.3.3	process	pressure	M
I6.3.4	process	pressure	M
I6.3.5	input	pressure	M
I6.3.6	process	pressure	M
I6.3.7	process	pressure	M
I6.3.8	process	pressure	M
I6.3.9	process	pressure	M
I6.3.10	process	pressure	M
I6.3.11	process	pressure	M
I6.3.11a	N/A	N/A	M
I6.3.11b	N/A	N/A	M
I6.3.11c	N/A	N/A	M
I6.3.11d	N/A	N/A	M
I6.3.11e	N/A	N/A	M
I6.3.11f	N/A	N/A	M
I6.3.11g	N/A	N/A	M
I6.3.12	process	pressure	M
C7.1			
7.1.1	input	N/A	M
7.1.2	input	N/A	M
7.1.2a	N/A	N/A	M
7.1.2b	N/A	N/A	M
7.1.2c	N/A	N/A	M
7.1.2d	N/A	N/A	M
7.1.2e	N/A	N/A	M
7.1.2f	N/A	N/A	M
7.1.2g	N/A	N/A	M
7.1.2h	N/A	N/A	M
7.1.2i	N/A	N/A	M
7.1.3	input	N/A	M
7.1.3a	N/A	N/A	M
7.1.3b	N/A	N/A	M
7.1.3c	N/A	N/A	M
7.1.3d	N/A	N/A	M
7.1.3e	N/A	N/A	M
7.1.3f	N/A	N/A	M
7.1.3g	N/A	N/A	M
7.1.4	process	pressure	M

C7.2			
7.2.1	process	N/A	M
C8.1			
I8.1.1	process	pressure	M
I8.1.2	process	N/A	M
I8.1.3	process	pressure	M
I8.1.4	process	pressure	M
CIFOR 1999			
P2			
C2.1			
I2.1.2			
V2.1.2.1	result	response	E
V2.1.2.2	result	response	E
V2.1.2.4	result	response	E
V2.1.2.5	result	response	E
V2.1.2.7	result	response	E
V2.1.2.8	result	response	E
I2.1.3			
V2.1.3.1	result	response	E
V2.1.3.2	result	response	E
V2.1.3.6	result	response	E
I2.1.4			
V2.1.4.3	result	response	E
V2.1.4.3'	result	response	E
V2.1.4.6	result	response	E
I2.1.5			
V2.1.5.4	result	response	E
I2.1.6			
V2.1.6.1	result	response	E
V2.1.6.2	result	response	E
V2.1.6.3	result	response	E

Class: M = Production of Goods and Services, E = Ecology

field forms

Parcelas de 5x5m

Fecha: **Nombre del observador:**

Formularios para la toma de datos asociados con los verificadores:

V2.1.3.1 Abundancia relativa de latizales bajos (1.5m altura - 4.9cm dap):

V2.1.6.3 Abundancia de residuos leñosos pequeños (RLP) (< 10cm diam, >1m de largo)

(* RLP = Residuos leñosos pequeños)

# de parcela	# de indvdo	Nombre Común	dap (cm)		# de RLP	# de sección	diam inf (cm)	diam sup (cm)	largo (m)

Parcelas de 10x10m **Fecha:** **Nombre del observador:**

Formulario para la toma de datos asociados con los verificadores:

V2 1.3.1 Abundancia relativa de gremios de latizales altos (LA) (5.0 cm - 9.9cm dap):

V2 1.2.8 Descomposicion de la madera muerta en el suelo (RLG: >10cm, >1.5m)*

V2 1.6.1 Volumen de madera muerta en el suelo (RLG: >10cm, >1.5m)*

*RLG = Residuos leñosos grandes; TC = troncos caidos; R = ramas)

** Favor usar la escala de Pyle y Brown 1999)

# de parcela	# de arbol	Nombre Común	dap (cm)		# de RLG	# de sección	diam Inf (cm)	diam sup (cm)	largo (m)	escala de descomp**	# de huecos	entradas si=1 no=0

Parcelas de 10x10m **Fecha:** **Nombre del observador:**

Formulario para la toma de datos asociados con los verificadores:

~~V2.1.2.1 Estructura vertical del bosque~~

V2.1.2.4 Distribución de fases del ciclo de vida

~~V2.1.2.5 Apertura del dosel del sotobosque~~

(* **0** = 0%; **1** = 1-33%; **2** = 34-66%; **3** = 67-100%)

(** ~~**1** = claro, > 50% debajo de apertura en el dosel; **2** = reconstrucción, < 50% debajo de apertura; **3** = dosel cerrado~~)

# de parcela	% de cobertura (**0-3**)* a la altura de:					Fase de ciclo de regen (**1-3**)**
	0-2m	2-10m	10-20m	20-30m	>30m	

rcelas de 30x100m **Fecha:** **Nombre del observador:**

nulario para la toma de datos asociados con los verificadores:

3.1 Abundancia relativa de fustales (> 10.0 cm dap):
2.2 Distribución por clases de tamaños (> 10cm dap)
2.7 Distribución de biomasa arriba del suelo (> 10cm dap)
5.3 Estructura de edad/tamaño de árboles (> 10cm dap)
5.4 Tasas de crecimiento de poblaciones (> 10cm dap)
2.8 Decomposicion de la madera muerta en el suelo (AMP, T)*
6.1 Volumen de madera muerta en el suelo (AMP, T)*
6.2 Estado de descomposicion de toda la madera muerta

P=Arbol muerto en pie; T=Tocon)
= sin ningún daño; **2** = moderatemente dañado; **3** = gravamente dañado)
vor usar la escala de Ghazoul 1998)

# de indv	Nombre Común	# de eje	dap (cm)	alt tot(m)	alt com(m)	estado copa**	estado fuste**		# de indv	AMP / T*	dap(cm)/ diam(cm)	alt tot(m)	escala*** descomp	# de huecos		secn de camino	largo (m)	ancho (m)

Parcelas de 30x100m

Nombre del observador:

Formulario para la toma de datos asociados con los verificadores:

V2.1.3.2 Abundancia de gremios de aves

(* # P = numero de parcela; V = Vista; E = Escuchada)

Fecha:	# P*	# Indv	Especie	V/E*

Fecha:	# P*	# Indv	Especie	V/E*

Parcelas de 30x100m

Nombre del observador:

Formulario para la toma de datos asociados con los verificadores:
V2.1.3.2 Abundancia de gremios de aves

(* # P = numero de parcela; V = Vista; E = Escuchada)

Fecha:	# P*	# Indv	Especie	V/E*

Fecha:	# P*	# Indv	Especie	V/E*

Transectos

Nombre del observador:

Formulario para la toma de datos asociados con el verificador:
V2.1.4.3' Riqueza/diversidad de escarabjos

(* # T = numero del transecto; T (m) = el largo del transecto en metros)

Dia 1 - Fecha				Dia 2 - Fecha				Dia 3 - Fecha			
# T*	T(m)*	Especie	Cantidad	# T*	T(m)*	Especie	Cantidad	# T*	T(m)*	Especie	Cantidad

Transectos

Nombre del observador:

Formulario para la toma de datos asociados con el verificador:
V2.1.3.6 Actividad de mamíferos

(* # T = numero del transecto; T (m) = el largo del transecto en metros)

Dia 1 - Fecha				Dia 2 - Fecha				Dia 3 - Fecha			
# T*	T(m)*	Especie	Cantidad	# T*	T(m)*	Especie	Cantidad	# T*	T(m)*	Especie	Cantidad

Transectos

Nombre del observador:

Formulario para la toma de datos asociados con el verificador:
V2.1.4.3 Riqueza/diversidad de mariposas

(* # T = numero del transecto; T (m) = el largo del transecto en metros)

Fecha:	# T*	T(m)*	Especie	Cantidad

Fecha:	# T*	T(m)*	Especie	Cantidad

field results

Field Practice Application Data Results and Analysis

Dead Standing Wood (DSW) and trunks (T) in 30x100m plots

plot #	individ #	DSW / T*	dbh(cm)/ diam(cm)	tot ht (m)	vol m^3	decomp scale	# of holes
1	3	AMP	30	6	6.786	1	0
1	4	AMP	17	2	0.726	1	0
1	13	AMP	10	6	0.754	1	0
1	10	AMP	12	6	1.032	2	0
1	15	AMP	9	20	2.036	2	1
1	1	AMP	23	5	3.324	3	0
1	6	T	17	3.5	1.332	1	0
1	7	T	18	2	0.814	1	0
1	16	T	14	3	0.697	1	0
1	5	T	28	2.5	2.463	2	2
1	8	T	25	2	1.571	2	0
1	9	T	26	5	4.346	2	0
1	12	T	17	1	0.380	2	>10
1	2	T	66	1.1	6.021	3	1
1	14	T	35	2.3	3.541	3	1
1	11	T	15	3	0.848	4	≥10

# DSW /plot	# DSW /ha	Vol_{DSW} /plot	Vol_{DSW} /ha	# T /plot	# T /ha	Vol_{T} /plot	Vol_{T} /ha
6	19.98	14.658	48.811	10	33.3	21.165	70.481

Large woody debris (LWD) measured in 10x10m plots

plot #	LWD #	section #	diam inf (cm)	diam sup (cm)	length (m)	vol (m^3)	scale of decomp	# of holes	entrances y=1 no=0
1	1	1	10.3	10.5	2	0.272	3	0	0
1	2	1	10.1	10.2	2.2	0.285	3	0	0
1	2	2	10.2	10	2.1	0.269	3	0	0
2	1	1	9.4	17.2	1.8	0.400	2	0	0
2	2	1	11.6	13.2	3.3	0.638	3	0	0
2	3	1	16	16	2.6	0.836	4	1	0

# LWD /200m^2	# LWD /ha	Vol_{LWD} /200m^2	Vol_{LWD} /ha
5	250	2.700	135.001

Small woody debris (SWD) measured in 5x5m plots

plot #	SWD #	section #	diam inf (cm)	diam sup (cm	length (m)	vol (m^3)
1	1	1	6.5	6.5	2.1	0.111
1	2	1	4	3.5	2.8	0.049
1	3	1	4.4	4.9	1.3	0.035
2	1	1	5.2	4.9	2.4	0.077
2	1	2	4.5	3.8	2.3	0.050
2	2	1	3.7	2.6	1.7	0.021
2	3	1	9.1	10	1.6	0.183
3	1	1	7	5.4	2.5	0.121
4	1	1	4.2	4.4	1.8	0.042
4	2	1	2.3	3.3	1.7	0.017
4	3	1	4.7	5.2	2.4	0.074

# SWD /100m^2	# SWD /ha	Vol_{SWD} /100m^2	Vol_{SWD} /ha
10	1000	0.781	78.079

Abundance and volume of dead standing trees according to degree ofdecomposition

Degree of Decomposition (per plot)									
1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
3	8.266	2	3.068	1	0.012	0	0	0	0

Degree of Decomposition (per ha)									
1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
9.99	27.526	7	10.22	3	0.0394	0	0	0	0

Abundance and volume of trunks according to degree of decomposition

Degree of Decomposition (per plot)											
0		1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
0	0.000	3	2.843	4	8.760	2	9.562	1	0.848	0	0

Degree of Decomposition (per ha)											
0		1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
0	0	10	9.468	13	29.172	7	31.841	3	2.8238	0	0

Abundance and volume of LWD according to degree of decomposition

Degree of Decomposition (per plot)											
0		1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
0	0.000	0	0.000	1	0.400	4	1.464	1	0.836	0	0

Degree of Decomposition (per ha)											
0		1		2		3		4		5	
Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol	Abn	Vol
0	0	0	0	50	20.000	200	73.200	50	41.800	0	0